Adoption of Innovations in Irish General Practices:

Prescription Drugs, Medical Equipment and ICT

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ABSTRACT

In this thesis we explore innovation in general practices in Ireland. Drawing on an encompassing equilibrium, disequilibrium and learning-by-using model of adoption, we examine the influences of general practitioner (GP) and practice characteristics, strategic behaviour, learning and knowledge spillovers, and cumulative learning from previous adoption decisions on the perceived benefits of adopting and using innovations in general practices. Ours is the first application of this theoretical framework to timing of adoption, multiple technology adoption and intensity of adoption decision-making in a health care setting. Our examination focuses on three innovations, prescription drugs, medical equipment and Information and Communications Technology (ICT).

Our analysis is based on two data sources, a secondary dataset which brings together GPs prescribing history over a 4½ year time period with information on the characteristics of the 625 GPs themselves, and a cross-sectional primary dataset which provides us with information for 601 general practices concerning practice structure and use of medical equipment and ICT. Employing duration analysis, multivariate Probit and ordered Probit econometric techniques, we examine the adoption, use and intensity of use of prescription drugs, medical equipment and ICT respectively.

Irish GPs exhibit notable innovative behaviour with respect to prescribing innovation and practice development. Our research demonstrates that Irish GPs respond to informational stimuli with respect to adoption and use of new prescription drugs, medical equipment and ICT. Furthermore, Irish GPs are incentivised by commercial and market considerations. In addition, we find the extent which a practice adopts technologies and learns from that experience influences both ensuing prescribing and investment decision-making. Our empirical findings support an economic approach to examining decision-making in a health care setting and the application of our encompassing theoretical model to examinations of adoption and use of innovations by health care professionals.

CHAPTER 1: ADOPTION OF INNOVATIONS IN IRISH GENERAL PRACTICES

1.1 Introduction

In this thesis we explore innovation in general practices in Ireland. It is widely accepted that the contribution of innovations to economic growth is only realised when innovations are widely adopted and used (Baptista, 1999; Hall and Khan, 2003). Likewise, the contribution of innovations to health care provision and outcomes is realised when they are adopted and used within health care settings. The overall aim of this thesis is to examine the adoption and use of innovations in Irish general practices. Our examination focuses on three innovations, new prescription drugs, medical equipment and Information and Communication Technology (ICT), and specifically addresses the following research questions:

(i) What are the determinants of timing of adoption of new prescription drugs by Irish GPs?

(ii) What influences the use of medical equipment in Irish general practices?

(iii) What factors influence the intensity of ICT use in Irish general practices?

The general practice environment in Ireland is slightly different to that in other countries, particularly in relation to the autonomy enjoyed by Irish GPs in the running of their practices, therefore, providing us with a unique context for this study. For instance, Irish GPs are self-employed private practitioners who compete for customers, both public and private patients, similar to other professionals, such as architects, dentists, solicitors and engineers (Competition Authority, 2010). They also enjoy considerable autonomy in how they staff and equip their practices, and are not constrained by prescribing guidelines, such as the National Institute for Clinical Excellence (NICE) guidelines in the UK. These commercial and health care provision features of Irish general practice enables the novel application of economic approaches to examining the adoption of health care innovations.

Previously, three complementary theoretical approaches have been used to explain the timing of innovation decisions. Disequilibrium models reflect the learning and informational influences on timing of adoption (Rogers, 2003). By contrast, equilibrium models take account of how organisational characteristics and strategic interactions influence timing of adoption (Karshenas and Stoneman, 1993). While learning-by-using models reflect how cumulative learning experience from previous adoption decisions influence timing of adoption (McWilliams and Zilbermanfr, 1996). The disequilibrium approach has been used primarily to explain adoption by individuals, whereas the equilibrium and leaning-by-using approaches are generally used to explain adoption by firms. In addition to empirical examinations of timing of adoption, these theoretical models have also been extended to examinations of multiple technology adoption (Colombo and Mosconi, 1995; Stoneman and Toivanen, 1997) and intensity of adoption (Battisti and Stoneman, 2003; Hollenstein, 2004; Battisti et al., 2007). This encompassing theoretical framework informs the empirical analyses of this thesis.

The data sources for our study include both a secondary dataset and a primary dataset. The secondary dataset brings together GPs prescribing history over a 4½ year time period with information on the characteristics of the 625 GPs themselves, and enables us to explore the factors which shape the timing of the first prescription of new drugs by GPs in Ireland. Primary survey data provides us with information relating to practice characteristics and use of medical equipment and ICT for a sample of 601 general practices in Ireland. This survey data allows us to examine the determinants of medical equipment use and intensity of ICT use by general practices in Ireland. Through the lens of our theoretical framework and using both datasets, we employ a number of econometric approaches to examine the adoption and use of prescription drugs, medical equipment and ICT by GPs.

The rest of the chapter is organised as follows. Section 1.2 describes the general practice environment in Ireland. The motivation for this study and the contributions of this research are discussed in Section 1.3. Finally, Section 1.4 provides an overview of this thesis, briefly describing the content of each chapter.

1.2 General Practice in Ireland

The Irish government considers primary care to be the appropriate setting to meet 90-95 per cent of all health and personal social service needs, with GPs central to its provision (Department of Health and Children, 2001). In fact, along with Denmark, the Netherlands and the UK, Ireland is identified as one of the European countries where GPs are predominately the first point of contact with health care services (Boerma and Dubois, 2006).

Irish GPs are by and large self-employed private practitioners who choose where they set up practice, who they employ and how much they charge for consultations and any additional services they provide (Department of Health and Children, 2001; Wren, 2003). The majority of Irish GPs treat private patients but also hold a contract with the government to treat those patients who qualify for a Medical Card. Medical card or General Medical Services (GMS) patients are public patients who are entitled to attend GPs free of charge.[1] Approximately, one-third of the Irish population are entitled to these means-tested medical cards (Department of Health and Children, 2010).[2] The remainder of the Irish population are classed as private patients and they pay directly for each visit to a GP and for any additional services provided.[3]

Irish GPs enjoy considerable autonomy with respect to prescribing and practice development decisions (Department of Health and Children, 2001; Wren, 2003). In Ireland, there are no explicit guidelines in relation to prescribing decisions. Once a

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[1] GPs are remunerated for treating GMS patients on a capitation basis. The capitation fees are calculated based on the following factors: (1) a demographic factor designed to reflect differences in demands by various age and gender groups, and (2) a geographic factor designed to reflect the expenses incurred in visiting patients in various age/distance categories (Thomas and Layte, 2009). In 2008, the average payment to a GP principal in Ireland with a GMS contract was €220,000. Approximately 70 per cent of this payment comprises fees for services provided to public patients; the remainder comprises allowances for secretarial/nursing support, locum hire to cover annual leave, and out-of-hours payments (24 per cent); superannuation (5 per cent); and 'other' payments (2 per cent) (Competition Authority, 2010). This payment does not include fees received directly from private patients for care and treatment provided.

[2] In 2009, 33.2 per cent of the population were entitled to medical cards. Those entitled to free GP care under the GMS scheme has been increasing in recent years. In 2007, 29.4 per cent of the population was entitled to a medical card, whereas in 2008, this figure had increased to 30.6 per cent. Approximately, 2.2 per cent of the population are entitled to GP Visit Card which also entitles the holder to free GP care. GP Visit Cards were introduced in 2005 as a graduated benefit to extend free GP care to individuals and families on moderate incomes (Department of Health and Children, 2010).

[3] General practices are not obliged to display the price of a consultation, although an updated Guide to Professional Conduct and Ethics for Registered Medical Practitioners specifies that GPs may display prices. In 2009, the Competition Authority estimated that the average cost of a GP visit for a private patient is approximately €50-55 in urban areas, with slightly lower charges in rural areas (Competition Authority, 2010). The National Consumer Agency also reported a wide range of prices for GP visits, averaging at €51, with a minimum of €35 and a maximum of €70 (Thomas and Layte, 2009).

drug is approved for use by the Irish Medicines Board, GPs can prescribe it to their patients. Irish GPs also have considerable autonomy in how they equip their practices (Department of Health and Children, 2001; Wren, 2003), and there is evidence of considerable variation concerning the range of medical equipment (Boerma and Dubois, 2006; O'Dowd et al., 2006) and the extent of ICT use (Irish College of General Practitioners, 2003; Lordan and Normand, 2005; O'Dowd et al., 2006; Dobrev et al., 2008; Meade et al., 2009) in Irish general practices.

In Ireland, general practices also vary greatly in size and personal characteristics. Approximately one in four practices is a solo-practitioner practice. The majority of practices are two or three GP practices, although 12 per cent of practices have five or more GPs. Practices tend to be male GP dominated (Bourke and Bradley, 2010). Not all practices have nursing or administrative support. One in five practices does not employ a nurse and one in ten does not employ administrative support.[4] In general, practices tend to be located in urban locations. General practices are regularly visited by pharmaceutical representatives, less so by suppliers of medical equipment and ICT. Many practices are involved in research projects (24 per cent), affiliated to academic institutions (38 per cent) and hold clinics delivered by other health care professionals (49 per cent). 29 per cent of practices are training practices (Bourke and Bradley, 2010).

[4] A survey report pertaining to the primary data collection of this thesis was published in the Department of Economics, University College Cork Working Paper Series (Bourke and Bradley, 2010). This report provides a timely profile of Irish general practices. A comparison with previous surveys of general practices in Ireland reveals a move away from solo-practitioner practices, with practices more likely to employ support staff, in recent years. In 2005, 35 per cent of general practices in Ireland were solo-practitioner practices; 35 and 40 per cent of practices employed a full- and part-time nurse respectively; and 70 per cent of practices employed full-time clerical assistance (O'Dowd. et al., 2006)

In general, Irish GPs invest in a range of medical equipment (Bourke and Bradley, 2010), in fact, to a greater extent than many of their European counterparts (Boerma and Dubois, 2006). Almost all Irish general practices are computerised, although there is variation in the ICT applications used (Bourke and Bradley, 2010; Meade et al., 2009). In a European context, Irish GPs are considered 'average' performers with respect to their use of ICT (Dobrev et al., 2008). It is worth noting that Ireland has a low number of GPs per capita in comparison with other EU countries. It is estimated Ireland has approximately 52-56 GPs per 100,000 of the population. Countries such as Austria, France and Germany have over 100 GPs per 100,000 (Thomas and Layte, 2009).[5]

It is important to discuss the different incentives Irish GPs may face in their adoption decision-making. Irish GPs incur no monetary cost in relation to their prescribing decisions. The cost of the prescription is borne by the patient or in the case of public patients by the State. Neither are Irish GPs constrained by prescribing budgets for their public patients.[6] Therefore, GPs need not consider the price of drugs when prescribing them to their patients. Although, it is important to note that private patients who bear the cost of any drugs prescribed may request a less expensive drug if they consider the cost of a drug too high. However, for the most part, it is reasonable to assume that the cost of a new drug does not feature in GPs prescribing decisions, and such a decision is not influenced by commercial considerations.

[5] In fact, there are concerns in relation to the future supply of GPs in Ireland, due in part to the increased feminisation of the profession, accompanied by a rise in part-time working, among both male and female GPs, and a movement towards early retirement (Competition Authority, 2010).
[6] The Indicative Budget Treatment Scheme (IDTS) was introduced in an attempt to contain public patient prescribing costs, and is discussed in Section 3.3.

On the other hand, Irish GPs do incur a monetary cost with respect to how they equip their practices. Therefore, when a practice invests in a new piece of equipment the GP(s) will consider the cost incurred from investing in such equipment because that cost is borne solely by the practice. It is also important to note that when judging the benefits of equipment investment decisions it is likely that Irish GPs consider the benefits to health care provision as well as commercial considerations from expanding the diagnostic and treatment capabilities of the practice. To reiterate, Irish GPs face different incentive structures with respect to their prescribing and practice investment decisions. Irish GPs incur no monetary cost from prescribing decisions and the benefits of such decision-making are bestowed solely to the patient. In contrast, Irish general practices incur a monetary cost, in some instances a substantial monetary cost, in the procurement of practice equipment; however the benefits of such investments may include business efficiencies as well as improved patient care.

In addition, an interesting feature of the Irish health care system is the mobility that Irish patients enjoy with respect to registering with a GP. Public patients choose their GP from a panel of GPs who are part of the GMS scheme and, provided the GP is willing to accept them as patients, they register with that GP. It is relatively easy for public patients who wish to change GP to subsequently register with a different GP in their area if they so wish. At the present time, there is no register of private patients in Ireland. Consequently, private patients may not be registered with any practice or may be registered with more than one practice. It is reasonable to assume that Irish GPs are mindful of the mobility of their patients and potential patients in their adoption decision-making. GPs that are seen to be innovative may be more likely to attract both public and private patients.

In Ireland, general practice plays a pivotal role in health care provision. Given the independent nature of general practices in Ireland, decision-making concerning prescribing new drugs and investing in medical equipment and ICT is at a practice or individual GP level. Therefore, the general practice environment in Ireland provides us with a unique setting for examining the adoption of health care technologies by health care practitioners.

1.3 Motivation and Contribution

Primary care is the central focus of the Irish health system (Department of Health and Children, 2001). More than two-thirds of the Irish population attend their GP each year (Central Statistics Office, 2008) and, therefore, are directly affected by how their GP chooses to run their practice. As previously mentioned, GPs are independent contractors who decide what drugs to prescribe to their patients, what medical equipment they invest in, and for what purposes they use ICT. In fact, the innovation capabilities of Irish GPs are confined to these three areas of decision-making.[7] Therefore, our examination of the adoption and intensity of adoption of prescription medicines, medical equipment and ICT provides us with a holistic view of the innovativeness of Irish GPs. This section discusses the contribution to theory (1.3.1), knowledge (1.3.2) and policy (1.3.3) of this thesis.

[7] Interviews with GPs, described in Chapter 5, confirmed that decision-making concerning adoption and use of innovations comprise of these three areas.

1.3.1 Contribution to Theory

The primary theoretical contribution of this thesis is the importance of experiential learning on adoption decision-making. In this thesis, we hypothesise that individual and corporate learning from previous adoption decisions influences subsequent decisions concerning uptake and use of technologies. Our empirical analysis clearly illustrates the influence of learning-by-using effects on the adoption and use of three innovations in a health care setting. In the innovation literature, measures of learning-by-using effects have focused on learning from the adoption of complementary technologies and earlier technology vintages (Colombo and Mosconi, 1995; Arvantis and Hollenstein, 2001). In our examination of the adoption and use of innovations by Irish GPs, we extend earlier conceptualisations of learning-by-using effects to capture learning from a range of similar and differing adoption decisions. Therefore, our variable measurements of learning-by-using effects include learning from an individual GP's portfolio of drugs, learning from a general practice's portfolio of medical equipment, and learning from ICT use for contrasting purposes. To date, in innovation studies learning-by-using models of adoption have been appended to the more established equilibrium and disequilibrium models of adoption as a means of understanding adoption decision-making. However, we would argue that our robust and consistent evidence of the influence of learning-by-using effects on adoption decision-making places these experiential learning effects at the centre of the theoretical debate.

In addition, our empirical findings justify the application of the encompassing theoretical framework of learning-by-using, equilibrium and disequilibrium models of adoption to adoption decision-making in a health care setting. Due to the commercial free-market elements of general practice in Ireland, we take an economic approach to our exploration of innovative decision-making in Irish general practices and examine the influence of practice heterogeneity and strategic behaviour of adoption decision-making. Our findings illustrate that decision-making in general practices is influenced by commercial and business motivations. Previous studies have implicitly drawn on the disequilibrium model of adoption to examine the adoption of health care innovations by health care professionals (Coleman et al., 1966; Rogers, 2003). This thesis ascertains the influence of epidemic effects on timing of adoption, multiple technology adoption and intensity of adoption of innovations by GPs. Therefore, our empirical findings illustrate the need to consider the influence of commercial and business motivations, as well as learning and experiential stimuli, on adoption decision-making in general practices, and ultimately substantiate the application of an encompassing theoretical model incorporating the disequilibrium, equilibrium and learning-by-using approaches to adoption decision-making in a health care setting.

This encompassing theoretical framework informs the empirical examinations on timing of adoption, multiple technology adoption and intensity of adoption of innovations by GPs. However, there is some variation in the application of this theoretical model to the three empirical exercises. This is discussed in detail in the relevant chapters. Table 1.1 summarises the application of the theoretical framework, as well as the data and econometric methodology employed, in the three empirical exercises. This thesis' contribution to knowledge is discussed in the following section.

Table 1.1: Summary of Application of Theoretical Framework, Data and Econometric Methodology in Empirical Analyses

Research Focus	**Application of Theoretical Framework**	**Dataset**	**Econometric Methodology**	**Chapter**
Timing of Adoption - New Prescription Drugs	Equilibrium (rank, stock, and order effects) Disequilibrium (epidemic learning effects) Learning-by-Using (learning-by-using effects)	Matched Dataset – GMS Prescribing and GP Characteristics Databases	Duration Analysis	4
Multiple Technology Adoption - Medical Equipment	Equilibrium (rank and order effects) Disequilibrium (epidemic learning effects) Learning-by-Using (learning-by-using effects)	*Medical Equipment and IT in General Practice* Survey Data	Multivariate Probit Analysis	6
Intensity of Adoption - ICT use for Administrative and Patient Care functions	Equilibrium (rank effects) Disequilibrium (epidemic learning effects) Learning-by-Using (learning-by-using effects)	*Medical Equipment and IT in General Practice* Survey Data	Ordered Probit Analysis	7

1.3.2 Contribution to Knowledge

This thesis provides us with a holistic picture of Irish GPs innovative behaviour. Our examination of Irish GP's prescribing and practice development decision-making points towards an innovative group of health care practitioners. Our empirical findings demonstrate that Irish GP's decision-making is influenced by informational and learning stimuli. In fact, they exhibit capabilities for accumulating knowledge and learning from experience with technologies which informs ensuing adoption decisions. Furthermore, our research reveals that Irish GPs respond to commercial and market incentives with respect to practice development and health care provision.

Drawing on our encompassing theoretical model of adoption, we employ a number of econometric approaches and datasets in our empirical analyses of innovative decision-making in a health care setting.[8] We employ duration models in our analysis of the adoption of drugs new to the Irish market by GPs. Duration analysis enables the application of timing of adoption models to prescribing behaviour, allowing us to examine equilibrium, disequilibrium and learning-by-using effects on the time of first prescription of new drugs by Irish GPs. To our knowledge, our study is the first to use duration analysis to examine prescribing innovation.

Primary data was collected as part of this research process, with postal questionnaires distributed to the Irish general practice population in Spring 2010. 601 general practices responded to the survey, providing us with a timely profile of

[8] The data analysis and statistical software package Stata 11 is used to conduct all statistical and econometric analysis (StataCorp 2009).

general practices in Ireland, along with information on decision-making concerning use of medical equipment and ICT.[9]

As mentioned in Section 1.3.1, we extend our theoretical model to multiple technology and intensity of adoption decision-making. We use multivariate Probit analysis to examine the adoption of six items of medical equipment by general practices. Multivariate Probit analysis allows us to account for the unobservable factors that influence the adoption of all items of medical equipment (Greene, 2003). We understand that this is the first time such an econometric approach has been employed to medical equipment adoption. Therefore, this analysis contributes to our understanding of what determines adoption by controlling for unobservable individual-specific heterogeneity within a multiple technology adoption framework.

In our empirical analysis of intensity of ICT adoption by general practices, our econometric technique is ordered Probit analysis, which allows us to identify the determinants of the probability of practices being intensive users of ICT. This econometric approach has been used in previous studies of intensity of ICT adoption (Hollenstein, 2004; Battisti et al., 2007). However, this is the first study where ordered Probit analysis has been used to examine intensity of ICT adoption by small health care organisations. This analysis deepens our understanding of what influences intensity of adoption, considered to be the more important element of the entire diffusion process.

[9] The survey report presents findings in relation to the structure of general practices in Ireland and highlights high levels of medical equipment and ICT use. It also reports findings by Health Service Executive (HSE) region; practice size and support staff (Bourke and Bradley, 2010).

In summation, this thesis contributes to our knowledge of Irish GPs and their prescribing and practice development decision-making. Furthermore, our research reveals how GPs are influenced by informational and learning stimuli, as well as commercial and market incentives. This thesis also broadens our understanding of timing of adoption, multiple technology adoption and intensity of adoption decision-making.

1.3.3 Contribution to Policy

The objective of this thesis is to identify the determinants of the adoption and use of innovations by Irish GPs. It is expected that our research can contribute to Irish health care policy in relation to influencing the uptake of new drugs, the use of medical equipment, and the intensity of ICT use by GPs. As this study identifies factors and types of practices which influence adoption and use of health care technologies, we can also highlight possible areas for intervention to shorten the time to adoption and use of health care technologies.

In Ireland, there exists a two-tier system with respect to primary care. Means-tested GMS patients are entitled to attend their GP free of charge, whereas the remainder of the population pay out-of-pocket for consultations and services provided. However, the Irish government, as part of a package of healthcare reforms, proposes to introduce Universal Primary Care in Ireland within a five year timeframe (Department of the Taoiseach, 2011). The proposed reforms, to be financed through social insurance, will affect the reimbursement of GPs. These changes may remove many of the market-based elements of general practice and consequently may affect GPs innovativeness behaviour. However, the move towards group practices with more nursing support may increase learning and knowledge acquisition opportunities, and therefore positively influence innovative behaviour.

Health care reforms in the UK include the establishment of GP-led commissioning consortia, which will be given budgets to commission health care on behalf of patients in their local communities (Barratt, 2011). While there are clear distinctions in the mandates of the GP-led commissioning consortia in the UK and general practices in Ireland, it may be possible to consider some of the potential implications of these reforms through the lens of this thesis. Consideration should be given to the fact that placing decision-making concerning health care resourcing in the hands of health care professionals may encourage innovative health care provision.

In brief, we aspire to guide policy to support GPs innovation in Ireland and elsewhere, and also to identify the potential implications of policy reforms in international health care systems to innovative behaviour in general practice. The policy implications of this thesis, as well as our contributions to theory and knowledge, are discussed in detail in Chapter 8.

1.4 Thesis Overview

The rest of this thesis is structured as follows. In **Chapter 2**, the conceptual framework of the thesis is presented. Three complementary theoretical approaches have been used to explain the timing of adoption of innovation decisions. Disequilibrium models reflect the learning and informational influences on timing of adoption and generally have been used to examine innovation by individuals

(Rogers, 2003). Equilibrium models take account of how organisational characteristics (rank effects) and strategic interactions (stock and order effects) influence timing of adoption by firms (Karshenas and Stoneman, 1993). Learning-by-using effects reflect how cumulative learning experience from previous adoption decisions influence timing of adoption (McWilliams and Zilbermanfr, 1996). Chapter 2 also discusses the extension of these models to multiple technology adoption and intensity of adoption. This encompassing theoretical framework informs the empirical exercises of Chapters 4, 6 and 7. The rationale for its' application to adoption and use of innovations in a health care setting, as well as previous empirical research on the adoption and use of new prescription drugs, medical equipment and ICTs by GPs, is discussed in the relevant empirical chapters.

In **Chapter 3**, we introduce our secondary dataset, comprising of the GMS Prescribing and GP Characteristics Databases, which is used in the empirical investigation of the timing of first prescription of new drugs by Irish GPs in Chapter 4. The GMS Prescribing Database provides us with data on GPs prescribing history over a 4½ year time period with information on the characteristics of the 625 GPs themselves. Diffusion curves are used to graphically illustrate prescribing patterns of the sample of 1,137 drugs. In general, three patterns emerge: a relatively constant proportion of GPs prescribing these drugs, an increase in the proportion of GPs prescribing these drugs, and a decrease in the proportion of GPs prescribing these drugs. In addition, the GP Characteristics Database, representing a third of all GPs who hold a contract to treat public GMS patients in Ireland, includes information on nursing and clerical support, location, and GP age. This matched dataset provides us with a rich source of data, and enables us to investigate the influence of disequilibrium, equilibrium and learning-by-using influences on adoption of new prescription drugs by GPs.

In **Chapter 4**, we address our first research question and explore the determinants of the timing of the first prescription of new drugs by GPs in Ireland. The Irish primary health care system provides a distinctive setting for this empirical exercise, given the commercial and prescribing autonomy which characterise Irish general practice. A focused literature review on prescribing behaviour by physicians is presented in this chapter. In our empirical analysis, we identify six drugs new to the Irish market, which see strong take-up by GPs and which operate on different physiological organs and systems, and identify commonalities in the adoption of these six drugs. Drawing on the theoretical framework described in Chapter 2, we use duration analysis to explore the influence of GP characteristics (rank effects), strategic behaviour (stock and order effects), informational acquisition (epidemic learning effects) and learning-by-using on prescribing innovation.

Primary data collection, described in detail in **Chapter 5**, was undertaken to enable the empirical analyses of medical equipment and ICT adoption by general practices in Ireland, presented in Chapters 6 and 7 respectively. The purpose of this data collection is to reflect the nature of the general practices surveyed and their use and medical equipment and ICT, within the equilibrium, disequilibrium and learning-by-using framework. All Irish general practices were surveyed. A sample size of 601 was achieved, representing a 42 per cent response rate. This representative sample of Irish general practices and provides us with, previously unavailable, data to analyse the adoption of medical equipment and ICT by Irish general practices from an economic perspective.

In **Chapter 6**, we address our second research question and examine what influences the use of medical equipment by general practices in Ireland. A review of previous empirical studies on adoption and use of medical equipment in general practice is included in this chapter. In our empirical analysis, we focus on six items of medical equipment. In general, the majority of general practices utilise this equipment and we use diffusion curves to graphically illustrate their adoption over time. Here, we extend the application of our encompassing theoretical framework to multiple technology adoption, and apply multivariate Probit analysis to identify commonalities in the determinants of the probability of use of these six items of medical equipment. Specifically, we determine the influence of epidemic, rank, order and learning-by-using effects on the inter-related use of these six items of medical equipment.

In **Chapter 7**, we address our third research question and identify the factors which influence intensity of ICT use in Irish general practices. A review of literature relating to ICT use is presented in this chapter, and our encompassing theoretical framework is extended to intra-practice diffusion. We distinguish between ICT use for administrative and patient care functions, and categorise practices as being 'basic', 'intermediate' or 'enhanced' users of ICT for both these purposes. We use ordered Probit analysis to identify the influence of epidemic, rank and learning-by-using effects on intensity of ICT use with respect to both administrative and patient care functions.

Chapter 8 outlines the contribution of this thesis to knowledge and theory, and discusses potential policy implications arising from this research. Research limitations are briefly discussed. A future research agenda is also suggested.

CHAPTER 2: THEORETCIAL MODELS OF ADOPTION

2.1 Introduction

The purpose of this chapter is to present the conceptual framework of this thesis. The main theoretical approaches used to explain adoption and intensity of adoption of innovations are presented. Our encompassing theoretical model of adoption, incorporates the equilibrium, disequilibrium and learning-by-using models of adoption, and informs the empirical analyses of this thesis. We also outline how the Irish general practice environment and the nature of the innovations examined may influence adoption decision-making.

The contribution of new technology to economic welfare is only realised when the technology is widely used and diffused (Hall and Khan, 2003; Rogers, 2003; Hall, 2004). Diffusion results from a series of individual decisions to begin using the new technology, i.e. to adopt the new technology (Hall and Khan, 2003). Adoption and diffusion are often discussed as two separate literatures, however, diffusion is the cumulative or aggregate result of a series of individual calculations that weigh the incremental benefits of adopting an innovation against the costs of change (McWilliams and Zilbermanfr, 1996). The rate or level of diffusion can be determined by summing up these individual decisions (Hall and Khan, 2003), and it is widely accepted that the rate of diffusion varies across technologies, industries, and countries (Rosenberg, 1972; Stoneman, 1987).

Three complementary theoretical approaches have been used to explain the timing of innovation decisions. Equilibrium models, reflecting organisational characteristics and strategic interactions, have been used primarily to examine the first adoption of new technologies by firms (Karshenas and Stoneman, 1993), while disequilibrium models, which take account of epidemic and learning effects, have been used primarily to examine innovation by individuals (Rogers, 2003), and learning-by-using models reflect how cumulative learning from previous adoption decisions influence timing of adoption (McWilliams and Zilbermanfr, 1996). These theoretical models of adoption inform the empirical analyses of this thesis. To our knowledge, these models have not previously been applied to an empirical analysis of the adoption of innovations by health care professionals.

In addition to presenting previous theoretical and empirical studies of adoption, we also outline the distinguishing features of the adoption decision-making examined in this thesis. We discuss how the Irish general practice environment is likely to influence adoption decision-making, as well as outlining how the nature of the innovation, such as prescription drugs, medical equipment and ICT, may also influence uptake and use.

The rest of the chapter is organised as follows. The disequilibrium, equilibrium and learning-by-using approaches to the adoption and use of innovations are presented in Section 2.2, and the extension of these theoretical approaches to intensity of adoption is discussed in Section 2.3. Section 2.4 discusses how the general practice environment, as well as the nature of the three innovations, may influence adoption decision-making. Section 2.5 concludes this chapter.

2.2 Theoretical Models of Timing of Adoption

This section discusses the disequilibrium, equilibrium and learning-by-using models of timing of adoption, specifically, the influence of epidemic, rank, stock, order and learning-by-using effects on the timing of adoption of new innovations. This section also outlines how these theories of adoption have developed, as well as discussing their complementary and competing aspects. Table 2.1 also provides a brief description of these influences on the timing of adoption of new technologies.

Table 2.1: Influences on Timing of Adoption of Innovations

Disequilibrium Model of Adoption	Epidemic Learning Effects	Potential adopters adopt a new innovation upon learning of its existence
Equilibrium Model of Adoption	Rank Effects	Potential adopters obtain different returns from the use of a new technology due to different inherent characteristics and therefore adopt at different times
	Stock Effects	As the number of users of a new technology increases, the marginal benefits from adoption declines
	Order Effects	Early adopters (those higher in the adoption order) obtain greater returns from their use of the new technology than later adopters
Learning-by-Using Model of Adoption	Learning-by-Using Effects	Potential adopters adopt a new technology earlier if they have cumulative learning experience from previous adoption decisions.

In the disequilibrium models of adoption, information is asymmetric and adoption is driven by information flows. The epidemic models regard diffusion as resulting from the spread of information, and assume that (i) a potential user will adopt a new technology upon learning of its existence and (ii) information on the existence of the technology is spread by direct contact between a potential user and user (Baptista, 1999). Therefore, the simple epidemic models purport that potential users are more likely to adopt an innovation, the more widespread the use of that innovation by other members of their social system. A key aspect of the structure of the epidemic models is that there is an end level of use for the new technology, and the diffusion path is the disequilibrium approach to that end point (Stoneman, 1987).

Disequilibrium studies of adoption, exemplified in Rogers' *Diffusion of Innovations* book, examine the adoption of a variety of innovations through the lens of epidemic and learning effects (Rogers, 2003). Rogers (2003) found that when the number of adopters of a new product or technology is plotted on a cumulative frequency basis over time, the resulting distribution is an S-shaped curve. Whether examining the adoption of agricultural innovations, new prescription drugs or public health initiatives, these S-shaped curves, referred to as 'diffusion curves', follow a similar pattern. Adoption levels are initially slow, more rapid as adoption increases, then levelling off until only a small percentage of individuals have not adopted (Rogers, 2003).

In brief, epidemic theories of diffusion assume information asymmetries between different potential adopters resulting from factors such as location and interaction with external agents. In what is considered the most influential diffusion study of all time, Ryan and Gross (1943) investigated the adoption of hybrid corn in Iowa (Rogers, 2003). This pioneering study found that early adopters of hybrid corn were those farmers with formal education and those who were frequent visitors to Des Moines, Iowa's largest city (Ryan and Gross, 1943). Another classic diffusion study also found evidence of epidemic learning effects with respect to the adoption of a new drug by physicians, with early adopters of a new antibiotic, tetracycline, attending more out-of-town medical meetings that late adopters (Coleman et al., 1966).

Since these earlier studies, a substantial diffusion and adoption literature has developed across a range of disciplines. Epidemic effects have been measured in many ways and applied to the analysis of the adoption of a wide range of technologies and innovations, although their influence on the timing of adoption is not always consistent (Karshenas and Stoneman, 1993; Baptista, 1999; Baptista, 2000; Burton et al., 2003; Hall and Khan, 2003). However, the basic hypothesis of the simple epidemic model is that non-adopters are more likely to innovate, the more widespread adoption by other member of their social system.

Unlike the implicit assumption of asymmetric information in disequilibrium models of adoption, equilibrium models assume that information in the economy is perfect. In equilibrium models, differences in the timing of adoption therefore occur not because of the spread of information but because of the gains from adoption relative to its costs. As these gains change over time, so too does the number of adopters.

Interestingly, Stoneman (1983) in equilibrium studies of adoption also reports evidence of S-shaped diffusion curves when the cumulative percentage of adopters is graphed over time.

Three equilibrium effects on the timing of adoption are generally identified: rank, stock and order effects. Rank effects result from the assumption that potential adopters of a technology have different characteristics and therefore may obtain different returns from the use of a new technology. Here, potential adopters' heterogeneity is the key driver of the timing of adoption (Karshenas and Stoneman, 1993). Empirical studies use firm characteristics, such as firm size and human capital, to measure rank effects. There is substantial evidence of rank effects influencing timing of adoption of new technologies, although these effects are not always consistent across economies or technologies (Baptista, 2000; Battisti et al., 2007). In a study investigating the adoption of Computer Numerically Controlled (CNC) machines in the UK engineering industry, Karshenas and Stoneman (1993) report that firm size positively influences timing of adoption. A subsequent study of the adoption of CNC machines and microprocessors in the UK also reports a positive size effect on timing of adoption (Battisti et al., 2007). Similarly, a study, examining ICT adoption by businesses in the UK and Switzerland, reports a positive size effect in relation to ICT adoption by Swiss firms, but no such effect in relation to adoption by UK firms. Rank effects are also measured in the adoption literature as human capital, firm age, and R&D, although the empirical evidence of their influence on adoption is not altogether consistent. Human capital positively influences the timing of ICT adoption in the UK and Switzerland, whereas R&D investment positively influences the timing of ICT adoption by Swiss firms only (Battisti et al., 2007).

However, there is no evidence of R&D investment influencing the adoption of CNC machines and microprocessors in the UK (Battisti et al., 2007). In general, there is strong evidence in the innovation literature of firm heterogeneity, or rank effects, influencing timing of adoption. The equilibrium model of adoption purports that, in addition to firm characteristics, strategic behaviour, conceptualised as stock and order effects, also influences timing of adoption.

Stock effects are based on the idea that as the number of users of a new technology increases, the benefits from adoption decline. This steadily reduces the benefit-cost ratio until, at a certain point in time, the number of accumulated adopters makes adoption by the remaining non-adopters undesirable. Order effects suggest that an individual or organisation's position in the adoption order determines its returns from the use of the technology. Earlier adopters – those higher in the adoption order – will obtain greater returns than later adopters. Therefore, if a potential adopter expects the number of future adopters to be high, it will decide to adopt earlier (Karshenas and Stoneman, 1993). Both the stock and order effects capture strategic behaviour reflecting trade-offs between the costs and benefits of adoption by co-related agents.

Although the order and stock effects models imply that the profitability of adoption declines as the number of adopters increases, these effects are conceptually different. Firstly, the stock effect models focus on the equilibrium number of adopters and the associated lower profitability of adoption. Therefore, given an increase in the stock of adopters, the stock effect models predict a lowering of the probability of adoption.

In essence, the stock effect captures a negative effect on adoption. Contrastingly, the order effect models focus on the anticipation of subsequent adoptions. Therefore, if potential adopters anticipate high levels of uptake of a new technology, the order effect models predict a higher probability of adoption. So, the order effect has a positive effect on adoption.

This conceptual distinction underlies the choice of variables used to capture the order and stock effects in empirical analyses. Therefore, in the limited empirical studies to date, stock and order effect variables are constructed based on the stock of pervious adopters and the timing of adoption relative to timing of adoption by other firms in the sample respectively. There is limited evidence of stock and/or order effects influencing timing of adoption (Karshenas and Stoneman, 1993; Baptista, 2000), although there is evidence of such effects in relation to the adoption of multiple technologies, where the technologies are complementary (Stoneman and Kwon, 1994) or simultaneously adopted (Stoneman and Toivanen, 1997).

Recent literature has also focused on learning-by-using effects when modelling adoption decisions, whereby a firm increases its' stock of knowledge based on its' previous experience with technologies.[10] Previous studies report that learning from

[10] McWilliams and Zilbermanfr (1996) highlight three types of "learning" that play an important role in the adoption and demand for new technologies. "Learning by Doing", as described by Rosenberg (1982), which is producers of a new technology learning over time how to make the technology more cheaply and/or to improve the quality of technology. "Learning by Doing" explains the supply of technology, and so is not pertinent to this study. The second type of learning is "Learning-by-using", which Rosenberg (1982) describes as the effect of the users of a given technology increasing their productivity over time as they learn how to better use this new technology. McWilliams and Zilbermanfr (1996) highlight how economists use learning by doing and learning-by-using

the adoption of complementary technologies, complementarities between various functional groups of the same technology and the use of previous technology vintages positively impact on adoption decisions (Stoneman and Kwon, 1994; Colombo and Mosconi, 1995; McWilliams and Zilbermanfr, 1996; Stoneman and Toivanen, 1997; Arvantis and Hollenstein, 2001).

A number of studies which report evidence of learning-by-using effects influencing timing of adoption are briefly discussed. Empirical studies report learning-by-using effects influencing adoption patterns within the Italian metalworking industry (Colombo and Mosconi, 1995) and the adoption of computer technology by farmers in California (McWilliams and Zilbermanfr, 1996). These studies highlight that technological interdependencies and cumulative learning-by-using effects are important determinants of firms' adoption decisions. Arvantis and Hollenstein (2001) also find strong evidence of learning-by-using effects in the adoption of technologies. They specifically investigated the existence of cumulative learning effects that may arise from the use of an earlier generation of manufacturing technologies which embody constituent elements of later applied, more advanced ones. Their findings are in line with those of Colombo and Mosconi (1995) that learning from the use of previous technology vintages within the same functional

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interchangeably, however, there is a clear supply and demand side distinction between the two (Rosenberg, 1982). Therefore, we will also refer to this particular learning process whereby a firm increases its' stock of knowledge based on its' previous experience with technologies as learning-by-using. McWilliams and Zilbermanfr (1996) present the third type of learning as the 'traditional' form of learning which involves potential adopters gathering information about the performance of the new technology. These epidemic 'learning' effects, which have previously been discussed, capture a firm's ability to absorb knowledge from external sources and exploit it for its own innovative activities.

group positively impacts on the adoption of more advanced technologies. Therefore, previous empirical studies clearly indicate that learning-by-using effects positively influence the adoption of new technologies. It is nonetheless important to note that in contrast to much of the literature, Cabral and Leiblein (2003) find no evidence that experience with older technologies influences adoption decision-making.

It is also worth noting that given the influence of learning-by-using effects on adoption decisions, there is clear validation in examining adoption within a multiple technology adoption framework. For instance, Stoneman and Kwon (1994) were the first to explore the simultaneous diffusion of two new technologies. In line with Karshenas and Stoneman (1993), their study incorporated the main theoretical streams in the diffusion literature, namely the rank, stock, order and epidemic effects. Stoneman and Kwon (1994) put forward the hypothesis that the adoption of any one technology will be affected not only by variables relating to itself but also by variables relating to other technologies. Stoneman and Kwon's (1994) empirical results clearly indicate the existence of significant cross-technology effects in relation to the price and adoption timing of the technologies. As previously mentioned, subsequent studies also found evidence of cross-technology effects with respect to adoption decisions (Colombo and Mosconi, 1995; Stoneman and Toivanen, 1997), and highlight the importance of examining adoption and use of technologies within a multiple-technology framework as there may be cross-technology effects influencing adoption decisions.

We conclude this section with a brief discussion on how the three theories of adoption, equilibrium, disequilibrium and learning-by-using, have developed as complementary approaches to adoption decision-making. The epidemic models of adoption were initially based on theories modelling the spread of diseases, and also feature very strongly in the marketing and sociological literature on diffusion (Baptista, 1999; Hall, 2004). Within this literature, the epidemic model of adoption has been used primarily to explain uptake of new technologies by individuals. Karshenas and Stoneman (1993) were forerunners in incorporating the disequilibrium model of adoption with the equilibrium model of adoption to investigate businesses adoption decisions.

As discussed above, the main distinctions between the disequilibrium and equilibrium approaches to modelling timing of adoption is their implicit assumption about the availability of information and their behavioural content. In disequilibrium models information is asymmetric and adoption is driven by information flows; in equilibrium models information is perfect and adoption is driven by benefit-cost ratios. Despite these differences, Karsheanas and Stoneman (1993) viewed the equilibrium and disequilibrium models of diffusion as complementary rather than conflicting approaches and modelled both simultaneously.

This approach of treating the equilibrium and disequilibrium approaches as complementary has continued in the innovation literature; with little discussion as to how the disequilibrium and equilibrium models of adoption interrelate with each other, particularly in relation to the conflicting assumptions of imperfect and perfect information. The equilibrium model of adoption assumes perfect information;

however, if this assumption is relaxed to less than perfect information it is likely that the model continues to work, and predictions that timing of adoption is influenced by firm characteristics and strategic behaviour still hold true. Relaxation of the assumption of perfect information removes the primary competing aspect of these two models.

More recently, learning-by-using effects have been incorporated in economic studies of adoption. To date, learning-by-using effects have been used to explain adoption by businesses. Some authors have attempted to categorise learning-by-using effects within the equilibrium or disequilibrium models of adoption. It has been argued that the extent to which a firm has learned from the experience of previous adoption decisions can be considered a firm characteristic, i.e. the firm's stock of knowledge that distinguishes firms from each other. This line of reasoning would indicate that learning-by-using effects can be considered an extension of rank effects. However, one could also argue that learning-by-using effects could be deemed a feature of the disequilibrium model of adoption, and as a result of information asymmetries, information acquisition and learning can develop from within the business as well as from interactions with those outside the business. Categorising learning-by-using effects within the equilibrium or disequilibrium model of adoption is not necessarily important given that they are generally treated as complementary approaches in the innovation literature.

Empirical studies exploring the influence of cumulative learning on timing of adoption decisions have generally treated learning-by-using effects as an appendage to the more established equilibrium and disequilibrium models of adoption, and have not specifically identified the learning-by-using model of adoption as a mechanism for examining adoption decision-making on a par with the disequilibrium and equilibrium models of adoption. Also, the conceptualisation of learning-by-using effects has remained limited to focusing on learning from the adoption of complementary technologies and earlier technology vintages (Colombo and Mosconi, 1995; Arvantis and Hollenstein, 2001).

The disequilibrium, equilibrium and learning-by-using theoretical models, employed to examine the timing of adoption and multiple technology adoption decisions, have also been extended to examine the intensity of use of an innovation following its adoption. Section 2.3 focuses on the application of the disequilibrium, equilibrium and learning-by-using models to intensity of use of adopted innovations.

2.3 Theoretical Models of Intensity of Adoption

Recent economic literature examining the adoption of innovations argue that an understanding of the intensity of use by adopting firms is of as much importance as understanding the decision to adopt an innovation in the first instance (Mansfield, 1963; Battisti and Stoneman, 2003; Hollenstein, 2004; Battisti and Stoneman, 2005; Battisti et al., 2007). In the diffusion literature, the extent of use of an innovation is referred to as intra-firm diffusion, whereas the decision to adopt an innovation initially is referred to as inter-firm diffusion. There is limited data on within firm use of a new technology over time, resulting in few empirical studies of intra-firm diffusion (Battisti et al., 2007). However, a small number of studies have examined the intra-firm diffusion of technologies drawing on aspects of the equilibrium, disequilibrium and learning-by-using models of adoption. Interestingly, these studies find that inter-firm and intra-firm adoption decisions are driven by different factors (Hollenstein, 2004; Battisti et al., 2007), indicating that being an early adopter does not necessarily translate into being an extensive user.

Our knowledge of the intra-firm diffusion process is much less developed than our knowledge of the inter-firm diffusion process (Battisti and Stoneman, 2003). Mansfield's (1963) seminal work identifies 'stylised facts' in relation to intra-firm diffusion: (i) intra-firm diffusion takes time and follows a similar shaped growth curve to inter-firm diffusion, i.e. initial levels of use are low, increasing rapidly to a point of inflexion, and then increases at a decreasing rate until an asymptote is reached, (ii) different firms exhibit different paths of intra-firm diffusion, and (iii) different technologies exhibit different paths of intra-firm diffusion. Battisti and Stoneman (2003) suggest that these facts are widely accepted but there is little agreement in the literature as to why these patterns emerge in this way. Mansfield (1963) hypothesises that initial use of a technology by a firm is limited because risks of use are high. However, this risk reduces with ownership and use, and as it does extent of use increases and intra-firm diffusion proceeds. Consequently, much of the limited literature on intra-firm diffusion has largely relied on epidemic effects models.

However, subsequent studies have disputed that these epidemic effects explain intra-firm diffusion. For example, Battisti and Stoneman (2003) in an examination of timing of adoption and intensity of adoption of CNC machines, report that low-use and high-use co-exist for common adoption dates. Therefore, time since adoption cannot be the sole determinant of intra-firm diffusion as suggested by the epidemic model. Using backward projection techniques, Battisti and Stoneman (2003) show empirically that the inter-firm effect is more important in the early stages, and the intra-firm effect is more important in the later stages of the whole diffusion process. Battisti and Stoneman (2003) stress that inter-firm diffusion patterns alone are a poor indicator of overall diffusion and argue that much greater emphasis should be placed on intra-firm issues in future diffusion research.

A number of studies (Battisti, 2000; Battisti and Stoneman, 2003) argue that theoretical propositions made in the inter-firm diffusion literature, namely the equilibrium model effects, should also be applied to studies of intra-firm diffusion. Thus, in determining the extent to which to use a new technology the firm will compare the profitability of further use against the cost of use. The profitability of further use may differ across firms, due to firm characteristics and capabilities, and may differ across technologies, due to various technology-related factors (Battisti and Stoneman, 2003; Battisti and Stoneman, 2005). Empirical investigations of the hypothesis that equilibrium effects influence intra-firm diffusion report conflicting results. For instance, Battisti and Stoneman (2005), in an examination of intensity of use of CNC machines, report that profitability considerations are important in relation to intra-firm diffusion, particularly in relation to firm size and the use of complementary technologies and managerial techniques. Interestingly, Battisti et al. (2007) find that firm size does not impact on intra-firm diffusion in either the UK or Switzerland, indicating that smaller firms, having adopted ICT, use it to the same extent as larger firms. There is a lack of empirical studies of the influence of learning-by-using effects on intensity of adoption, however, Battisti and Stoneman

(2005) report that use of complementary technologies positively influences intensity of use of CNC machines.

There is conflicting evidence in relation to the influence of epidemic effects on intra-firm diffusion, i.e. intensity of use. For example, Battisti and Stoneman (2005) report little evidence of epidemic effects; however, they acknowledge that their epidemic effects' variables may not be capturing the essence of the non-equilibrium model. They further hypothesize that learning may involve active search rather than passive information acquisition as purported by the epidemic model. In a previous study, Hollenstein (2004) reports that the capacity to absorb external knowledge is important in relation to intensity of ICT use, distinctly more important than its' impact on adoption in the first instance. Hollenstein (2004) purports the plausibility of this finding given the more complex problems to be solved when a large set of ICT elements are being used.

To summarise, it is clear that the theoretical models of adoption developed to examine timing of adoption can also be applied to empirical examinations of intensity of adoption of innovations, i.e. intra-firm diffusion. Previous research indicates that being an adopter does not necessarily translate into being an extensive user (Hollenstein, 2004; Battisti et al., 2007), highlighting the need to examine the overall adoption process – adoption and intensity of adoption.

2.4 Adoption Decision-Making in Irish General Practices

As previously discussed in Section 1.2, Irish general practices enjoy considerable strategic freedom with respect to health care provision and practice development. As self-employed private health care practitioners, Irish GPs are assumed to maximise utility functions that are increasing in profits and service delivery. In this thesis we examine GPs decision-making concerning the adoption of three distinctive types of innovation: new prescription drugs, medical equipment and ICT. In this section, we discuss how the nature of the three types of innovation may influence GPs' decision-making.

The prescribing adoption decision differs from other adoption decisions in a number of ways due to the distinctive nature of this innovation. Firstly, a GP prescribes a drug to a patient to treat a particular condition or ailment; therefore, in weighing up the costs and benefits of adoption of a new drug a GP is primarily concerned with the clinical efficacy of the drug which will have a direct impact on their patient's health. Secondly, given that Irish GPs are not constrained by prescribing budgets nor directly affected financially from prescribing decisions it is unlikely that drug prices influence their decision-making. Therefore, for the most part, prescribing decisions are likely to be altruistic in nature. Although, we must assume that, like any small business, GPs' decision-making is influenced by commercial considerations, and they will, at the very least, consider how their decisions may be perceived by potential patients. Furthermore, as previously mentioned, Irish GPs prescribing decisions are not constrained by NICE guidelines or based on practice or nationally-agreed formularies, such as the British National Formulary (BNF). Therefore, although we expect GPs to be influenced by peer prescribing decisions, prescribing decisions are made at the individual GP level. A further interesting aspect of the adoption of 'new-to-market' branded drugs is the intense pre-release marketing which accompanies new drugs, and ensures GPs are well informed of their arrival on the market.

Similar to a prescribing innovation, the adoption and use of medical equipment by general practices has direct implications for patients and the health care they receive. However, the nature of the adoption decision differs in that a general practice must decide to invest in a piece of equipment as opposed to an individual GP deciding to write a prescription. As previously discussed, Irish general practices incur the monetary cost of acquiring an item of medical equipment and this cost would usually be shared by the GPs in the practice. In addition, costs may include upkeep of equipment, as well as training costs to ensure efficient and correct use. Therefore, this innovation, where the cost of acquisition and use is incurred by the business unit, is closer to the innovations generally examined within the economics literature and through the lens of the equilibrium models of adoption. Also, increasing the range of diagnostic and treatment capabilities of a practice must influence commercial aspects of the business. However, the health care provision aspect to the use of medical equipment cannot be ignored, with uptake of medical equipment equally likely to be influenced by the desire to improve service provision.

The third innovation that features in our examination of adoption decision-making is ICT. Numerous studies have examined the adoption of ICT by firms. Indeed, the benefits to businesses of adopting ICT are well documented, as it is medical settings, including general practice (Kvist and Kidd, 1998; Misan, 2003). In our intra-practice diffusion exercise, we explore the factors which influence the intensity of ICT use by general practices. Therefore, we are not concerning with the adoption of the innovation in this instance, but more so with increasing use of a range of ICT applications. There are similarities between this adoption decision and the previously discussed adoption decisions, particularly the use of medical equipment decision-making. We assume that general practice's ICT use is influenced both by profitability and service provision considerations, and similar to medical equipment use can improve business efficiency as well as health care provision. Furthermore, intensity of adoption decision-making differs from adoption decision-making with respect to the costs and benefits of such decision-making. Within the context of this study, the cost of adopting ICT in the first instance would be considerable for an individual practice; although the cost of incorporating additional ICT applications is likely to vary relative to the types of ICT applications. In some instances costs are likely to be significantly lower as practices choose to use additional ICT applications available from their existing ICT package; although, on other occasions, more extensive ICT use may necessitate the purchase of new software. Similarly, some ICT applications such as a practice website development may incur additional costs. Similar to medical equipment use, more intensive ICT use might require additional training. However, in general, risks of adoption reduce with ownership and use of technologies and, consequently, general practices can reap the benefits of more extensive ICT use.

The types of innovation examined in this thesis are discussed above to illustrate how the similar and contrasting features of these innovations are likely to influence their adoption and use by Irish GPs. GPs are assumed to maximise utility functions that are increasing in profitability and service provision. Given the commercial and health care provision elements of the general practice environment and in line with the literature documented in the previous sections, we expect equilibrium, disequilibrium and learning-by-using effects to influence adoption decision-making in Irish general practices. As discussed above, the specific features of each innovation are likely to influence the trade-off between business and patient care motivations, and subsequently affect the relative impact of the three sets of influences on adoption behaviour. For completeness, we incorporate the equilibrium, disequilibrium and learning-by-using effects on adoption to our integrated examination of adoption decision-making in Irish general practices. Further justification for the application of this theoretical framework to the adoption and use of new prescription drugs, medical equipment and ICT in Irish general practices is discussed in Chapters 4, 6 and 7 respectively.

2.5 Conclusion

Three complementary theoretical approaches are used to explain the timing of adoption decisions. In general, disequilibrium models of adoption reflect informational and learning effects. In empirical analyses, epidemic effects are conceptualised to measure the likelihood of individuals interacting with others, and, therefore, learning about new technologies. Then, according to the disequilibrium model of adoption, potential adopters adopt new technologies upon learning of their existence.

In equilibrium models, differences in the timing of adoption occur, not because of the spread of information but, because of the incremental benefits of adoption relative to its costs. The equilibrium model of adoption identifies three effects on the timing of adoption: rank, stock and order effects. Ranks effects result from the assumption that potential adopters of a technology have different inherent characteristics, therefore, obtaining different returns from adoption. Here, potential adopters' heterogeneity is the key driver of timing of adoption. Stock and order effects capture strategic behaviour, whereby potential adopters are influenced by the adoption decisions of co-related agents. Specifically, as the stock of adopters increases, the marginal benefits from adoption declines (stock effect); and those higher in the adoption order obtain greater returns from adoption (order effect).

The final influence on timing of adoption of new technologies identified is learning-by-using effects. Learning-by-using effects are based on the assumption that potential adopters adopt a new technology earlier if they have cumulative learning experience from previous adoption decisions. Many authors view the disequilibrium, equilibrium and cumulative learning models of adoption as complementary and empirically model them simultaneously with respect to timing of adoption. These theoretical models have also extended to multiple technology adoption and intensity of adoption studies.

The equilibrium, disequilibrium and learning-by-using models of adoption inform our empirical analyses. The autonomous nature of Irish general practice suggests the potential for both commercial and service provision motivations to influence adoption decision-making. The nature of the innovation being adopted is likely to influence the extent to which commercial or service provision considerations impact on decision-making. In Chapters 4, 6 and 7, we discuss the applications of these theoretical models to innovative decision-making in general practices in Ireland and also present previous empirical research on the adoption and use of new prescription drugs, medical equipment and ICT by GPs.

CHAPTER 3: A DESCRIPTION OF THE GMS PRESCRIBING AND GP CHARACTERISTICS DATABASES

3.1 Introduction

This chapter describes the GMS Prescribing and GP Characteristics Databases. The GMS Prescribing Database has information on GPs prescribing history over 4½ years, and the GP Characteristics Database provides us with information about the GPs themselves. This data is used to address our first research question and identify the determinants of the timing of adoption of new prescription drugs by Irish GPs, as presented in Chapter 4.

In Ireland, GPs play a core role in the provision of primary care to the general population (Department of Health and Children, 2001; Thomas and Layte, 2009). As previously discussed in Chapter 1, in general, Irish GPs are self-employed, private practitioners who choose where they set up their practices, who they employ, and how they equip their practices (Department of Health and Children, 2001; Wren, 2003). They provide a range of services to their patients, including patient examination and diagnosis, prescription of medication, ordering of tests, performance of minor surgeries, and referral of patients to other health care providers (Competition Authority, 2010).

Certainly, an integral part of the health care service provided by GPs to their patients is the prescribing of medication, and consequently consumer access to new prescription drugs is mainly through GPs (Prosser et al., 2009; Thistlehwaite et al., 2010). In line with the commercial autonomy Irish GPs enjoy, they also have considerable autonomy with respect to their prescribing decisions. Once a particular drug has been approved for use by the Irish Medicines Board, GPs can prescribe it to their patients.[11] Nor are they constrained by prescribing guidelines, such as the National Institute for Clinical Excellence (NICE) guidelines in the UK. We have at our disposal a dataset which allows us to match prescribing data with data on GP charactersitics. The purpose of this chapter is to describe this matched dataset, comprising of the GMS Prescribing Database and the GP Characteristics Database. This data is used in the empirical analysis in Chapter 4, where we explore the factors which shape the timing of the first prescription of six new drugs by GPs in Ireland.

This chapter is organised as follows. Section 3.2 describes the GMS Prescribing Database, and identifies patterns and trends in the prescribing patterns of a sample of approximately 625 Irish GPs. Section 3.3 describes the GP Characteristics Database. Finally, section 3.4 concludes this chapter with a synoposis of the matched dataset, outlining the advantages and limitations of this data.

3.2 GMS Prescribing Database

The GMS Prescribing Database contains data for all prescriptions filled for GMS patients in the Southern, South-Eastern and North-Eastern Health Boards for the period October 1999 to March 2004.[12] When a GMS (public) patient gets a prescription from a GP, they fill it either in a pharmacy or, if their GP has a

[11] Drugs authorised by the IMB do not automatically receive a GMS code, although most drugs do. Drugs that receive a GMS code can be prescribed to public (GMS) patients.

[12] Prior to January 2005, the Irish health care system comprised of eight regional health boards which were responsible for delivering health care to the population of those regions. The Health Act (2004) legislated for the establishment of the Health Service Executive (HSE), a single entity, responsible for delivering health care for the population of Ireland (See Appendix 1 for maps of regional health boards and HSE regions).

dispensing licence, at the GP practice. The medicine is dispensed free of charge to the patient and a duplicate of the prescription is sent by the dispenser to the GMS (Payments) Board for payment.[13] A number of details are entered into the prescribing database, including GP identifiers, dispenser identifiers, drug details which follow the Anatomical Therapeutic Chemical (ATC) classification system[14], and quantity prescribed. As this dataset relates to payment of dispensers, it provides a complete record of all prescriptions dispensed. The GMS Prescribing Database provides monthly data for the period October 1999 to March 2004. This section, firstly, describes the process of restructuring the GMS Prescribing Data to drug-level observations and, secondly, describes the prescribing patterns by GPs over the 54 month time period.

As received, the GMS Prescribing Database consisted of 54 monthly files comprising of two data files – the extract file and the drug file.[15] The extract files contain information on each prescription filled for each patient, consisting of variables such as GP number, pharmacy number, patient number, prescribing GP number and drug code. The corresponding drug file contains information on each drug, such as drug code, ATC classification, defined daily dose, strength and price. The link variable, drug code, enabled us to merge the extract and drug files for each month. The prescription level observations in each monthly file ranged from approximately 600,000 to 1,000,000.

[13] In Budget 2010, a new charge of 50 cent per item was announced to be introduced in October 2010. This charge did not apply within the timeframe of this study.
[14] The ATC classification system is described in detail later in this section.
[15] The monthly files were provided by the HSE in the form of Digital Audio Tapes (DAT) (Oct 1999 – Dec 2001) and CDs (Jan 2002 – Mar 2004). These DAT files were downloaded to CDs using a DAT tape drive in *.out* format. All monthly files were converted to Stata 11.

Next, the prescription level observations were converted to drug level observations. Each drug is classified according to the Anatomical Therapeutic Chemical (ATC) classification system, which divides drugs into different groups according to the organ or system on which they act and their chemical, pharmacological and therapeutic properties (World Health Organisation, 2008). Drugs are classified in groups at five different levels. The drugs are divided into fourteen anatomical main groups (1st level), with one pharmacological/therapeutic subgroup (2nd level). The 3rd and 4th levels are chemical/pharmacological/therapeutic subgroups and the 5th level is the chemical substance. The following example illustrates the structure of the ATC code A10BA02 for the drug *metformin*.

Table 3.1: ATC classification of *metformin*

ATC Code	Classification Levels
A	Alimentary tract and metabolism (1st level, anatomical main group)
A10	Drugs used in diabetes (2nd level, therapeutic subgroup)
A10B	Blood glucose lowering drugs, excl. insulins (3rd level, pharmacological subgroup)
A10BA	Biguanides (4th level, chemical subgroup)
A10BA02	Metformin (5th level, chemical substance)

Source: World Health Organisation (2008)

Therefore, in the ATC classification system all plain *metformin* preparations are given the code A10BA02. As illustrated in Table 3.1, the code A10BA02 provides five levels of information regarding this particular drug. This drug acts on the alimentary tract and metabolism system (A) and is a drug used to treat diabetes (A10). It is a blood glucose lowering drug (A10B), with a chemical subgroup comprising biguanides (A10BA) and the chemical substance metformin (A10BA02). All ATC codes provide the same level of information and can be read in the same manner.[16]

The restructured database provides drug-level observations for 1,137 drugs over 54 months. The GMS Prescribing Database also contains GP identifiers for the GPs in the Southern, South-Eastern and North-Eastern Health Boards. The number of GPs over the period October 1999 to March 2004 ranged from 573 to 799.[17] The restructured database provides us with data on whether or not each GP prescribed each drug in each of the 54 months. This allowed us to identify the date of first adoption of each drug by each GP and to construct diffusion curves for each drug reflecting the proportion of GPs prescribing each drug each month.

The GMS Prescribing Database, even in its restructured format, is a large and cumbersome dataset. To provide an overview of dynamics within the dataset, it was decided to generate the percentage of GPs prescribing each drug in the first year (October 1999 – September 2000) and last year (April 2003 – March 2004) of the sample, categorise them into deciles and construct a 10 by 10 crosstabulation (Table 3.2). This 10 by 10 crosstabulation is essentially a transition matrix, reflecting transitions in the level of prescribing by GPs of all 1,137 drugs in the first year of the

[16] The ATC codes are referred to as 'drugs' from this point onwards. However, it is important to note that the ATC codes essentially provide the generic names for these drugs, and there may be a number of brands of each ATC code on the market.

[17] The analysis was constrained to prescribing decisions by GPs for patients on their GMS patient list, i.e. prescriptions written by locums are not included in this restructured database. In general, GP characteristics data is not available for locums, so they were removed from the analysis. This allows the analysis to focus on GPs prescribing decisions in relation to public patients on their GMS lists.

sample and in the final year of the sample. Each count in the transition matrix refers to a drug, and while the drugs in each cell cannot be identified from the transition matrix, they can be identified from the dataset. The transition matrix allows for a greater understanding of general transitions in prescribing patterns by GPs at the beginning and end of the sample. In general, the level of prescribing of each drug follows one of three patterns: (i) a relatively constant proportion of GPs prescribing it, (ii) an increase in the proportion of GPs prescribing it, or (iii) a decrease in the proportion of GPs prescribing it. We identify and discuss a number of drugs which follow one of these three adoption patterns and draw diffusion curves to illustrate adoption patterns over the 54 months.[18]

The transition matrix can be read as follows. Each count in the transition matrix refers to a drug. Therefore, 596 drugs were prescribed by the first decile of GPs in the first year of the sample (October 1999- September 2000) and by the first decile of GPs in the last year of the sample (April 2003 – March 2004). While the 596 drugs in this cell cannot be identified from the transition matrix, they can be identified from the dataset. An example of one of these drugs consistently prescribed by less than 10% of GPs is D01AA01 or *nystatin*, an antibiotic.

Similarly, all other cells on the leading diagonal represent drugs which are prescribed by a similar proportion of GPs in the first and last year of the sample. As is evident from Table 3.2, one drug is prescribed by more than 90 per cent (tenth decile) in the first and last year of the sample. From the database, this drug is identified as *acetylsalicylic* (B01AC06), or as it's more commonly called aspirin.

[18] It is important to note that these drugs are chosen to illustrate adoption patterns, and are not chosen for any other reason.

Further examples of drugs that are generally prescribed by the same proportion of GPs in the first and last year of the sample include *phenobarbital* (N03AA02), an antiepileptic, and *chloramphenicol* (S01AA01), an eye antibiotic.

It must be stressed that the transition matrix identifies patterns in prescribing patterns in the first and last year of the sample. We have identified four drugs from the transition matrix which are prescribed by the same proportion of GPs in the first and last years of the sample. Next, we draw diffusion curves for these four drugs, which illustrate the cumulative percentage of GPs prescribing these drugs over the 54 month sample. Diffusion curves, discussed in detail in the previous chapter, essentially illustrate the cumulative percentage of adopters over time. In general, diffusion curves follow a similar pattern – adoption levels are initially slow, more rapid as adoption increases, then levelling off until only a small percentage of individuals have not adopted (Rogers, 2003). As discussed in Chapter 2, the epidemic models of adoption generally assume that a potential user will adopt a new technology upon learning of its existence. Rogers (2003) found that when the number of adopters of a new product or technology is plotted on a cumulative frequency basis over time, the resulting distribution is an S-shaped curve. Stoneman (1983), examining adoption within the equilibrium model, also states "if one can explain the date of adoption by individual firms, then by aggregation one should have the inter-firm or intrasectoral diffusion curve". As per Rogers (2003) and Stoneman (1983), we illustrate adoption levels of the aforementioned drugs over the 54 month time frame (Figure 3.1).

Table 3.2: Transition Matrix of Drug Adoption in First and Last Year of Sample

Last Year of Sample (April 2003 – March 2004)	First Year of Sample (October 1999- September 2000)										
	First Decile	Second Decile	Third Decile	Fourth Decile	Fifth Decile	Sixth Decile	Seventh Decile	Eight Decile	Ninth Decile	Tenth Decile	Total
First Decile	**596**	28	10	2	1	2	1	0	1	0	**641**
Second Decile	48	**57**	15	2	0	1	0	0	0	0	**123**
Third Decile	19	22	**19**	9	2	0	0	0	0	0	**71**
Fourth Decile	8	7	15	**25**	7	4	0	0	1	0	**67**
Fifth Decile	3	8	2	11	**16**	7	4	0	0	0	**51**
Sixth Decile	5	1	1	4	8	**18**	8	0	0	0	**45**
Seventh Decile	6	0	2	3	6	6	**20**	5	0	0	**48**
Eight Decile	3	0	2	0	1	6	7	**22**	12	0	**53**
Ninth Decile	2	0	1	0	0	0	2	6	**15**	11	**37**
Tenth Decile	0	0	0	0	0	0	0	0	0	**1**	**1**
Total	**690**	**123**	**67**	**56**	**41**	**44**	**42**	**33**	**29**	**12**	**1,137**

Figure 3.1: Illustrative Curves for Consistently Prescribed Drugs: Oct 99-Mar 04

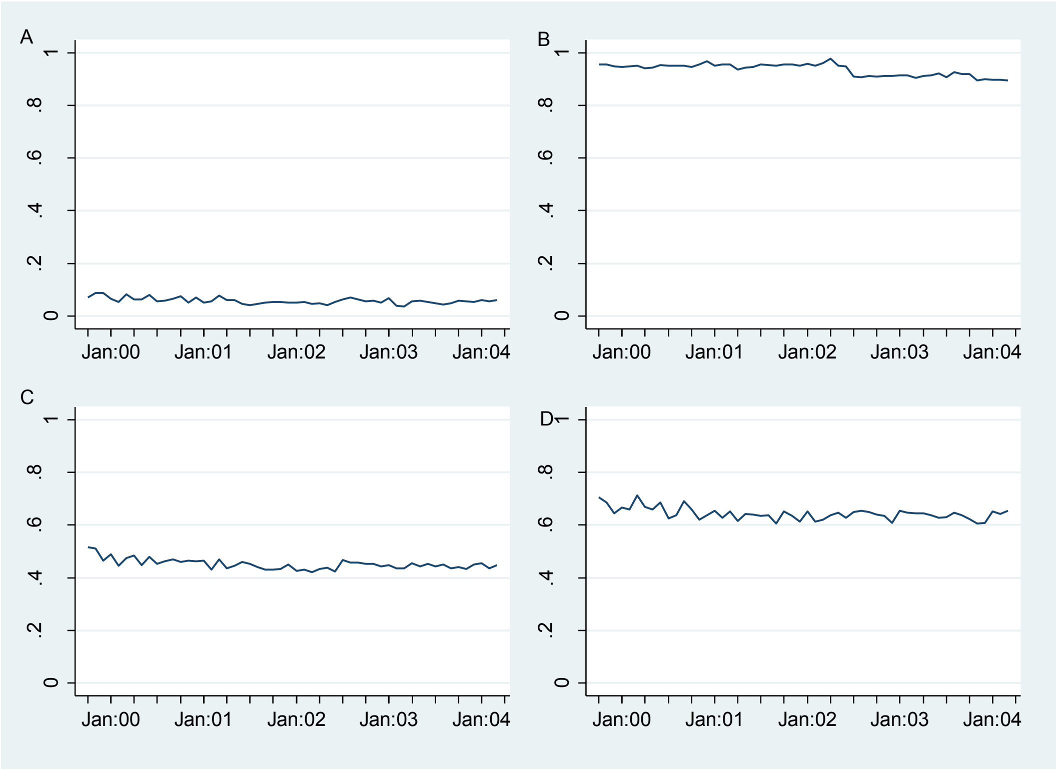


Figure Key: Graphs present the proportion of GPs prescribing Nystatin (A), Acetylsalicylic (B), Phenobarital (C), and Chloramphemicol (D) over time.

Figure 3.1 clearly illustrates that the proportion of GPs prescribing these drugs is relatively constant across the 54 month time-frame. When viewing these diffusion curves, it is necessary to remember the sample is a 4½ year time-frame. Therefore, the diffusion curves presented in Figure 3.1 are in fact a snapshot or a portion of the S-shaped curve of these drugs over a longer timeframe. Given the flatness of these diffusion curves (Figure 3.1), it is possible to surmise that we are seeing the latter portion of their corresponding S-shaped curves where the level of adoption levels off. It is also likely that the remaining GPs in the sample are essentially non-adopters.

789 of the 1,137 drugs are accounted for in leading diagonal in the transition matrix, indicating that approximately 70 per cent of the drugs in this sample are prescribed by the same proportion of GPs in the first and last year of the sample. We can assume that the diffusion curves for these 789 drugs would be, similar to the diffusion curves in Figure 3.1, relatively flat over the 4½ year period. However, we are particularly interested in identifying drugs that are prescribed by increasing proportions of GPs over time. Such drugs can also be identified from the transition matrix.

Cells below the leading diagonal of the transition matrix indicate drugs which are being prescribed by a higher proportion of GPs in the last year of the sample than the first year of the sample. 214 of the 1,137 drugs fall into this category. The closer the cell is to the leading diagonal the smaller the movement between deciles, while the further the cell is from the leading diagonal the greater the movement between deciles. For example, in the first year of the sample two drugs were prescribed by the first decile of GPs and by the ninth decile of GPs in the last year of the sample. One of these drugs was identified from the dataset as being *esomeprazole* (A02BC05), a proton pump inhibitor. The diffusion curve for *esomeprazole* is presented in Figure 3.2(A). As is evident from the graph, in the first year of the sample, no GPs in the sample were prescribing *esomeprazole*, although from early 2002 over 80% of GPs in the sample were prescribing it to their patients. The diffusion curve for *celecoxib* illustrates a similar pattern (Figure 3.2(B)).

It is likely that the diffusion curves for *esomeprazole* and *celecoxib* are in fact complete S-shaped curves, illustrating patterns of no adoption, followed by increasing adoption levels and then a levelling-off with respect to adoption levels. Given the length of time with respect to the levelling-off of adoption levels for both drugs, it is likely that the remaining GPs are essentially non-adopters. As previously mentioned, the change in the proportions prescribing each drug from the beginning to the end of the time-frame can be easily seen in the transition matrix by the distance of the cell in which a drug is accounted for from the leading diagonal. When the increase in the proportion of GPs prescribing a drug from the first to the last year of the sample is relatively large, then such a drug is accounted for in a cell far from the leading diagonal. This is the case for *esomeprazole* and *celecoxib.*

Figure 3.2: Illustrative Curves for Drugs with Increasing Adoption Levels

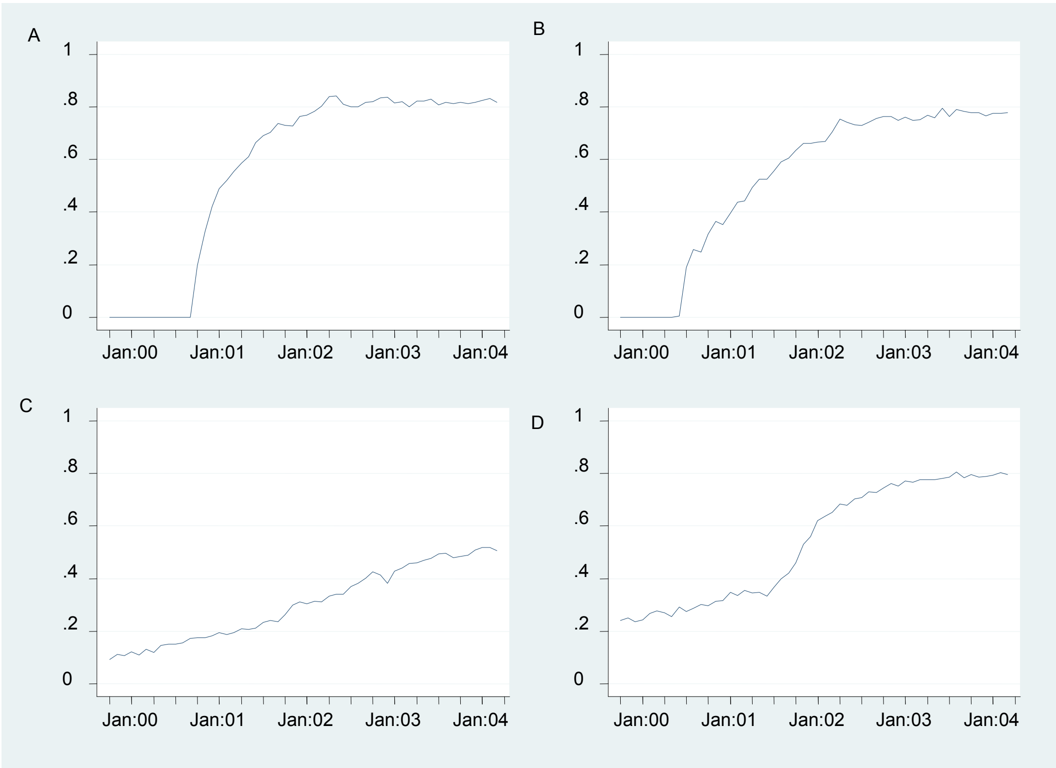


Figure Key: Graphs present the proportion of GPs prescribing Esmoprazole (A), Celecoxib (B), Alfuzosin (C), and Alendronic Acid (D) over time.

Diffusion curves (Figure 3.2(C-D)) are also drawn for two additional drugs, *alfuzosin* (G04CA01) and *alendronic acid* (M05BA04), which are also prescribed by more GPs later in the time-frame. It is clear from the diffusion curves for both drugs that they were being prescribed by some GPs in the sample prior to October 1999, so again it is likely that we are viewing a portion of an extended S-shaped curve over a longer time period. It is also worth noting that both drugs were identified from cells close to the leading diagonal in the transition matrix. Therefore, the increase in the proportion of GPs prescribing *alfuzosin* and *alendronic acid* is less relative to the increase in the proportion of GPs prescribing *esomeprazole* and *celecoxib* in the sample time-frame.

To reiterate, approximately 70 and 19 per cent of the 1,137 drugs in the GMS Prescribing Database are prescribed by a similar and higher proportion of GPs in the last year of the sample compared to the first year of the sample respectively. The remaining drugs in the sample are prescribed by a lower proportion of GPs in the last year of the sample than in the first year of the sample. These drugs are accounted for in cells above the leading diagonal in the transition matrix. 134 of the 1,137 drugs, approximately 11 per cent of the sample, fall into this category.

From the transition matrix, one drug is identified as being prescribed by over 80% (ninth decile) of the sample in the first year falling to under 40% (fourth decile) of the sample in the last year. From the dataset, this drug is identified as *thioridazine* (N05AC02), an antipsychotic. From the transition matrix, it is clear two drugs prescribed by the sixth decile of GPs in the first year of the sample decreased to being prescribed by the first decile in the last year of the sample. From the dataset, one of these drugs is identified as *loratadine* (R06AX13), an antihistamine. Diffusion curves for both *thioridazine* and *loratadine,* presented in Figure 3.3, illustrate that both drugs saw a general decrease in adoption levels across the 54 month time-period. The adoption pattern with respect to *loratadine* indicates a seasonal effect in the first half of the time-frame with less GPs prescribing this antihistamine in the winter months, however, adoption levels decrease steadily from mid-2001, with evidence of a small increase in adoption levels in Summer 2003.

Figure 3.3: Illustrative Curves for Drugs with Decreasing Adoption Levels

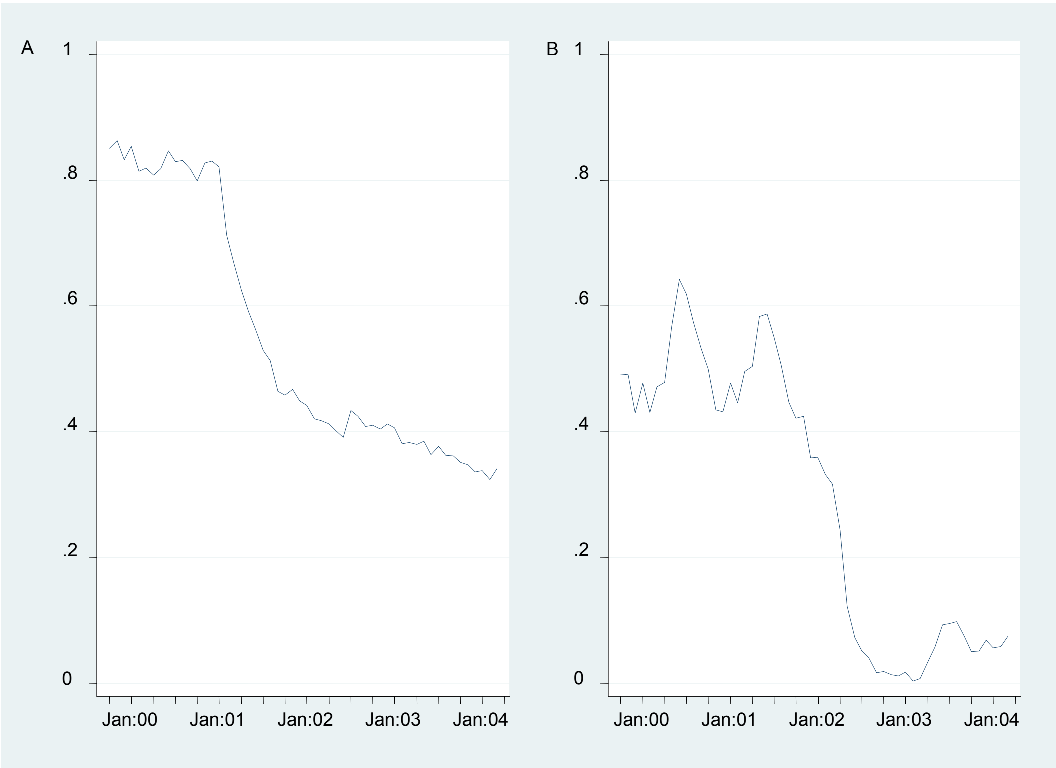


Figure Key: Graphs present the proportion of GPs prescribing Thiordazine (A) and Loratadine (B) over time.

The purpose of this section is to describe the restructured GMS Prescribing Database. This data provides a rich source of data in relation to Irish GPs' prescribing patterns. The transition matrix allows us to identify some general patterns in relation to the adoption levels of these 1,137 drugs in the first and last year of the sample. Diffusion curves are used to further illustrate these patterns over the entire 4½ year time frame.

Approximately 70% of the 1,137 drugs are prescribed by the same proportion of GPs in the first and last year of the sample. The diffusion curves for these drugs are generally flat, indicating that we are seeing a snapshot of the latter part of Rogers' (2003) S-shaped diffusion curve, where the level of adoption has levelled off. Over 50% of the 1,137 drugs are prescribed by less than 10 per cent of GPs in the first and in the last year of the sample.

The level of adoption of 214 drugs increased over the 4½ year time-period. The level of adoption of 134 drugs decreased over the same time-period. This indicates that the GPs in the sample increased the portfolio of drugs they prescribe to public patients over the 4½ year time period.

3.3 GP Characteristics Database

In the GMS Prescribing Database each GP has a unique numerical identifier which is also included in the GP Characteristics Database. These identifiers are used to match each GP's prescribing innovations to their background characteristics in the GP Characteristics Database. Compiled in 2001, approximately the middle of the time period covered by the GMS Prescribing Database, the GP Characteristics Database provides GP & practice characteristics for 625 GPs in the Southern, South-Eastern and North-Eastern Health Boards. This sample of GPs comprises almost a third of all GPs in Ireland who hold a contract to treat provide public GMS patients (Health Service Executive, 2002), and provides this study with time-invariant GP and practice characteristics variables.

Table 3.3: Description of Variables in GP Characteristics Database

Variable Name	Variable Description	Mean	St. Dev.
Practice Nurse	Practice with a nurse	0.58	0.49
Practice Secretary	Practice with a secretary	0.79	0.41
Rural Practice	Practice located in rural area (and in receipt of Rural Practice Allowance)	0.12	0.32
Dispensing Practice	Practice has in-house dispensary	0.12	0.32
IDTS60	GPs receive 60 per cent of savings made from meeting prescribing targets	0.37	0.48
IDTS50	GPs receive 50 per cent of savings made from meeting prescribing targets	0.24	0.42
IDTS40	GPs receive 40 per cent of savings made from meeting prescribing targets	0.39	0.49
GP Age	GP age in years	49 yrs	8.3 yrs

Source: GP Characteristics Database

Table 3.3 provides descriptive statistics for the GP and practice characteristics in this dataset.[19] In 2001, 58 per cent and 79 per cent of GPs in the sample worked in a practice with a nurse and secretary respectively. 12 per cent of GPs in this sample were in receipt of a rural practice allowance, as they live and practice in an area with a population of less than 500 people. Given their remote location, these practices often dispense medication. 12 per cent of GPs worked in a dispensing practice. The average age of GPs in the sample is 49 years of age.

The GP Characteristics Database also contains variables identifying whether GPs were beneficiaries from the Indicative Drug Treatment Scheme (IDTS). This initiative, intended to reduce overall prescribing costs, provided incentives for GPs

[19] These variables are discussed in the context of the theoretical models of adoption in Chapter 4.

able to reduce their prescribing costs and receive a percentage of the savings made to invest in their practice. Targets were calculated based on their previous year's prescribing costs, controlling for the age and sex of the patients.[20] GPs were placed in one of three categories, which indicated the percentage of savings they were entitled to as a result of meeting drug costs targets. 37 per cent of GP's previous years' prescribing costs were less than 95 per cent of the national age related average costs and qualified for 60 per cent of any savings made due to meeting targets. 24 per cent of GPs qualified for 50 per cent of any savings made due to meeting targets. A further 39 per cent of GPs qualified for 40 per cent of any savings made due to meeting targets. In each of these categories, the remaining savings were made available to the local health board.

3.4 Conclusion

The purpose of this chapter is to introduce the GMS Prescribing Database and the GP Characteristics Database. The GMS Prescribing Database provides a rich source of data in relation to Irish GPs prescribing patterns. A transition matrix (Table 3.2) is used to describe the prescribing patterns of the sample of 1,137 drugs from the beginning and the end of the sample period. Diffusion curves are used to graphically illustrate these patterns of a number of drugs. In general, three patterns emerge with respect to the adoption of each drug: a relatively constant proportion of GPs prescribing these drugs, an increase in the proportion of GPs prescribing these drugs, and a decrease in the proportion of GPs prescribing these drugs. Almost 70 per cent

[20] Participation in the Indicative Drug Treatment Scheme was voluntary and GPs retained the right and obligation to prescribe as they considered necessary. No sanctions were in place for those GPs who failed to reduce costs.

of the 1,137 drugs represented in the GMS database were prescribed by a similar proportion of GPs over the entire 54 months covered by the database. These are likely to be established drugs for which no alternative became available during the sample period. The level of adoption of 214 drugs (approximately 19 per cent) increased over the time period, with the level of adoption of 134 drugs (approximately 11 per cent) decreasing over the same period.

The GMS Prescribing Database is matched to the GP Characteristics Database, by means of a unique GP identifier. The GP Characteristics Database provides us with data relating to GP and practice characteristics, such as GP age, nursing and administrative support, and practice location. In summation, the average age of GPs in our sample is 49 years. More than half of the GPs work with the support of a nurse, and three in four GPs have clerical support. One in eight GPs are entitled to a rural practice allowance and have a dispensary attached to their practice. The majority of GPs adjusted their prescribing to benefit from the IDTS.

Our matched dataset brings together information of GPs prescribing history over a 4½ year time period with information on the characteristics of GPs themselves. The GMS Prescribing Database was provided to the Department of Economics, University College Cork on a monthly basis from October 1999 to March 2004.[21] While we would prefer more timely data, this unique dataset allows us to identify the month that GPs first prescribe drugs new to the Irish market during a 4½ year time period.

[21] Along with the Departments of General Practice and Pharmacy at University College Cork, the Department of Economics has applied for the re-instatement of the provision of this data from April 2004 to the present. To date, the request has not been granted.

The matched dataset covers three of the eight Irish health boards, the Southern, South-Eastern and North-Eastern Health Boards. These three health boards provided health services to 34 per cent health services to of the Irish population and to 35 per cent of all GMS patients (Department of Health and Children, 2002; Health Service Executive, 2002). Our GP Characteristics database, which is an administrative database, provides us with information on GP and practice characteristics for 625 GPs, almost all GPs with a GMS contract in these three health boards.[22] This sample provides us with prescribing information for approximately one third of all Irish GPs who hold GMS contracts and approximately one third of all public GMS patients (Department of Health and Children, 2002; Health Service Executive, 2002).

Both the GMS Prescribing Database and the GP Characteristics Database provides us with a range of variables and opportunities to construct variables to enable the empirical analysis in Chapter 4. These variables are discussed briefly below.[23] Given the monthly nature of the prescription data, we are able to determine the date a GP first prescribes a new drug, and also construct time -invariant stock effects and 'first-mover' order effects. From the GMS Prescribing Database, we also construct a portfolio breadth variable which captures learning-by-using effects. The GP Characteristics data provides us with a number of explanatory variables which allow us to sufficiently measure GP heterogeneity, i.e. rank effects. However, we are limited to measuring epidemic learning effects by whether or not a practice is in receipt of a rural practice allowance.[24]

[22] In 2001, 1,863 GPs held contracts with the Irish government to treat public patients. Of these 1,863 GPs, 35 per cent (657) were located in the Southern, South-Eastern and North-Eastern Health Boards.
[23] These variables are discussed in detail in the context of the conceptual framework in Chapter 4.
[24] For example, the *Medical Equipment and IT in General Practice* survey includes questions relating to frequency of supplier visits, educational activities, whether the practice is a training practice or

Our matched dataset matches two rich sources of data, the GMS Prescribing Database which contains data relating to the payment of dispensers for prescriptions filled, and the GP Characteristics Database which provides data on approximately one-third of all GPs who hold a GMS contract. This matched dataset allows us to determine the influence of equilibrium, disequilibrium and learning-by-using effects on the timing of adoption of new prescription drugs by Irish GPs, as presented in Chapter 4.

holds clinics. These questions provide us with a broader range of epidemic effects to test for in the empirical analyses of Chapters 6 and 7.

CHAPTER 4: TIMING OF ADOPTION OF NEW PRESCRIPTION DRUGS BY IRISH GPS

4.1 Introduction

The overall aim of this thesis is to explain the adoption and use of innovations in general practices in Ireland. As discussed in Chapter 1, Irish GPs enjoy considerable autonomy in terms of their prescribing and commercial decision-making. In fact, their scope for innovative behaviour includes decisions such as whether to prescribe drugs new to the market to their patients, whether to invest in particular items of medical equipment, and the extent to which they use ICT in the running of their practices. This chapter focuses on prescribing innovation, specifically addressing our first research question: what are the determinants of the timing of adoption of new prescription drugs by Irish GPs?

Recent years have witnessed the rapid development of drug treatments in a number of therapeutic areas. In Ireland, as in most other European Union (EU) economies, access to new drugs and treatments is mainly through primary healthcare providers such as GPs or family doctors (Prosser et al., 2009; Thistlehwaite et al., 2010). An important element of the process by which new drugs achieve widespread use is therefore their adoption by GPs as part of the portfolio of drugs which they prescribe. In this chapter we explore the factors which shape the timing of the first prescription of new drugs by GPs in Ireland and hence their availability to potential patients. We focus specifically on the adoption of six new drugs which were introduced to the Irish market during the period October 1999 to March 2004 and which represent different therapeutic areas.

As previously discussed, Irish GPs have significant autonomy with respect to prescribing decisions. In Ireland, there are no explicit guidelines in relation to prescribing decisions, such as the National Institute for Clinical Excellence (NICE) in the UK.[25] Once a particular drug has been approved for use by the Irish Medicines Board, GPs can prescribe it to their patients. The majority of Irish GPs treat private patients but also hold a contract with the government to treat public (GMS) patients. Approximately, one-third of the Irish population are entitled to these means-tested medical cards, however, it has been estimated that the GMS patients account for approximately 50 per cent of all GP consultations (Competition Authority, 2010), and that government spending through medical card patients makes up a substantial part of general practices' funding (Thomas et al., 2008; Competition Authority, 2010).

As discussed in Chapter 2, there is a substantial body of theoretical and empirical literature examining individual and business decision-making concerning the use of new technologies and innovations. In the innovation literature, informational or learning effects are generally interpreted as disequilibrium determinants of adoption, while commercial factors are interpreted as equilibrium elements of adoption reflecting the influence of individual practice heterogeneity (rank effects) and strategic behaviour (stock and order effects). The commercial and prescribing autonomy which characterise Irish general practice suggests that the prescribing decisions of Irish GPs may reflect both medical and commercial factors. Prescribing innovation may enable GPs to provide more effective treatments but may also help

[25] However, previous studies have reported that NICE guidance has little or no impact on GPs prescribing behaviour or uptake of new medicines (Wathen & Dean, 2004; Carlsen et al. 2009).

to attract and retain mobile and commercially valuable private and public patients. This suggests the potential value of considering both informational and commercial factors as determinants of GPs' prescribing innovation (Karshenas and Stoneman, 1993).

This study is the first to examine prescribing innovation through the lens of equilibrium, disequilibrium and learning-by-using models of adoption. We attempt to identify commonalities in the determinants of first prescription of six drugs by Irish GPs. Data is taken from a matched dataset which brings together information on GP's prescribing history with information on the characteristics of GPs themselves (see Chapter 3 for a detailed description of both sources of data). To our knowledge our study is the first to use duration analysis to examine prescribing innovation (Baptista, 2000). Duration analysis focuses on the factors which determine the probability that a GP will prescribe a new drug by a specific point in time, and provides a method of modelling the adoption S-shaped curve for newly introduced drugs (Rogers, 2003). The advantage of duration analysis is that it enables us to adopt a holistic approach to modelling the determinants of timing of prescribing innovation including a range of GP and practice characteristics, strategic behaviour, previous prescribing behaviour and informational factors.

The rest of the chapter is organised as follows. Section 4.2 briefly revisits the main influences on adoption (discussed in detail in Chapter 2), along with a discussion of previous empirical prescribing studies and the potential for both informational and strategic influences on the timing of GPs prescribing innovations. Section 4.3 describes our matched dataset, profiles the group of drugs which we consider and outlines our econometric approach. Section 4.4 summarises the main econometric results, and the implications are considered in Section 4.5.[26]

4.2 Theoretical & Empirical Influences on Adoption and Prescribing Behaviour

Our unit of analysis here is the individual GP, and our focus is on the factors which shape their prescribing innovations. For the purposes of this paper and in line with previous literature, a GP makes a prescribing innovation when s/he prescribes a drug on at least one occasion to at least one patient (Jones et al., 2001; Rogers, 2003).[27] Individual prescribing innovations will reflect the perceived benefits of the new drug compared to the alternatives, and may reflect the availability of information on the efficacy of the new drug as well as any commercial implications. Taken together, the cumulative or aggregate result and timing of prescribing innovations by GPs will determine the level of diffusion of each new drug (Schumpeter, 1942; Rogers, 2003; Hall, 2004). It is important to note that here we are concerned with the diffusion of these drugs in relation to GPs decisions to prescribe them for the first time, not the number of times which they prescribe them to their patient(s) or the extent to which these drugs penetrate the market, i.e. their market share.

Three complementary theoretical approaches have been used to explain the timing of innovation decisions. These theoretical approaches to examining timing of adoption of new innovations are discussed in detail in Chapter 2; however it is useful to

[26] Some of this material has already been published in the European Journal of Health Economics (Bourke and Roper, 2011).
[27] We are concerned with the 'prescribing innovation', i.e. a GPs decision to prescribe a new drug for the first time, rather than the 'new drug' innovation.

briefly recall the propositions of these theoretical approaches.[28] Disequilibrium models reflect the learning and informational influences on timing of adoption (Rogers, 2003), equilibrium models take account of how organisational characteristics and strategic interactions influence timing of adoption (Karshenas and Stoneman, 1993), and learning-by-using effects reflect cumulative learning experience from previous adoption decisions influencing timing of adoption (McWilliams and Zilbermanfr, 1996).

Within the equilibrium framework, three influences on timing of adoption are identified; rank, stock and order effects. Rank effects result from the assumption that potential adopters of a technology have different characteristics and therefore may obtain different returns from the use of a new technology. Therefore, potential adopters' heterogeneity is the key driver of the timing of adoption (Karshenas and Stoneman, 1993). Stock effects assume that as the number of users of a new technology increases, the benefits from adoption decline. This steadily reduces the benefit-cost ratio until a point where the number of accumulated adopters makes adoption by the remaining non-adopters undesirable. Finally, order effects suggest that an individual or organisation's position in the adoption order determines its returns from the use of the technology. Adopters higher in the adoption order will obtain greater returns than later adopters. Therefore, if a potential adopter expects the number of future adopters to be high, it will decide to adopt earlier (Karshenas and Stoneman, 1993).

[28] See Table 2.1 for a summary of the influences on timing of adoption.

Within the disequilibrium framework, epidemic learning effects assume that potential adopters will adopt upon learning of the existence of a new technology. Potential adopters learn about a new technology from adopters within their social system. Finally, learning-by-using effects assume that potential adopters adopt a new technology earlier if they have benefitted from cumulative learning experiences from previous adoption decisions.

In line with previous studies (Karshenas and Stoneman, 1993; Battisti et al., 2007), we consider the equilibrium, disequilibrium and learning-by-using models of adoption to be complementary approaches and simultaneously model them in our examination of the timing of adoption by Irish GPs of new prescription drugs. We acknowledge that previous studies implicitly use the disequilibrium approach in examinations of the adoption of new prescription drugs (Coleman et al., 1966; Williamson, 1975; Steffensen et al., 1999; Tamblyn et al., 2003; Kozyrskyj et al., 2007). However information about new drugs is likely to be readily available to GPs through pre-release marketing. Indeed, four of the drugs we consider here were prescribed by Irish GPs in the same month they entered the Irish market and the diffusion curves we observe for each of the drugs exhibit relatively rapid early adoption again suggesting the general availability of information and the potential relevance of equilibrium models.

To date much of the empirical literature examining the adoption of new prescription drugs has focused on physician's personal adoption decisions and the information asymmetries influencing these choices (Coleman et al., 1966). Kozyrskyj, Raymond, and Racher (2007), for example, conducted a study on newly marketed drugs in

Canada to determine if early prescribers had different socio-demographic or professional characteristics to later adopters. In two of the four drugs examined, Kozyrskyj et al. (2007) found that early prescribers were more likely than later adopters to be hospital affiliated. Previous studies also report that adoption times for new drugs are shorter for partnerships than single-handed practices (Williamson, 1975; Steffensen et al., 1999). This may reflect the idea that the larger the number of patients in a practice, the more likely the GP is to see a patient who might be a candidate for a new drug (Tamblyn et al., 2003; Dybdahl et al., 2004). However, Williamson (1975) puts forward a different explanation suggesting that the longer a doctor spends in discussion with his or her doctor colleagues, the more likely s/he is to be an early adopter.

Other studies have highlighted the potential importance of other practice characteristics on the timing of first prescription emphasising that most prescribing decisions are multi-factorial. For example, Tamblyn et al. (2003) examined the initial utilisation rate of new prescription drugs among physicians in Quebec, and found lower utilisation rates of new drugs among physicians with a rural or remote practice location. The same study also reports lower utilisation rates of new drugs among female physicians and those with a higher proportion of elderly patients in their practice who might, perhaps, be less receptive to ‘new’ drugs. Similarly, Prosser et al. (2009), in a qualitative study of the factors influencing GPs’ uptake of new drugs in the North-West of England, emphasise the importance of biomedical factors on drug choice, along with recommendations from hospital consultants and patient requests.

Previous prescribing studies have not explicitly modelled learning-by-using effects. However, some studies have examined if experience with other drugs impacts on a GPs' prescribing decisions. Florentinus (2006), in a qualitative study examining the adoption of five drugs by a sample of approximately 100 GPs in the Netherlands, reports that a GP's decision to prescribe a new drug is very much drug dependent, and did not identify GP characteristics specific to early drug adoption or an 'innovator' category of GP. Kozyrskyj et al. (2007), in an examination of four newly marketed drugs, found that early prescribers of one new drug were not early prescribers of all four medications. They report that attributes of a drug, such as perceived efficacy and improvement over existing alternatives, impact early use. Steffensen et al. (1999) also report that their data did not indicate a universal innovator or laggard with respect to adoption of all five studied drugs. Their data indicates that the shape and slope of the adoption curve is both dependant on physician and drug characteristics. Similarly, Dybdahl et al. (2004) report that early adoption of one type of drug is not associated with early adoption of another; reporting no consistent association between GPs' level of drug prescribing and their adoption of new drugs of the same therapeutic group. Therefore, the empirical evidence suggests that GPs' previous prescribing decisions do not impact on their decision to prescribe a new drug for the first time.

The commercial and prescribing autonomy of Irish GPs suggests the potential for both equilibrium – i.e. market – and disequilibrium – i.e. informational – influences on the timing of prescribing innovation. Previous studies of prescribing innovation by GPs – based almost solely in the disequilibriumm tradition – have also emphasised the potential importance of informational effects. Given the heterogeneous nature of Irish general practices, it is likely that Irish GPs prescribing decisions may be influenced by commercial factors. In fact, there is previous evidence of Irish GPs adjusting their prescribing behaviour in response to economic incentives (Walley et al., 2001).[29] In addition, health economics literature frequently profiles GPs as economic agents who respond to economic incentives and are aware of the competitive structure of their environment (Scott, 2000; Morris et al., 2007; Kann et al., 2010), indicating the potential for strategic behaviour influencing prescribing decisions.

4.3 Data and Methods

Section 4.3.1 describes the six new drugs analysed in this study and graphically illustrates the uptake of these new drugs over time. Our empirical analysis is based on two matched databases, the GMS Prescribing Database and the GP Characteristics Database. The GMS Prescribing Database contains data for prescriptions filled for GMS Patients in the Southern, South-Eastern and North-Eastern health boards for the period October 1999 to March 2004. The GP Characteristics Database, which is matched to the GMS Prescribing Database using a unique identifier, provides GP and practice characteristics for 625 GPs in the three health boards. Both databases are discussed in detail in Chapter 3. In Section 4.3.1, the data is described in the context of the conceptual framework of this study, and the variables measuring rank, stock, order, learning-by-using and epidemic effects

[29] The Indicative Drug Treatment Scheme (IDTS) was developed to contain prescribing costs. GPs were set indicative prescribing budgets for their public patients, and received a proportion of the savings for practice development. In the first year alone of the IDTS, this scheme resulted in savings of IR£13.5 million (€17million) (Walley et al. 2001). The IDTS is discussed in detail in Section 3.3

are discussed. Section 4.3.2 describes the econometric analysis employed to address our research question.

4.3.1 Description of Prescribing Dataset

The GMS Prescribing Database, in its restructured form, allows us to identify the date of first adoption of all drugs by each GP and to construct adoption curves for each drug reflecting the proportion of GPs prescribing each drug each month. In general, these adoption curves follow one of three patterns: a relatively constant proportion of GPs prescribing a drug, an increase in the proportion of GPs prescribing each drug, or a decrease in the proportion of GPs prescribing the drug. Here, our focus is on the factors which shape the timing of GPs' prescribing innovations, i.e. the date at which they first adopt a new prescription drug. We therefore focus on a group of six drugs which have increasing adoption curves and which operate on different physiological organs or systems. Using this diverse range of drugs should help to eliminate any potential inter-relationships between adoption patterns which might stem from individual GPs having a particular interest in a certain therapeutic area or medical condition. It is important to also note that the adoption of these drugs should not be influenced by a GP's patient-list as they are not drugs which are prescribed for very specific, infrequent-occurring conditions. Therefore, patient demand or need should not unduly influence adoption of these drugs, as we would expect that all GPs in this sample would face ample opportunity to prescribe these drugs.[30] The drugs we consider are:

[30] Nonetheless, it is important to acknowledge that GPs adoption of new prescription drugs may be influenced by patient-lists, particularly if a practice has a large proportion/number of patients with a particular condition the new drug is intended to treat. Given the drugs chosen for this analysis, we do not expect this to influence their uptake.

(1) *escitalopram,* an antidepressant used in the treatment of major depressive episodes, panic disorder with or without agoraphobia, social anxiety disorder, generalised anxiety disorder, and obsessive-compulsive disorder,

(2) *esmoprazole,* a proton pump inhibitor used in the treatment of active duodenal ulcer, active benign gastric ulcer, symptomatic erosive or ulcerative gastro-oesophageal, reflux disease (GORD), gastro-oesophageal reflux disease long-term management (GORD Maintenance), symptomatic treatment of moderate to very severe gastro-oesophageal reflux disease (symptomatic GORD), and Zollinger-Ellison Syndrome,

(3) *rofecoxib,* a nonsteroidal anti-inflammatory drugs (NSAID), used to reduce pain, inflammation, and stiffness caused by osteoarthritis, rheumatoid arthritis and certain forms of juvenile rheumatoid arthritis, to manage acute pain in adults, to treat migraines, and to treat menstrual pain,

(4) *desloratadine,* an antihistamine, is used to relieve the symptoms of allergic rhinitis (inflammation of the nasal passages caused by an allergy, for example, hay fever or allergy to dust mites) or urticaria (a skin condition caused by an allergy, with symptoms including itching and hives),

(5) *nicotine* is used for the treatment of tobacco dependence by relieving nicotine craving and withdrawal symptoms, thereby facilitating smoking cessation in smokers,[31] and

(6) *drospirenone & estrogen* is a hormonal contraceptive which acts on the endocrine system (Irish Medicines Board, 2008).

Under European and Irish legislation, all medicinal products must be authorised before being marketed. Medicinal products marketed in Ireland must be authorised by the IMB (Irish Medicines Board, 2008). Table 4.1 provides information on the date of authorisation of these six drugs to the Irish market. Once authorised by the IMB, Irish GPs can prescribe these drugs to both public and private patients.[32] However, pharmacists can only dispense drugs assigned a GMS code to public patients free of charge (Health Service Executive, 2006). This information is also provided in Table 4.1, along with the date when the first prescription for each drug was written by a GP(s) in the sample. For instance, *Escitalopram* was first licensed in Ireland on the 21st October 2002 and received a GMS code on 1st November 2002 (Table 4.1).

[31] *Nicotine* drugs, nasal sprays and chewing gum, are also available to purchase without prescription.

[32] An agreement between the Irish Pharmaceutical Healthcare Association (IPHA) and the HSE outlines the supply, terms, conditions and pricing of medicines supplied to the health care service in Ireland. Under the terms of the 2006 Irish Pharmaceutical Healthcare Association (IPHA)/HSE agreement, the HSE reserves the right to assess new and existing technologies which may incur a high cost or have a significant budget impact. In response to requests from the HSE, the National Centre for Pharmacoeconomics (NCPE) appraises the cost effectiveness of technologies (medicines, diagnostics and devices) to the Irish health care system. However, it is important to note that prior to the current 2006 IPHA/HSE agreement, pharmacoeconomic data was used on an informal basis in Ireland (Tilson et al, 2010). Therefore, given the time period of this study (1999-2004) this current authorisation process would not impact on GP's prescribing decisions.

Table 4.1: Time Line of Authorisation of Drugs to Irish Market and GMS Scheme

ATC Code	Chemical Compound	License Issued by IMB	Assigned a GMS code	First Prescription
N06AB10	Escitalopram	21 Oct 2002	1 Nov 2002	Nov 2002
M01AH02	Rofecoxib	12 Nov1999	1 Jan 2000	Oct 2000
A02BC05	Esomeprazole	18 Aug 2000	1 Oct 2000	Oct 2000
R06AX27	Desloratadine	15 Jan 2001	1 May 2001	May 2001
N07BA01	Nicotine	25 Jul 1996	1 Apr 2001	Apr 2001
G03AA12	Drospirenone & Estrogen	27 Oct 2000	1 Mar 2001	Apr 2001

Source: GMS Prescribing Database and Irish Medicines Board (2008). Date of assignment of GMS code was provided by the HSE South Primary Care Unit.

Diffusion curves for each of these drugs are included in Figure 4.1a-e.[33] *Escitalopram* was first prescribed in November 2002, with approximately 10 per cent of the sample prescribing *escitalopram* to their patients. From the time of first adoption, levels of adoption increased rapidly and by March 2004 (the last month of the sample period) the level of adoption was approximately 70 per cent (Figure 4.1a).

[33] It is important to note that these diffusion curves are not 'cumulative' diffusion curves. Figure 4.1 presents graphs indicating the proportion of GPs prescribing each drug over time. Therefore, if the proportion of GPs prescribing these drugs decreases at certain times we see a decline in the curve, which would not be evident in a cumulative diffusion curve. However, Figures 4.1a-e allow us to observe seasonal effects.

Figure 4.1a: Proportion of GPs prescribing Escitalopram – Oct 1999 to Mar 2004

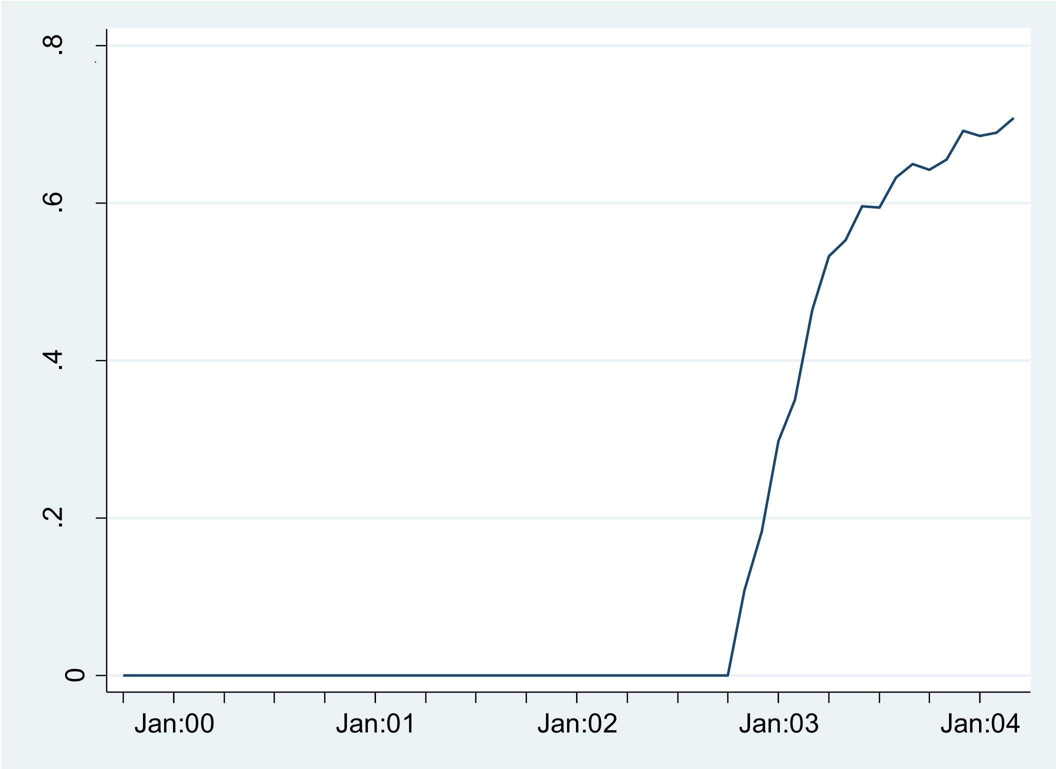


Figure 4.1b: Proportion of GPs prescribing Esomeprazole - Oct 1999 to Mar 2004

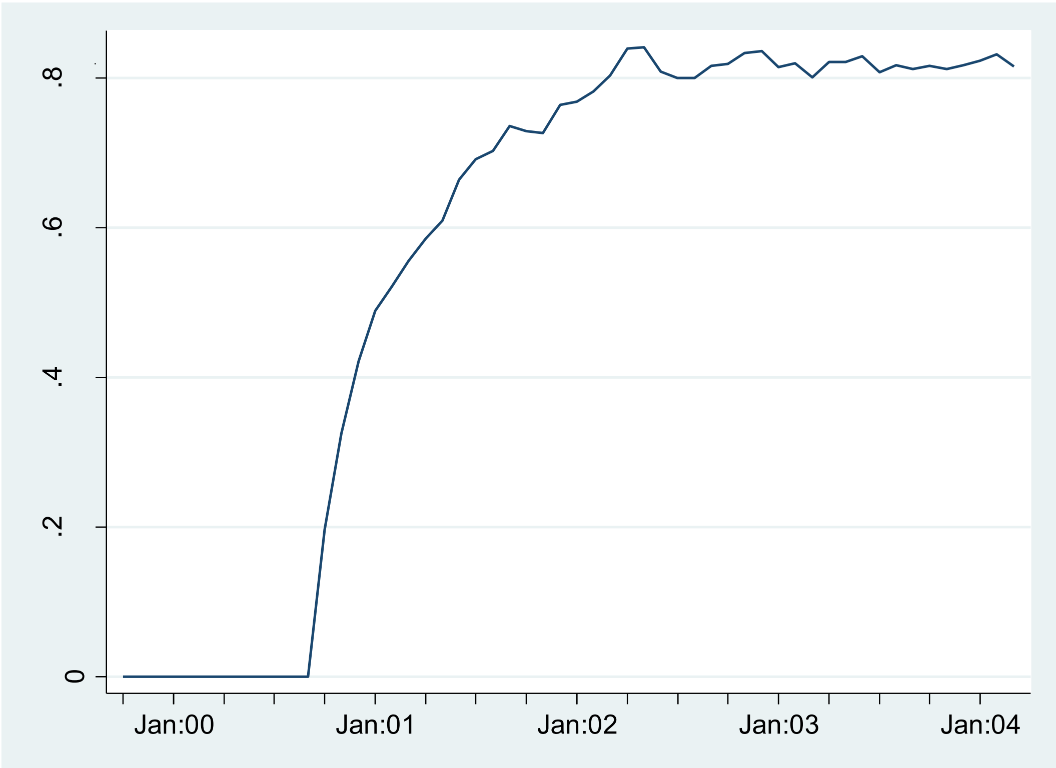


Figure 4.1c: Proportion of GPs prescribing Rofecoxib - Oct 1999 to Mar 2004

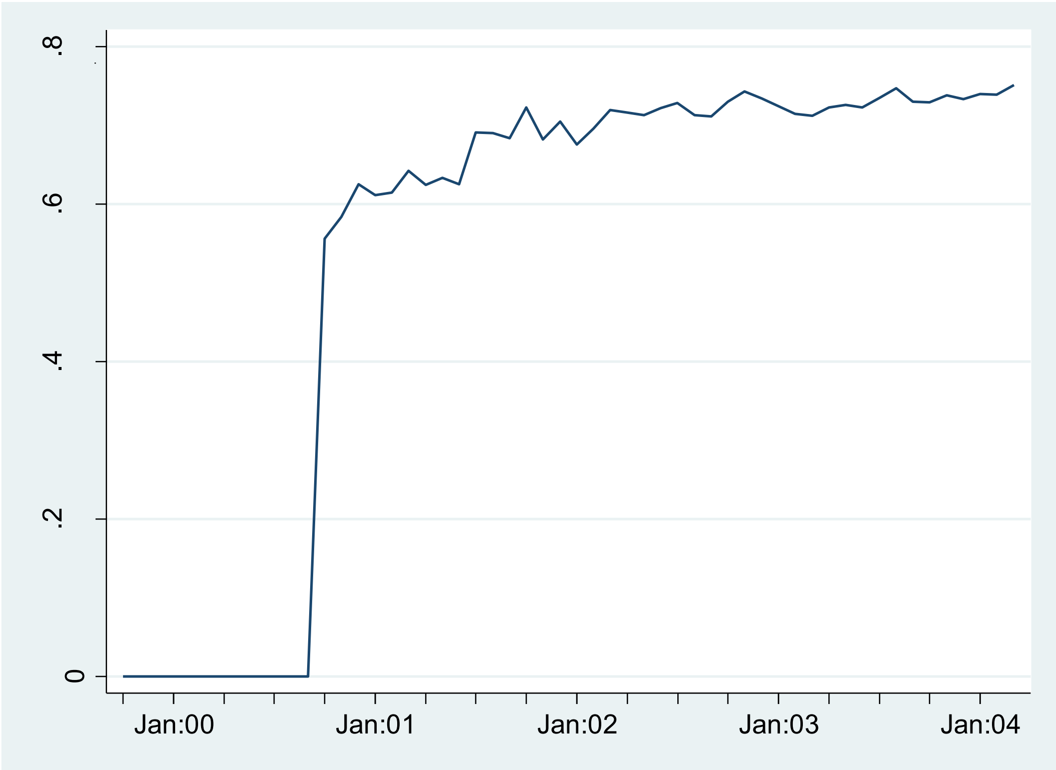


Figure 4.1d: Proportion of GPs prescribing Desloratadine - Oct 1999 to Mar 2004

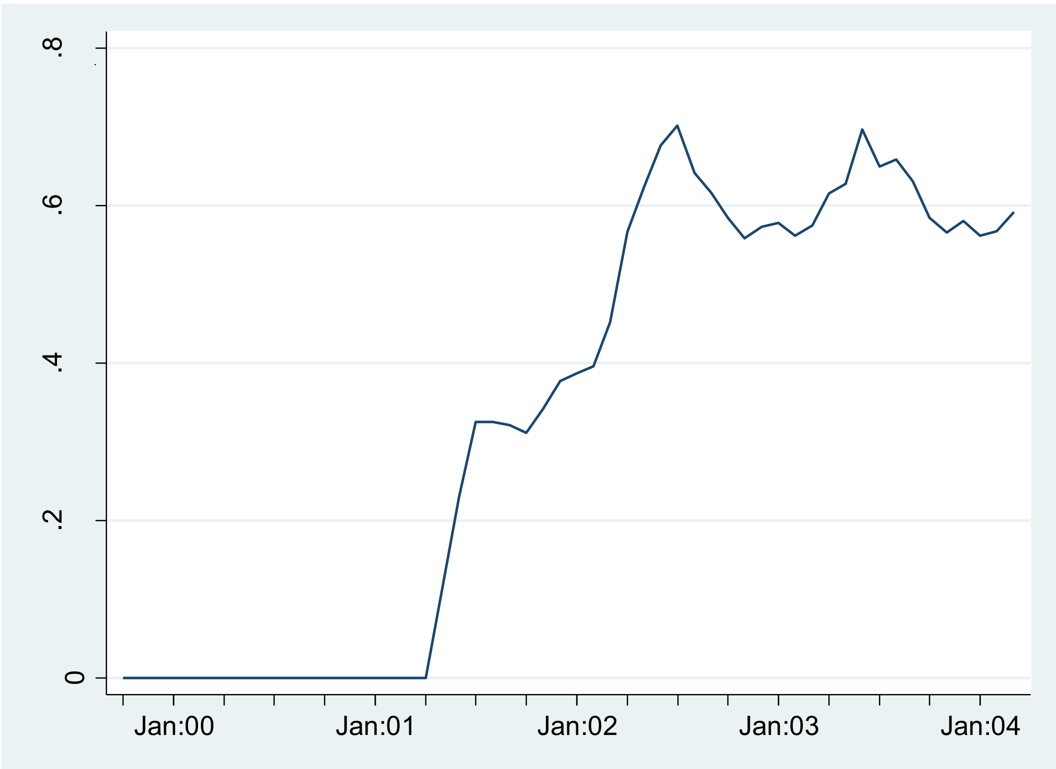


Figure 4.1e: Proportion of GPs prescribing Nicotine - Oct 1999 to Mar 2004

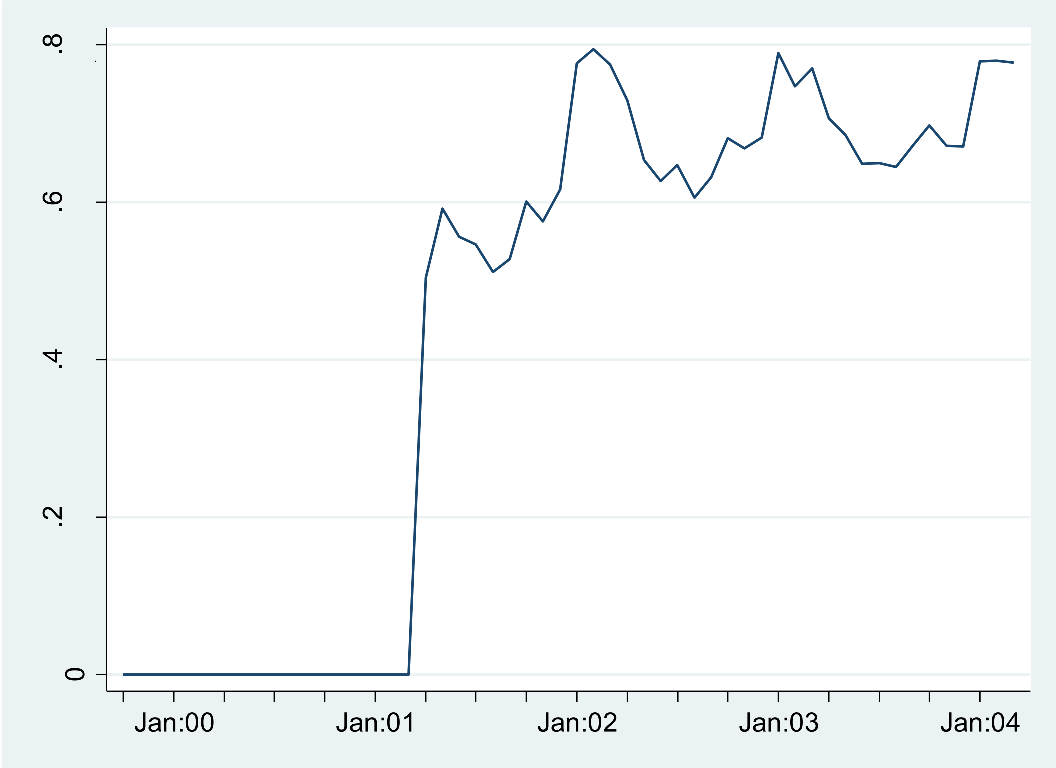
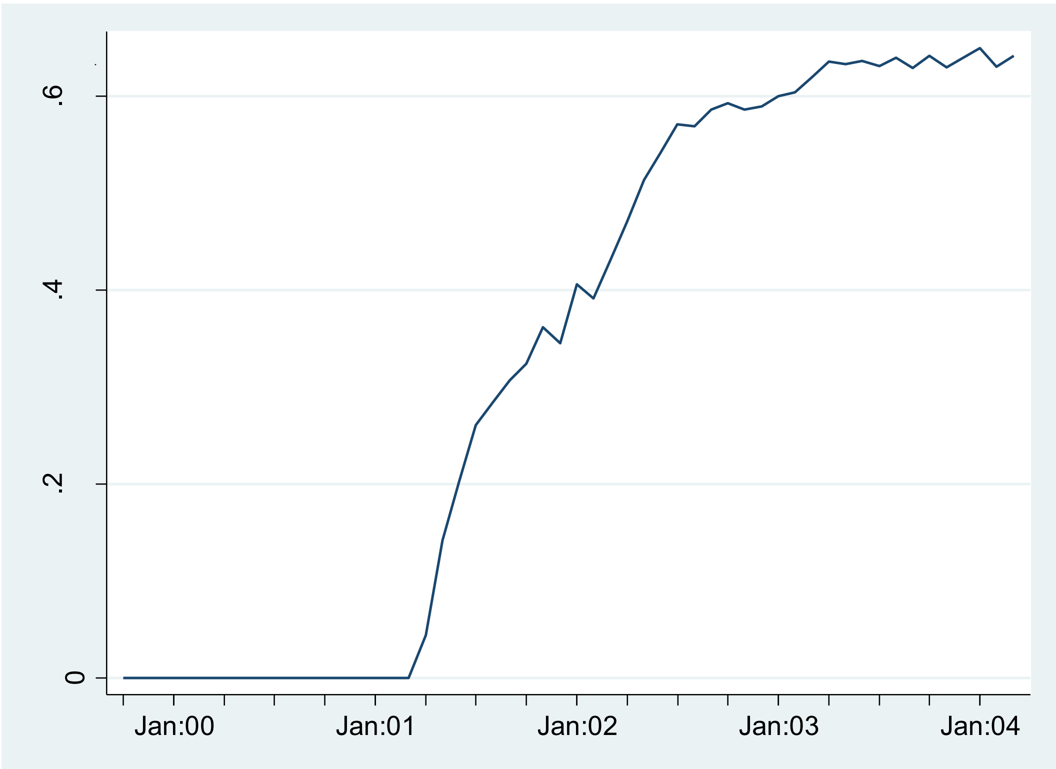


Figure 4.1f: Proportion of GPs prescribing Drospirenone & Estrogen – Oct 1999 to Mar 2004



Similar diffusion curves are evident for *esmoprazole* (Figure 4.1b), *rofecoxib* (Figure 4.1c) and *drospirenone & estrogen* (Figure 4.1d) where the proportion of GPs prescribing the drugs increased steadily throughout the sample period. As expected with an antihistamine, we see a marked seasonal pattern to the proportion of GPs prescribing *desloratadine* with up to 70 per cent of GPs prescribing it during the summer months, and lower prescribing levels during the winter months (Figure 4.1e). The diffusion curve for *nicotine* also displays a seasonal pattern with more GPs prescribing this drug at the beginning of the calendar year.[34]

The variables reflecting the timing of GPs' prescribing innovations for the six drugs we consider form the dependent variables for our econometric analysis. A notable feature of each of these drugs is the extremely short time period from authorisation under the GMS scheme and their prescription by Irish GPs to their patients. This very rapid rise in the initial adoption of each new drug is also evident in the drug adoption curves (Figures 1a-1f), and is reported in previous literature (Dybdahl et al., 2004; Dybdahl et al., 2005; Florentinus, 2006). This differs from the slower initial adoption which characterises most new technologies (Karshenas and Stoneman, 1993; Baptista, 1999; Battisti and Stoneman, 2005), and may be a result of intensive pre-release marketing by pharmaceutical companies.

As discussed in Section 1.2, Irish GPs do not incur a monetary or budgetary cost with respect to prescribing decision-making. Within the time-period of this study, there was no element of cost-sharing on the part of public patients for prescription drugs received. Therefore, we assume that the price of each of the six drugs

[34] This may reflect a 'new year resolution' effect as people seek support for giving up smoking.

examined does not influence the uptake of these drugs, nor does it influence the uptake of these drugs relative to the uptake of alternative drug treatments available.

Next, the explanatory variables, from the GMS Prescribing Database and the GP Characteristics Database, used in the econometric analysis are discussed. Both datasets are described in detail in Chapter 3. Descriptive statistics for the explanatory variables, categorised within the equilibrium, disequilibrium and learning-by-using framework, are presented in Table 4.2. A range of independent variables are constructed from the GMS Prescribing Database to reflect learning-by-using, stock and order effects on prescribing innovation. We anticipate, for example, that GPs which are already prescribing a wide range of drugs, i.e. have broad prescribing portfolios, may be better informed about drug options. This may influence their access to information on new drugs potentially reducing their time to adoption. To reflect this learning-by-using effect, we create a prescribing portfolio variable defined as the range of drugs prescribed by each GP as a percentage of the total number of drugs being prescribed by all GPs. This variable was constructed from the June 2001 GMS Prescribing Database to provide consistency with the 2001 GP Characteristics Database. In the GMS Prescribing Database for June 2001 a total of 874 different drugs were prescribed by GPs, with each GP prescribing on average 25 per cent of these drugs. The broadest prescribing portfolio of any GP was 45 per cent of all drugs prescribed (Table 4.2).[35] There is little research as to the influence the breadth of a GPs prescribing portfolio has on the likelihood of he/she adopting a new drug. However, there is evidence that practices with large patient numbers are more

[35] In a robustness check, we also constructed this variable for the first and last month of the sample; both portfolio variables have similar means and standard deviations to the June 2001 portfolio variable.

extensive users of new drugs than practices with small patient numbers (Tamblyn et al., 2003). It is likely that GPs with large patient numbers require a larger portfolio of drugs (See Table 4.3 for a symbolic summary of our anticipated results).

To capture potential order effects we create an order variable for each of the six drugs. Each order variable takes a value of one where a GP was among the first adopters in at least one of the other five drugs being examined. Specifically, the order variables take a value of one where a GP first prescribed one of the other five drugs considered here in the first six months after its first adoption. Between 25 and 35 per cent of GPs may be considered 'first adopters', and take a value of one in relation to these order variables. A stock effect variable was also constructed for each of the six drugs. This is defined as the cumulative percentage of GPs who had adopted the drug. This variable is time-variant and is intended to reflect the stock of previous adopters at each point in time (Table 4.2).

Table 4.2: Descriptive Statistics of Explanatory Variables

		Mean	St. Dev.
Rank Effects			
Practice Nurse	Practice with a nurse	0.58	0.49
Practice Secretary	Practice with a secretary	0.79	0.41
Dispensing Practice	Practice has in-house dispensary	0.12	0.32
GP Age	GP age in years	49 yrs	8.3 yrs
IDTS60	GPs receive 60 per cent of savings made from meeting prescribing targets	0.37	0.48
IDTS50	GPs receive 50 per cent of savings made from meeting prescribing targets	0.24	0.42
IDTS40	GPs receive 40 per cent of savings made from meeting prescribing targets	0.39	0.49
Learning-By-Using and Epidemic Effects			
Prescribing Portfolio Breadth	Per cent of drugs prescribed by GP out of portfolio of drugs prescribed by all GPs	0.25	0.10
Rural Practice	Practice located in rural area (and in receipt of Rural Practice Allowance)	0.12	0.32
Order & Stock Effects			
Order effect esciatlopram	GP is an early adopter (i.e. in first 6 months of adoption) in at least one of the other five drugs	0.30	0.46
Order effect esomeprazole	GP is an early adopter (i.e. in first 6 months of adoption) in at least one of the other five drugs	0.34	0.47
Order effect rofecoxib	GP is an early adopter (i.e. in first 6 months of adoption) in at least one of the other five drugs	0.25	0.43
Order effect desloratadine	GP is an early adopter (i.e. in first 6 months of adoption) in at least one of the other five drugs	0.31	0.46
Order effect nicotine	GP is an early adopter (i.e. in first 6 months of adoption) in at least one of the other five drugs	0.33	0.47
Order effect drospirenone & estrogen	GP is an early adopter (i.e. in first 6 months of adoption) in at least one of the other five drugs	0.35	0.48
Stock effect esciatlopram	Time variant percentage of GPs who have adopted escitalopram	0.38	0.30
Stock effect esomeprazole	Time variant percentage of GPs who have adopted esomeprazole	0.19	0.30
Stock effect rofecoxib	Time variant percentage of GPs who have adopted rofecoxib	0.59	0.31
Stock effect desloratadine	Time variant percentage of GPs who have adopted desloratadine	0.50	0.34
Stock effect nicotine	Time variant percentage of GPs who have adopted nicotine	0.58	0.29
Stock effect drospirenone & estrogen	Time variant percentage of GPs who have adopted drospirenone & estrogen	0.59	0.30

Source: GMS Prescribing Database and GP Characteristics Database

There is limited empirical testing of stock and order effects in adoption behaviour mainly due to data restrictions, and to date the evidence of such effects are inconclusive (Karshenas and Stoneman, 1993; Stoneman and Toivanen, 1997; Baptista, 2000; Burton et al., 2003; Hollenstein and Woerter, 2004). However, for a number of reasons we include these strategic behaviour effects in our prescribing innovation analysis. Firstly the free-market environment of general practice in Ireland and the prescribing autonomy enjoyed by Irish GPs provides opportunities for strategic behaviour. Secondly, there is previous evidence of GPs responding to economic incentives (Scott, 2000; Morris et al., 2007; Kann et al., 2010) and, in particular, Irish GPs responding to monetary incentives and adjusted their prescribing behaviour (Walley et al., 2001). Therefore, we expect Irish GPs to consider the commercial costs and benefits of their decision-making; however, as GPs do not incur a monetary cost from prescribing new drugs, *a priori*, we do not expect these effects to unduly influence prescribing decision-making.

As discussed in Chapter 3, the GP Characteristics Database provides us with the explanatory variables which capture disequilibrium learning effects and equilibrium rank effects. The epidemic models of adoption purport that a potential user will adopt a new technology upon learning of its existence and information on the existence of the technology is spread by direct contact between a potential user and user. Ideally, we would like to examine the influence of prescribing patterns of other GPs within the practice on adoption decision-making. However, our prescribing dataset does not provide us with practice identifiers, and therefore, we are unable to determine which GPs work together in practices and which GPs work alone. We include a rural practice allowance to measure epidemic learning effects. As is evident from Table 4.2, in 2001 12 per cent of GPs in this sample were in receipt of a rural practice allowance, as they live and practice in an area with a population of less than 500 people. This variable is included as an epidemic effect, as GPs in rural practices are perhaps less likely to have frequent contact with colleagues or drug company representatives.

The GP Characteristics Database provides data reflecting individual and practice heterogeneity, i.e. rank effects. In 2001, 58 per cent and 79 per cent of GPs in the sample worked in a practice with a nurse and secretary respectively. We assume that each of these factors would have a positive impact on the benefit-cost ratio from prescribing innovation and will therefore have a negative effect on the time to adoption. GP age may also have an effect on time to adoption. 12 per cent of GPs worked in a dispensing practice. It is likely that this variable will have a positive effect on time to adoption, as there may stock level considerations in a small dispensary. The average age of GPs in this sample is 49 years. As in previous studies we anticipate this effect to be positive, i.e. older GPs will be slower to adopt new drugs. We also include the Indicative Drug Treatment Scheme (IDTS) variables. In the early 1990s, the Irish government developed the IDTS to try to contain prescribing costs, whereby GPs were set indicative budgets for prescribing for their public patients. GPs were entitled to keep a proportion (40-60 per cent) of savings for projects benefitting their patients and practices. Our three IDTS variables, IDTS60, IDTS50 and IDTS40, represent GPs who received 60, 50 and 40 per cent of savings made from meeting prescribing targets respectively.[36] *A priori*, it is difficult to anticipate how this variable would influence prescribing innovation. GPs seeking

[36] See section 3.3 for a discussion of the IDTS scheme.

to reduce prescribing costs in order to benefit from the scheme might delay prescribing new – and possibly more costly – drugs. Alternatively, if new drugs were more cost effective than existing treatments the IDTS might actually encourage prescribing innovation.

In brief, we expect rank effects to influence prescribing innovation. Specifically, we expect the human capital factors - nursing and secretarial support, which may also be proxies for practice size – to positively influence GPs' drug adoption decision-making. These expectations are in line with much of the literature (Karshenas and Stoneman, 1993; Baptista, 2000). We expect increasing age to negatively influence prescribing innovation, in line with previous studies of adoption behaviour in a health care setting (Masters, 2008; Meade et al., 2009). It is more difficult to anticipate how variables such as dispensing practice and the IDTS may influence prescribing behaviour. We do not anticipate the strategic behaviour order and stock effects having a significant influence on prescribing behaviour, given the altruistic non-commercial nature of this decision-making as discussed in Section 2.4. However, we expect learning-by-using effects, measured by the variable 'portfolio breadth', to positively influence prescribing innovation. On the other hand, we expect rural practitioners to be slower adopters of new drugs, as purported by the disequilibrium model of adoption.

Table 4.3: Symbolic Summary of Anticipated Effects on Time to Adoption of New Drugs

Rank Effects	
Practice Nurse	-
Practice Secretary	-
GP Age	+
Dispensing Practice	+
IDTS 50	-
IDTS 60	-
Order & Stock Effects	
Order Effects	(-)
Stock Effects	(+)
Learning-by-using Effects	
Prescribing Portfolio	-
Epidemic Learning Effects	
Rural Practice Allowance	+

Notes: '-' denotes a negative and significant effect on time to adoption, i.e. faster adoption; '+' denotes a positive and significant effect on time to adoption, i.e. slower adoption; (-) denotes a negative and insignificant effect on time to adoption; (+) denotes a positive and insignificant effect on time to adoption.

This section describes the six drugs identified for inclusion in the analysis of the determinants of first prescription of drugs by GPs. It also describes the explanatory variables, in the context of the equilibrium, disequilibrium and learning-by-using models of adoption, used in the analysis, and our anticipated results based on previous literature and the economic general practice environment.

4.3.2 Econometric Methodology

To model the time to adoption or prescribing innovation for each of the six drugs we use duration analysis. This approach allows us to develop a multivariate model for time to adoption as well as allowing for the conditional nature of adoption decisions due to potential stock effects (Burton et al., 2003). The aim of duration analysis is to identify those factors which have a significant effect on the length of a spell and the dependent variable therefore measures the time elapsed before an event occurs (Baptista, 2000). In our analysis, the dependent variables measure the time elapsed before a drug is prescribed by a GP after the drug is first adopted by any GP in the sample. In other words, we are defining the length of a spell for a GP in the sample as the realisation of a continuous random variable, T, that has the following cumulative distribution function or failure function:

$$F(t) = P(T \leq t). \qquad \text{(Eqn. 4.1)}$$

For example, the Accelerated Failure Time (AFT) model assumes a linear relationship between the log of (latent) survival time T and characteristics X:

$$ln\ (T) = \beta^{*\prime}X + z \qquad \text{(Eqn. 4.2)}$$

where β^* is a vector of parameters and z is an error term.

An AFT regression coefficient relates proportionate changes in time to adoption to a unit change in a given regressor, with all other characteristics held constant (Jenkins, 2005). In our analysis, *t* is measured in months as the prescribing data relates to the monthly payment of dispensers.

The probability distribution of duration can be specified by the Weibull, exponential, log-logistic and log-normal distribution (Eqn. 4.2). To identify the appropriate distribution in any specific application specification tests can be used to determine which distribution best fits the failure time regressions. In line with previous studies (Kiefer, 1988; Baptista, 2000; Greene, 2003),specification testing of the failure time models in this study included an examination of *pseudo-residuals*, or generalised residuals, log-likelihood scores and Akaike's Information Criterion (AIC). These specification tests suggested that the log-logistic distribution was the best fit for five (*esctialopram*, *esmoprazole*, *rofecoxib*, *desloratadine, nicotine)* of the six failure time regressions and that the log-normal distribution was the best fit for the remaining failure time regression (*drospirenone & estrogen*).[37]

Two of the main benefits of duration models include the consideration of time and the capacity to control for unobserved heterogeneity in the analysis. Unobserved heterogeneity, or 'frailty' as it is called in the biomedical literature, eliminates the effects of unobserved characteristics that remain constant over time (Jenkins, 2003). In our study, unobserved heterogeneity may include characteristics, such as the number of GPs in a practice or the practice's patient profile, which we could reasonably assume to be constant over the sample period.[38]

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[37] The Cox semi-parametric proportional hazard models tend to be more widely used than the parametric AFT models. However, the regression parameter estimates from AFT models are robust to omitted covariates and are also less affected by the choice of probability distribution. In addition, the results of AFT models are more easily interpreted than hazard ratios (Kay and Kinnersley, 2002; Lambert at al., 2004).

[38] In practice, and despite some experimentation, we found that our duration models did not converge when we attempted to control for unobserved heterogeneity. This issue has been noted in the literature (Jenkins 2003) and we discuss the implications of this in the following section.

4.4 Econometric Results of Timing of First Prescription of Drugs

Duration models are used to explain time to adoption of the six drugs as a function of the independent variables. When interpreting the results of a duration model, a negative marginal effect means a factor reduces duration, i.e. reduces the time to adoption (Baptista, 2000). Our preferred duration models, with marginal effects reported, are given in Table 4.4.[39] Given that not all GPs have adopted each drug by the end of the sample period, the data is right-censored.[40] The influence of rank, stock, order, learning-by-using and epidemic effects on time to adoption of the six new drugs are discussed below.

In the models we represent potential rank effects using a series of variables reflecting the characteristics of GPs and their practices. As presented in Table 4.4, GP practices with a nurse have lower times to adoption than those without a nurse for two of the drugs examined. This finding is statistically significant at the 1 per cent level for the antidepressant and statistically significant at the 5 per cent level for the hormonal contraceptive drug. However, it is worth noting that the size of the practice nurse effect is relatively small, in that time to adoption decreases by one to two weeks (0.25 and 0.56 of a month) for practices with a nurse in relation to these two drugs. Similarly, a decrease in time to adoption is reported for practices with a secretary in one of the six drugs, the antihistamine. This finding is statistically significant at the 5 per cent level. Again, this is a relatively small effect with time to adoption decreasing by approximately two weeks (-0.50 of a month) for practices with a

[39] Initially, six baseline models were estimated, presented in Table A2.1. Subsequently, in a 'stepwise' fashion, variables with z-statistics of less than |0.5| were excluded from the relevant failure time models. Comparison of Tables A2.1 and 4.4 suggests that the exclusion of a number of insignificant variables has little effect on coefficient signs and values.

[40] As a robustness check, we removed the non-adopters for each drug from the sample and ran the duration models individually. The same results as those reported were obtained.

secretary in relation to one of these drugs. These findings are in line with much of the literature which report organisation size and human capital impacting positively on the adoption of innovations (Karshenas and Stoneman, 1993; Baptista, 2000). Also, as expected, GP age is found to have a statistically significantly positive effect on time to adoption in four of the drugs considered here (the antidepressant, the antihistamine, the smoking cessation drug and the hormonal contraceptive). However, the size of this effect is again relatively small, with time to adoption increasing in the region of 0.1 to 0.4 of a month for each increasing year. Following a systematic review of the literature, Masters (2008) reports similar findings in relation to doctors and internet adoption, with adoption being greater among younger doctors. There is also evidence of greater adoption of electronic patient records by younger GPs in Ireland (Meade et al., 2009).[41]

Results in relation to the dispensing practice variable are insignificant. Finally, the effect of IDTS, which reflects the effect on time to adoption of receipts from drug cost savings, impacts on one drug, the antihistamine. Time to adoption decreases by a little less than two weeks for the antihistamine drug for practices eligible for 50 per cent of savings from meeting prescribing targets and also for those practices that receive 60 per cent of savings relative to those practices eligible for 40 per cent of savings. It is worth acknowledging that the IDTS variables may also be capturing informational or experiential effects. The IDTS variables capture GPs that are willing to change their prescribing practices to meet budgetary targets, and are learning and gaining experience from these prescribing decisions.

[41] However, not all small business adoption studies report significant findings in relation to age. For example, Burton et al (2003) report no statistically significant relationship between age of a farmer and the adoption of organic horticultural technology.

Epidemic learning effects are captured in the models specifically by the rural practice variable. An increase in time to adoption is reported for practices in receipt of a rural practice allowance for two of the drugs examined. This finding is statistically significant at the 5 per cent level for the antidepressant and hormonal contraceptive drugs, with time to adoption increasing by 0.2 and 0.9 of a month for rural practices. Tamblyn et al. (2003) found similar results with lower utilisation rates of new drugs among physicians with a rural or remote practice location. Coleman et al. (1966) report in the classic drug diffusion study where physicians' decisions to prescribe a new antibiotic tetracycline were investigated that early adopters attend more out-of-town medical meetings that late adopters. While similar data is not available for this study, it is fair to suggest that GPs with practices in receipt of a rural practice allowance are less likely to be able to attend meetings and conferences than urban based GPs. Similarly, it is likely that such practices are visited less frequently by drug company representatives, which might be an important source of information for GPs in relation to prescribing decisions (Jones et al., 2001).

Table 4.4: Duration models of time to first adoption – Preferred Models

	Esciatlopram[1] mfx/se	Esmoprazole[2] mfx/se	Rofecoxib[3] mfx/se	Desloratadine[4] mfx/se	Nicotine[5] mfx/se	Drospirenone & Estrogen[6] mfx/se
Rank Effects						
Practice Nurse	-0.253***		-0.209	-0.08		-0.559**
	(0.062)		(0.170)	(0.164)		(0.236)
Practice Secretary	-0.106	0.058		-0.504**	-0.237*	-0.581*
	(0.078)	(0.095)		(0.216)	(0.131)	(0.304)
GP Age	0.012***	0.003		0.020**	0.015**	0.044***
	(0.004)	(0.004)		(0.010)	(0.007)	(0.014)
Dispensing Practice		0.163	-0.42		-0.22	0.718*
		(0.108)	(0.318)		(0.188)	(0.373)
IDTS50	-0.044	0.013		-0.459**	0.082	-0.328
	(0.071)	(0.089)		(0.196)	(0.124)	(0.276)
IDTS60	-0.06	-0.135		-0.458***		-0.269
	(0.063)	(0.083)		(0.176)		(0.243)
Epidemic Effects						
Rural Practice	0.181**		0.295	0.26	0.159	0.909**
	(0.083)		(0.311)	(0.225)	(0.183)	(0.380)
Learning-By-Using Effects						
Portfolio Breadth	-3.176***	-5.817***	-8.322***	-10.518***	-10.117***	-5.882***
	(1.118)	(1.861)	(1.398)	(3.181)	(2.188)	(1.292)
Portfolio Breadth^2	2.99	5.343		9.267	9.658**	
	(2.360)	(3.644)		(6.597)	(4.533)	
Order Effects	-1.698***	-0.277*	-6.016***	-8.635***	0.694***	-1.044***
	(0.128)	(0.153)	(0.374)	(0.318)	(0.130)	(0.297)
Stock Effects	12.375***	10.531***	15.954***		6.155***	20.632***
	(0.208)	(0.402)	(0.949)		(0.775)	(0.935)
N	23366	8607	8176	13628	10871	15082
Chi-squared	665.933	609.9	988.226	430.136	793.732	291.571
Log-likelihood	828.98395	294.391	395.43572	274.67431	714.38295	7.7404151
AIC	-1627.97	-560.782	-768.871	-521.349	-1400.77	14.519
BIC	-1507.08	-461.937	-691.773	-416.07	-1298.65	128.838

Notes: Models all include seasonal dummies (not reported). Models predict time after first adoption by any GP, hence N differs depending on time of first adoption. Specifically N denotes the number of GPs in each month who have not prescribed the drug. *** denotes significance at the 1 per cent level; ** at the 5 per cent level and * at the 10 per cent level. Variable definitions are given in Table 1.
Drug Descriptions: 1 – Antidepressant; 2 - Proton Pump Inhibitor; 3 - Anti-inflammatory; 4 - Antihistamine; 5 - Smoking Cessation Medicines; 6 -Hormonal Contraceptive.
Source: GMS Prescribing Database and GP Characteristics Database.

The portfolio breadth variable, which was constructed to capture learning-by-using effects, reveals a consistent effect. Across all six drugs and statistically significant at the 1 per cent level, time to adoption decreases for GPs who prescribe drugs from larger portfolios. As demonstrated by the marginal effects for this variable, time to adoption decreases substantially for all six drugs for GPs who have larger prescribing portfolios. A percentage increase in a GPs portfolio decreases time to adoption of these drugs from three to ten and a half months. As discussed in the previous section, this relationship between portfolio size and time to adoption is non-linear in relation to the nicotine drugs, suggesting a u-shaped relationship between portfolio breadth and time to adoption. Previous studies have highlighted that being an early adopter of one drug does not impact on subsequent adoption decisions (Steffensen et al., 1999; Dybdahl et al., 2004; Kozyrskyj et al., 2007), however, our study highlights that the relative size of a GP's prescribing portfolio significantly impacts on the decision to prescribe a new drug. It is also possible that our portfolio breadth variable could also be considered a proxy for practice size, as the more patients a GP sees the more likely they require a larger portfolio of drugs from which to prescribe. Previous studies have reported higher utilisation rates of new drugs for larger practices, as measured by practice volume (Tamblyn et al., 2003).

In our duration models, potential order effects variables for each drug are represented by a dummy variable taking a value of one where a GP prescribed at least one of the remaining five drugs in the first six months after their first adoption. There are strongly statistically significant negative order effects for four of the six drugs. As is evident from Table 4.4, time to adoption decreases in these drugs for GPs who are deemed 'first-movers' in the other drugs being examined. In relation to the antidepressant and hormonal contraceptive drugs, time to adoption decreases by approximately four to six weeks for ‘first-mover’ GPs. The order effect is quite large in relation to the anti-inflammatory and antihistamine drugs with time to adoption decreasing by six and eight months for ‘first-movers’ respectively. In standard terms, this suggests that some GPs are early adopters of new drugs in order to maximise the returns from that new adoption given anticipated future levels of adoption (Karshenas and Stoneman, 1993). It is important to note however that time to adoption of nicotine increases for ‘first mover’ GPs. Previous literature has reported order effects in relation to the adoption of multiple technologies, where the technologies are complementary (Stoneman and Kwon, 1994) or simultaneously adopted (Stoneman and Toivanen, 1997). While the six drugs in this study are not complementary therapies, they were adopted over a similar time-period. A plausible explanation here is that, some GPs who for whatever reason were early adopters of one drug have learnt the benefits of early adopting, and therefore tend to be early adopters of other drugs.

Finally, in our models potential stock effects are represented by the proportion of GPs who had adopted a drug at any given point in time (Karshenas and Stoneman, 1993). We find a positive effect (i.e. time to adoption increases as the stock of previous adopters increases) for five of the six drugs examined. As is evident from Table 4.4, for each percentage increase in the stock of previous adopters, time to adoption increases from six to twenty months for these five drugs. It is unlikely GPs have sufficient information or ability to correctly anticipate future adoption patterns. However, the stock of previous adopters in all 6 drugs over the time-period in question is high relative to the non-adopters. For instance, within the first year of the adoption of all 6 drugs, over half of GPs in the sample have adopted them; in fact, sometimes this figure is greater than 70 per cent. Therefore, given the rapid adoption rates of these drugs, it is perhaps not surprising that as the stock of previous adopters increases time to adoption increases for the remaining GPs (some of whom may remain non-adopters). Stoneman and Kwon (1994) in a study of the adoption of complementary technologies also report evidence of stock effects.

In this chapter, we examine the factors which lie behind the rapid adoption by Irish GPs of six prescription drugs following their launch in the Irish market. Our study highlights a range of commonalities across all of the drugs considered and suggests the importance of GP and practice characteristics, strategic behaviour, informational and cumulative learning factors in shaping prescribing decisions. Our evidence on rank effects, intended to capture the differential benefit-cost ratio of adoption by GPs with different characteristics, largely mirrors that of other studies. Practices with either a nurse or clerical support are more likely to be early adopters of new drugs as are younger GPs. We also find evidence that the IDTS, designed primarily to reduce prescribing costs, may also be having additional benefits by stimulating early adoption. However, it is important to note that in general the size of these rank effects is relatively small in terms of reducing or increasing time to adoption.

More surprising, perhaps, is that we find strongly significant stock and order effects. GPs who have a track record of early adoption tend also to be early adopters of any new drug (order effect)[42] and, the larger the proportion of GPs which have already

[42] Being an early prescriber of one drug in our data does predict early adoption of some drugs. However it is not a strong predictor of being an early adopter of all drugs examined. For instance, no GP in the sample adopted all six drugs within the first six months of them being adopted. This contradicts the image of early adopters as being related to a general innovative predisposition.

adopted a new drug the slower is subsequent adoption (stock effect). The standard interpretation of the stock and order effects in studies of new technology adoption by firms relates to the impact of the timing of adoption on the subsequent returns (Karshenas and Stoneman, 1993). Here, given the commercial autonomy of Irish GPs similar effects may be operating. Other potential, and observationally equivalent, explanations for these effects may relate more directly to information flows, a suggestion reinforced by the epidemic and learning-by-using effects we also find. Prescribing innovation tends to be slower in rural practices suggesting that isolated GPs with less opportunity for acquiring information about new drugs are slower to innovate. We find evidence of learning-by-using effects influencing the timing of first prescription of all six drugs examined, with slower adoption among GPs with narrower prescribing portfolios.

It is worth noting that the availability of similar drugs in the same therapeutic class may affect the uptake of each of the drugs examined. While Irish GPs' prescribing decisions are not constrained by NICE guidelines or based on the British Medical Formulary (BMF), it would be important to consider how availability of and information concerning alternative treatments may influence adoption decision-making. In Chapter 8, we discuss future research possibilities, one of which is an analysis of the determinants of adoption of drugs from the same therapeutic class. The availability of similar drugs could be incorporated in the study by including the 'stock' of adopters of alternative drugs in the analysis.

Therefore, it appears that a GPs decision to prescribe is heavily dependent on the new drugs in question (Dybdahl et al. 2005, Steffensen et al, 1999).

The duration models used enable the consideration of a wide range of factors on the timing of prescribing innovations. In fact, the innovation literature highlights the lack of panel data in relation to adoption of new innovations (Battisti et al., 2007). Three important limitations of this empirical study are worth highlighting, however. First, a common idea in the literature is that new drugs diffuse into general practice through a two-step model with hospital consultants as the innovators and GPs as the followers. In other words, it is the consultant who initially prescribes the new drug and GPs repeat prescribe these drugs when the patient returns to the primary care setting. Florentinus' (2006) study of the adoption of new drugs in a Danish primary care setting, however, contradicts this two-step model. While acknowledging the influence of medical specialists in GPs' prescribing decisions, Florentinus (2006) finds that GPs themselves are responsible for a considerable amount of all early prescriptions for new drugs. Here, data restrictions mean that we are not able to control for the potential influence of hospital consultants on GPs' prescribing decisions. However, of the six drugs examined, four (the antihistamine, the smoking cessation medication, the hormonal contraceptive and the antidepressant) are unlikely to be repeat prescriptions following an initial prescription by a hospital consultant. It is perhaps more likely that prescribing decisions for the proton pump inhibitor and the anti-inflammatory considered here may be more strongly influenced by hospital consultants' initial prescribing decisions. Secondly, due to data restrictions we do not control for the impact of advertising in relation to GPs decisions to adopt these six drugs. However, this is something to be considered in future research. Advertising noise or impact could be measured through a citation search in medical journals or ranking the market power of the pharmaceutical companies which initially released these drugs.

As discussed in the methodology section, an advantage of duration models is the ability to control for unobserved heterogeneity. However, our duration models did not fit when we attempted to control for unobserved heterogeneity.[43] Jenkins (2003) acknowledges that the frailty models can be relatively 'fragile' in the statistical sense, as they can be relatively hard to fit particularly if the frailty variance is close to zero. Jenkins (2003) highlights three sources of potential bias in 'non-frailty' duration models. Firstly there is potential to over-estimate the degree of negative duration dependence, and under-estimate the degree of positive duration dependence. Secondly, the proportionate effect of a given regressor on the hazard rate may no longer be constant and independent of survival time. Thirdly, the estimate of a positive (negative) coefficient derived from the non-frailty model will underestimate (over-estimate) the 'true' estimate. Jenkins (2003) also reports that the empirical literature generally confirms these theoretical propositions. However, he concludes that if a fully flexible specification of the baseline hazard function is used, then the magnitude of the biases in the 'non-frailty' model is diminished. While unobserved heterogeneity is likely to exist in these duration models, our explanatory variables differentiate between individual GPs well.

4.5 Conclusion

The purpose of this chapter is to explain the determinants of timing of first prescription of new drugs by GPs. The Irish primary health care system provides a distinctive setting for such an examination. The commercial and prescribing autonomy which characterise Irish general practice suggests that prescribing

[43] The Stata command 'streg' is used in our analysis. We included the 'frailty' option to control for unobserved heterogeneity.

decisions may reflect both commercial and medical factors. Six drugs new to the Irish market were identified for inclusion in the analysis, all of which were prescribed by Irish GPs to GMS patients in an extremely short time period from authorisation under the GMS scheme (see Table 4.1 and Figure 4.1a-e). Using data pertaining to 625 Irish GPs, duration analysis is performed to determine the equilibrium, disequilibrium and learning-by-using determinants of prescribing innovation (See Table 4.5 for a symbolic summary of results).

Our study finds some evidence of rank effects in relation to adoption of new prescription drugs by GPs. Practices with nursing and clerical support tend to be early adopters of new drugs, and younger GPs tend to be early adopters of new drugs. We find strongly significant and consistently signed, learning-by-using, stock and order effects across these drugs; GPs with broader prescribing portfolios tend to be early adopters of new drugs, GPs that have a track record of early adoption tend to be early adopters of other new drugs, and the larger the proportion of GPs which have already adopted a new drug the slower is subsequent adoption. Epidemic effects are also evident with slower adoption by rural practices.

Table 4.5: Symbolic Summary of Anticipated Results and Results

	Anticipated Effects	A	B	C	D	E	F
Rank Effects							
Practice Nurse	-	-					-
Practice Secretary	-				-	-	-
GP Age	+	+			+	+	+
Dispensing Practice	+						+
IDTS 50	-				-		
IDTS 60	-				-		
Order & Stock Effects							
Order Effects	(-)	-	-	-	-	-	-
Stock Effects	(+)	+	+	+	+	+	+
Learning-by-using Effects							
Prescribing Portfolio	-	-	-	-	-	-	-
Epidemic Learning Effects							
Rural Practice Allowance	+	+					+

Notes: A: Esciatolopram; B – Esmoprazole; C – Rofecoxib; D – Desloratadine; E – Nicotine; F – Drospirenone & Estrogen; '-' denotes a negative and significant effect on time to adoption (at the 10 per cent level or above), i.e. faster adoption; '+' denotes a positive and significant effect on time to adoption, slower adoption.

This empirical study validates the application of our theoretical model to Irish GPs decision-making concerning adoption of new drugs. As discussed in Chapter 1, this theoretical framework is extended to a multiple technology adoption and intensity of adoption approach to the use of medical equipment and ICT in general practices. These empirical exercises are presented in Chapters 6 and 7. In Chapter 8, we discuss and compare our findings from all three empirical examinations to form a holistic view of Irish GPs innovative behaviour.

CHAPTER 5: MEDICAL EQUIPMENT AND IT IN GENERAL PRACTICE – SURVEY DESIGN AND ADMINISTRTAION AND DESCRIPTION OF DATA

5.1 Introduction

The purpose of this chapter is to describe the design and administration of our primary data collection, as well as providing a detailed description of the data. The *Medical Equipment and IT in General Practice* survey data, cross-sectional in natures, provides us with a timely profile of 601 Irish general practices, along with information on decision-making concerning use of medical equipment and ICT. This data allows us to address our research questions concerning the influences on the use of medical equipment and intensity of use of ICT in Irish general practices, as presented in Chapters 6 and 7.

In Ireland, GPs play a core role in the provision of primary care to the general population (Department of Health and Children, 2001; Thomas and Layte, 2009). As discussed in previous chapters, an integral part of the health care service provided by GPs is the prescribing of medication to their patients. However, Irish GPs provide a range of services to their patients, including: patient examination and diagnosis, ordering of tests, performance of minor surgeries, and referral of patients to other health care providers (Competition Authority, 2010). Therefore, the extent and range of services provided by GPs is influenced by the use and extent of use of medical and ICT equipment in each practice. As outlined previously, Irish GPs have considerable freedom in how they equip their practices (Department of Health and Children, 2001; Wren, 2003), and there is evidence of considerable variation concerning the range of medical equipment (Boerma and Dubois, 2006; O'Dowd et al., 2006) and the extent of ICT use (Irish College of General Practitioners, 2003; Lordan and Normand, 2005; Boerma and Dubois, 2006; O'Dowd et al., 2006; Dobrev et al., 2008; Meade et al., 2009) in Irish general practices. In the previous empirical analysis, we focus on prescribing innovations and examine the determinants of the adoption of new prescription drugs by GPs (Chapter 4). In the following chapters, we further our understanding of GPs' innovative behaviour with an examination of use of medical equipment (Chapter 6) and intensity of use of ICT (Chapter 7) in Irish general practices.

With respect to the analysis of medical equipment and ICT use, the unit of analysis is the general practice rather than the GP, as decision-making concerning medical equipment and ICT is at the practice level rather than the individual GP level.[44] Existing data sources were consulted, but proved unsuitable for addressing our research questions.[45] Therefore, it was necessary to collect primary data that would reflect the nature of the general practices surveyed, as well as their characteristics within the equilibrium, disequilibrium and learning-by-using framework, and their use and extent of use of medical and ICT equipment. A further objective of the data collection procedure was to ensure that the sample obtained from the survey process is representative of all general practices in Ireland.

This chapter is organised as follows. Section 5.2 describes the exploratory work conducted prior to designing the questionnaire. Section 5.3 primarily describes the

[44] In meetings with a number of GPs, this viewpoint was also confirmed. It is worth mentioning that in Chapter 4, the unit of analysis is the GP; as the decision to prescribe a new drug to a patient is made at the individual GP level rather than at a practice level.
[45] These data sources are discussed in detail in Section 5.2

process of designing our questionnaire and Section 5.4 describes the administration of the pilot study and final survey. Section 5.5 describes the survey data, and Section 5.6 concludes the chapter with a discussion concerning the representativeness of the survey data and a description of a 'typical' Irish general practice.

5.2 Exploratory Work

Prior to designing the data collection instrument, it was necessary to ascertain if existing data sources were sufficient to address our research questions in relation to use of medical equipment and ICT, and also gain a deeper understanding of the Irish general practice environment. This aspect of the research design involved a detailed examination of existing data sources, as well as a number of exploratory interviews with GPs and HSE officials concerning the structure of general practice and the range of medical equipment and ICT applications used by GPs. A description of existing data sources and exploratory interviews conducting with GPs and HSE officials are given below.

In the last decade, the Irish College of General Practitioners (ICGP) has carried out two major surveys of GPs in Ireland. In 2005, the ICGP collected survey data on demographic and educational characteristics of GPs, the structure and organisation of their practices, practice equipment, service provision, and on a broad range of issues such as stress, morale and retirement plans (O'Dowd et al., 2006).[46] Similar studies had previously been carried out in 1982 and 1992, enabling trends in general

[46]A 22 per cent random sample of GPs was drawn from 2,477 GPs listed on the General Medical Service (GMS) and Mother and Infants (MIS) Schemes. Of the 545 GPs surveyed, 476 responded representing a response rate of 87 per cent. This sample size represents approximately 19 per cent of Irish GPs (0.22 random sample x 0. 87 response rate of 2,477 GPs).

practices to be reported (O'Dowd et al., 2006). The report, entitled Structure of General Practice in Ireland, provides a comprehensive depiction of general practice in Ireland, and is widely cited in official reports and policy documents (Thomas and Layte, 2009; Competition Authority, 2010). In 2003, ICGP members were surveyed on the extent of computerisation in their practices (Irish College of General Practitioners, 2003; Meade et al., 2009).[47]

Aspects of both these data sources fit some of the data requirements of this study.[48] However, it was felt that neither adequately covers all the data requirements necessary to conduct the empirical analyses of Chapters 6 and 7.[49] This is mainly due to different research objectives informing the data collection undertaken by the ICGP. Furthermore, with respect to both these studies, the unit of analysis is the GP, whereas our focus is on the practice. Collecting our own survey data, while an onerous task, benefits us with timely data concerning the structure of general practices in Ireland, and their interactions with external agents, and use of medical equipment and ICT. It is also widely acknowledged that there is a lack of data on all aspects of general practice in Ireland (Thomas and Layte, 2009; Competition Authority, 2010). Timely data is of particular importance given many of the changes in the GP profession in recent years, such as the increased numbers entering the profession, the increased feminisation of the profession, and changes in the structure of GP training, and the formalisation of general practice as a distinct speciality

[47] 2,362 ICGP members were surveyed. 1,452 completed questionnaires were returned representing a response rate of 66 per cent of all GPs registered with the ICGP. In 2005, a complementary qualitative study was commissioned examining the attitudes of GPs to computerisation in Ireland and Northern Ireland (Lordan and Normand, 2005).

[48] It is also worth noting that an application to the ICGP for access to this data may not have been successful.

[49] The disparities between these datasources and the requirements of our study are expanded on in more detail in Section 5.3.

within the wider medical profession.[50] It is widely accepted that GP services in the Irish health care system have developed in a fragmented and unsystematic fashion (Caulfield, 2001; Wren, 2003; Thomas and Layte, 2009). In this regard, both ICGP studies and their subsequent publications proved extremely helpful in terms of understanding the development of the general practice environment in Ireland, with respect to practice structure, interaction with external agents, staffing, and practice equipment (Irish College of General Practitioners, 2003; Lordan and Normand, 2005; O'Dowd et al., 2006; Meade et al., 2009).

Both surveys helped in the identification of medical equipment and ICT applications for possible inclusion in our questionnaire. The identification of medical equipment and ICT applications is particularly important, as the questions relating to medical equipment and ICT use provide information for the dependent variables in the analyses in Chapters 6 and 7. The Structure of General Practice in Ireland questionnaire asks respondents which medical equipment they use in their surgery and which equipment they have direct access to, i.e. without referral to the outpatient department (O'Dowd et al., 2006). O’Dowd et al. (2006) report that many of the items of medical equipment included in their survey are used by a large proportion of practices, possibly as all GPs with a GMS contract must equip their practice with such equipment. Therefore it was decided such equipment did not merit inclusion in this study. For the purposes of our study, it was necessary to focus on a small list of medical equipment, given the depth of information required, i.e. the year of adoption of medical equipment, and how the equipment was funded. We were conscious that item non-response in relation to these questions would have significant consequences

[50] It is estimated that the number of GPs per thousand of population grew from 0.60 in 2005 to 0.63 in 2008. 70 per cent of GP graduates between 1997 and 2003 were female. Since the mid-1990s, GPs are required to undertake a formal three year training programme (Competition Authority, 2010).

for our study. At this point, five items of medical equipment were identified for possible inclusion in our questionnaire.[51] As expected, a large percentage of practices use ICT. However given the range of ICT applications suitable for general practice use, there are large variations in extent of use (Irish College of General Practitioners, 2003; O'Dowd et al., 2006; Meade et al., 2009). Therefore, a substantial number of ICT applications were identified for possible inclusion in our questionnaire.

Next, it was decided that some inductive interviews with practicing GPs would be beneficial in terms of gaining an understanding of recent developments in general practice and obtaining some practitioner opinions on the medical equipment and ICT being considered for inclusion in our questionnaire. Meetings with the HSE South Primary Care Unit (PCU), a number of practising GPs, Dr. Paddy Ryan, Head of the GP Training Unit, UCC and Prof. Colin Bradley, Head of Department of General Practice, UCC were arranged and are discussed below. These interviews were conducted during August and September 2009.

An initial one-hour meeting with HSE South PCU officials was arranged in August 2009 to discuss the research being undertaken, to determine if any secondary data sources had been overlooked in the exploratory data search, and to discuss the collection of primary data for this research. A further meeting (2 hours) was arranged with the five GPs of the HSE South PCU. The primary purpose of this meeting was to discuss with GPs the medical equipment used and the extent of ICT use in general practices. These meetings confirmed that both ICGP surveys previously discussed

[51] The medical equipment identified comprises of ECG machines, 24 hour blood pressure monitors, spirometers, cryotherapy equipment, and minor surgery equipment. These items of medical equipment are discussed in more detail later in this section.

would be considered the most comprehensive surveys of Irish general practice to date. The GPs also advised that there is considerable 'survey fatigue' among GPs. Trainee GPs, undergraduate medical students and various undergraduate health care students frequently survey GPs. In line with this anecdotal evidence, UK researchers report evidence of falling response rates from GPs due to an increased use of questionnaires by researchers (McAvoy and Kaner, 1996; Barclay et al., 2002). The PCU GPs also recommended discussing the research with Dr. Paddy Ryan, Head of GP Training in UCC and Prof. Colin Bradley, Head of Department of General Practice, UCC.

Further interviews were conducted with two GPs in the Cork area in August 2009. Again, the purpose of these interviews was to deepen our understanding as to how general practices operate in Ireland. An interview schedule was designed and used in the interviews (see Appendix 3). As is evident from the interview schedule, open-ended questions were used to allow interviewees the opportunity to provide detailed answers. Interviewees were asked: how their practice is managed, who the decision-makers are, what factors inform decisions, what medical equipment they use and for what purposes ICT is used. Interviewees were also asked if there were other innovations or technologies, other than medical equipment, ICT and prescription drugs, that general practices use that this study may be overlooking. These interviews were approximately one hour in duration and, with the permission of the respondents, were recorded. Advice was also sought as to whether the survey should be distributed by post or email. Both GPs interviewed advised that a postal survey would generate a higher response rate. In subsequent meetings with Dr. Ryan and Prof. Bradley, postal questionnaires were also advised, based on their experiences with supervising students undertaking primary data collection. Previous studies also report favourable response rates to postal questionnaires (Jones and Pitt, 1999; Leece et al., 2004). From a practical perspective, it would be extremely difficult to acquire email addresses for the Irish GP population.[52]

In September 2009, Dr. Paddy Ryan, and Prof. Colin Bradley were also interviewed. Dr. Ryan and Prof. Bradley are practising GPs, whilst also holding academic positions. Both interviews were between one and a half to two hours in duration, and both interviewees consented to their interview being recorded. These interviews proved particularly fruitful with respect to identifying and choosing the medical equipment and ICT applications for inclusion in our questionnaire.

In relation to medical equipment, five items of medical equipment were identified from previous survey instruments and literature, for inclusion in the questionnaire. Dr. Ryan and Prof. Bradley thought that that there would be variation in the adoption and use of the equipment identified. Dr. Ryan and Prof. Bradley helped identify two further items of medical equipment, namely dexas scanning equipment and ultra sound and Doppler foetal monitors, which in their opinion warranted inclusion in the questionnaire. The seven items of medical equipment identified for inclusion in our questionnaire are listed and described below.

- An *ECG or Electrocardiogram machine* records the electrical activity of the heart. Electrodes are placed on the skin of the chest and connected in a

[52] In fact, one in five respondents to our survey does not use email (see Section 5.4).

specific order to the ECG machine which enables the measurement of electrical activity around the heart.

- A *24 hour Blood Pressure Monitor* is a portable battery-operated device, which continuously records a patients blood pressure throughout the day and night over and expired by the lungs, thus assessing pulmonary function.

- A *Spriometer* is a device for measuring flows and volumes inspired and expired by the lungs, thus assessing pulmonary function.

- *Cryotherapy* is the application of extreme cold, usually in the form of liquid nitrogen, to destroy abnormal or diseased tissue, such as warts, moles and skin tags. The liquid nitrogen may be sprayed on the diseased tissue, circulated through a tube called a cryoprobe, or simply dabbed on with a cotton or foam swab.

- A *Minor Surgery Equipment* kit contains the instruments necessary for minor surgical procedures. Such a kit would normally include scalpel, scissors, forceps, suture material and gauze pads.

- *Dexas scanning equipment* is used to measure bone mineral density, and is typically used to diagnose and follow osteoporosis.

- *Ultrasound and Doppler foetal monitors* are used to monitor a foetus' heartbeat and detect foetal abnormalities in prenatal care.

The ICT applications used in general practices were also discussed with Dr. Ryan and Prof. Bradley. From these discussions, it became clear that ICT is used in general practices for two functions: administrative and patient care. This distinction was not apparent from the previous surveys or studies reviewed. It was decided that our analysis of ICT use would benefit from distinguishing between these two distinct ICT functions. The administrative functions identified for inclusion in the questionnaire were: accounts, word processing, billing, patient registration, referral letters, appointments, practice staff's calendar, email, and practice website. The patient care functions identified were: recall of items (vaccinations, immunisations, smears), repeat prescriptions, downloading hospital laboratory reports, coding of diseases, internet research, scanning hospital and consultant correspondence, and audit/quality assurance. Dr. Ryan also advised including a question looking specifically at the extent to which consultation records are computerised in practices, i.e. completely computerised consultation records, completely paper-based consultation records or a combination of both.

Following this exploratory work, the data collection instrument, a self-administered postal questionnaire, was designed; and is discussed in the following section.

5.3 Designing the Questionnaire

This section provides a detailed description of the *Medical Equipment and IT in General Practice* questionnaire, with some excerpts from the questionnaire included for illustration. The questionnaire, as well as the cover letter, is included in full in Appendix 4.[53]

Much consideration was given to the design of the self-administered postal questionnaire. The questionnaire contained 20 closed-ended questions which encompassed all the data requirements of the study. In general, closed-ended questions result in higher response rates than open-ended questions (Fowler, 1995; Bryman and Bell, 2007). The questionnaire was printed, double-sided, on one sheet of paper, for the purpose of ensuring a high response rate. Bryman and Bell (2007) state that shorter questionnaires tend to achieve higher response rates than longer ones. The questionnaire was green in colour. There is evidence that self-administered postal questionnaires printed on green paper achieve higher response rates that those printed on white paper (Gullahorn and Gullahorn, 1963; Fox et al., 1988; Philips et al., 1991). In fact, the Central Statistics Office distributes many of their self-administered questionnaires on green paper, such as the Census of Population of Ireland. The questions relating to the adoption and use of medical equipment and ICT are discussed, followed by the questions relating to practice and GP characteristics, and prescribing decisions. Prof. Bradley also advised on a number of drafts of the questionnaire.

As discussed in the previous section, seven types of medical equipment were identified for inclusion in the *Medical Equipment and IT in General Practice* questionnaire. Question 9 asks whether or not the practice has seven types of medical

[53] A number of minor amendments were made to the questionnaire following the pilot study. These amendments are discussed in Section 3.2.4.

equipment, and if so, in what year did the practice obtain the equipment. This question is provided in Figure 5.1.[54]

Figure 5.1: Adoption of Medical Equipment Question

Q9. Does your practice have the following medical equipment? If so, approximately when did you first obtain this equipment?

	Practice Equipment	Equipment obtained in Year
ECG Machine		
24-Hr Blood Pressure Monitor		
Spirometer		
Cryotherapy		
Minor Surgery Equipment		
Dexas Scanning		
Ultra sound/doppler / foetal monitor		

Responses to Question 9 provide us with a binary measure as to whether the practice uses this equipment or not, which forms the basis of the econometric analysis in Chapter 6, and the year the practice adopted each item of equipment allowing us to draw diffusion curves depicting the level of adoption of these items of equipment over time (see Chapter 6). Additional questions also determined how each item of equipment was funded (Question 10), and how important several factors are in informing the decision to purchase medical equipment (Question 11).

[54] In other health care systems, such as the NHS, 'hub and spoke' service delivery models are being implemented in many areas. In general, a 'hub' would be a larger better-equipped centre of excellence, with a number of 'spokes', i.e. smaller centres, in the same geographical area. Such a model in a primary care setting enables the provision of a wider range of services across a geographical area without the need for individual practices to make considerable investments in medical equipment. However, at present, no such 'hub and spoke' model of primary care delivery operates in Ireland. However, in health care systems with 'hub and spoke' service delivery models uptake and use of medical equipment is likely to be influenced by whether a practice is categorised as a 'hub' or 'spoke'.

As discussed in Section 5.2, Dr. Ryan and Prof. Bradley advised to examine intensity of ICT use from the perspective of administrative and patient care functions. Questions 12 and 13, presented in Figure 5.2, ask for which administrative and patient care functions practices use ICT. These questions provided us with binary measures of use for all ICT applications for administrative and patient care functions, and also enabled the construction of intensity of use measures which provide the dependent variables for the econometric analysis in Chapter 7. It was deemed too onerous a task to ask respondents when they introduced each type of application, and also given the variation in the economic importance of each ICT application the benefits of including such a question are debatable.

Figure 5.2: Administrative and Patient Care ICT Questions

Q12. For which of the following administrative functions does your practice use Information Technology? *Please tick all that apply*

Accounts	
Word Processing	
Billing	
Patient registration	
Referral letters	
Appointments	
Practice Staff's Calendar	
Email	
Practice Website	

Q13. For which of the following patient care functions does the practice use Information Technology? *Please tick all that apply*

Recall of items: vaccinations; immunisations; smears	
Repeat prescriptions	
Download hospital laboratory reports	
Consultation Records	
Coding of Diseases	
Internet research	
Scan hospital/consultant correspondence	
Audit/Quality Assurance	

As advised by Dr. Ryan, we included a question which asks whether the practice keeps computerised or paper consultation records or a combination of both (Question 14).We also included a question to determine how important a number of factors are in informing practices' use of IT (Question 15).

The medical equipment and ICT use questions were included to provide us with the dependent variable measures for the econometric analysis in Chapters 6 and 7. These variables also enabled us to construct a number of explanatory variables, such as learning-by-using effects variables for both medical equipment and ICT use. Determining the year each item of medical equipment was obtained by each practice enabled the construction of an order effects variable. There variables are discussed in detail in Chapters 6 and 7. However, we also included a range of questions in the questionnaire to capture practice characteristics (rank effects), such as practice size, support staff, number of patients, and interaction and learning effects (epidemic effects), such as practice location, visits from suppliers, involvement with research projects and continuing education.

Questions relating to the number of GPs (male and female), the age of the GPs, and the number of principals (male and female) in the practice, nursing and administrative support (Questions 1-4), and the year the practice was established (Question 6) were included.[55] A question relating to the main location (city, large town, small town, village or rural) of the practice is also included. While there is an element of subjectivity about this question, it is reasonable to assume that

[55] Question 6 was included following the pilot study which is discussed in Section 5.4

respondents are able to identify which of the four categories correctly identifies the main location of their practice.[56]

Additional practice characteristics, such as whether it receives a rural practice allowance, acts as a training and/or dispensing practice, participates in a 'Primary Care Team' and, if so, whether it is co-located with the team, are included (Question 7). GP practices are entitled to a rural practice allowance if the practice is in an area with a population of less than 500 people. The allowance is also paid in some cases where the HSE is trying to attract a doctor to a remote area. Practices who qualify for the rural practice allowance are automatically entitled to receive full practice support subsidies for the employment of a nurse and a secretary, i.e. the full secretarial and nurse allowance (provided they are full-time) irrespective of patient panel list size. Approximately, one in eight GPs are in receipt of a rural practice allowance (O'Dowd et al., 2006). Given their remote location, these practices often dispense medication. A proportion of GP practices are registered GP training practices, and at different times of the year will employ a post-graduate GP trainee in the practice.

The Primary Care Strategy proposes that primary care be delivered through 'primary care teams' which include GPs, nurses, midwives, health care assistants, home helps, physiotherapists, occupational therapists, social workers, receptionists, clerical officers, and administrators. These inter-disciplinary teams will come together, preferably in a single location (co-location), to serve a population of 3,000 to 7,000 people (Department of Health and Children, 2001). The strategy envisages that 600 to 1,000 primary care teams will be required nationally based on a population of 3.8

[56] A cross-check of answers to this question and the mailing address was carried out on a sample of returned questionnaires to validate the responses to this question.

million. However, development has been very slow and it estimated that only one-tenth to one-sixth of that number had come into existence by April 2008 (Thomas and Layte, 2009).

The number of GMS (public) and private patients on the practice's list is also measured (Question 16). All GMS patients in Ireland must register with a GP. However private patients do not have to register with a GP, therefore making it difficult for GPs to know their practice's exact number of private patients. This question provides a measure of practice size. The number of GPs in the practice is determined from answers received in questions 1 and 2, and provides an additional measure of practice size.

Interaction with other health care professionals, in terms of clinics held at the practice, is measured (Question 8), as is the frequency with which respondents attend professional development meetings (Question 18), and respondents' professional and academic involvement over the previous three years (Question 17). Prof. Bradley advised the inclusion of these questions to facilitate distinguishing between respondents with an interest in continued learning and professional development and those without. Frequency of visits from suppliers of medical and IT equipment and pharmaceutical company representatives are also included (Question 19).

As discussed, this survey instrument was designed to provide data for the empirical exercises examining the adoption of medical equipment and IT in general practices. However, it was also decided to take the opportunity to ask some questions relating to prescribing decisions which would complement the empirical exercise examining the timing of adoption of prescription drugs (Chapter 4). The GMS Prescribing Database provides good quality data on prescribing decisions, however, it does not include variables which measure interaction with drug company representatives or variables that measure what factors influence prescribing decisions. Therefore, along with a question on the frequency of visits to the practice by pharmaceutical company representatives (Question 19), the final question of the questionnaire asks how important a number of factors are in informing the decision to prescribe a new drug for the first time.

While designing this survey, we considered including a question on the consultation fee charged for private patients. At present, general practices are not obliged to display the price of a consultation, although an updated Guide to Professional Conduct and Ethics for Registered Medical Practitioners specifies that GPs can display prices. The Competition Authority estimated that the average cost of a GP visit for a private patient is approximately €50-55 in urban areas, with slightly lower charges in rural areas (Competition Authority, 2010). The National Consumer Agency also reported a wide range of prices for GP visits, averaging at €51, with a minimum of €35 and a maximum of €70 (Thomas and Layte, 2009). A recent Competition Authority report highlighting the lack of transparency and data concerning private patient consultations fees provided justification for the collection of timely data on private patient consultation fees (Competition Authority, 2010). However, on reflection, it was decided to omit this question given the sensitivity of the topic.

In brief, the *Medical Equipment and IT in General Practice* questionnaire differs from previous questionnaires surveying general practice in Ireland in a number of ways. Firstly, it is the first questionnaire in relation to Irish general practices where the unit of analysis is the practice rather than individual GPs. Such an approach is warranted as investments in medical equipment and ICT are more likely to be at a practice level than at a GP level, and recent changes in general practice indicate a move away from solo-practitioner to multi-partner practices (O'Dowd et al., 2006; Bourke and Bradley, 2010; Competition Authority, 2010). More specifically, we focus on seven items of medical equipment, allowing us to ask more in-depth questions relating to when the equipment was obtained. Also, we distinguish between ICT use for patient care and administrative purposes. A possible omission by previous studies.[57] Also, our questionnaire provides us with extensive information concerning interaction with external sources, and their influence on decision-making, with respect to medical equipment and ICT use.

As previously discussed, it was advised that administering the *Medical Equipment and IT in General Practice* questionnaire by post would positively influence the overall response rate. The survey instrument pack contained a cover letter, the questionnaire and a stamped-addressed envelope. The cover letter, addressed to a GP in the practice, explained the purpose of the study, encouraged the practice's participation in the study, and explained that ideally a principle in the practice should complete the questionnaire. A practice principal usually owns (or part-owns) the practice and holds the GMS contract in the practice (Competition Authority, 2010). Therefore, a principal would be well informed as to the use and purchase of medical

[57] Our results in Chapter 7 clearly justify distinguishing between administrative and patient care ICT applications.

and ICT equipment, and all aspects of practice structure and organisation. The cover letter assured the participant that data provided would be treated confidentially and would be published only in aggregate form. The letter was signed by Prof. Colin Bradley, Department of General Practice, UCC and Ms. Jane Bourke, Department of Economics, UCC (see Appendix 4). The cover letter and questionnaire was submitted to the Social Research Ethical Committee, UCC for ethical approval, which was granted in February 2010.

5.4 Survey Administration

The following section describes the process of administering the survey, with respect to the sample frame employed (5.4.1), the pilot study (5.4.2) and the survey distribution (5.4.3).

5.4.1 The Sample Frame

Designing a sample frame of all general practices in Ireland is complicated by the fact that there is no official register of Irish GPs (O'Dowd et al., 2006). Under the Medical Practitioners Act (1978), it was not possible to distinguish GPs from other types of Medical Practitioner on the General Register (Government of Ireland, 1978). A new Medical Practitioners Act (2007) requires GPs, as of March 2009, to register as a GP specialist (Competition Authority, 2010). Therefore, up to recently, it was difficult to determine exactly how many GPs are practicing in Ireland. In fact, many reports projecting future supply of GPs were required to work from estimates based on the previous ICGP surveys discussed and HSE estimates (Thomas and Layte, 2009; Competition Authority, 2010).

It is also worth noting that the ICGP surveys devised sample frames from ICGP membership and GPs registered on the Maternity and Infant Care Scheme (MIS), neither listings would include all GPs in Ireland (Irish College of General Practitioners, 2003; O'Dowd et al., 2006). Consideration was given to approaching the ICGP for a list of GPs registered with them. However, this was decided against as it could be quite a lengthy process. Therefore, we decided to use the Golden Pages website as the sample frame for this study, as we would expect that most general practices would have a presence on the website.[58]

As stated previously, there is no official comprehensive register of practising GPs in Ireland. However it is estimated that there are approximately 2,500 GPs in Ireland (Leahy and Wiley, 1998; O'Dowd et al., 2006; Thomas and Layte, 2009) and approximately 1650 general practices in Ireland (Wren, 2003). At the outset, 2,363 GP names and addresses were downloaded from the Golden Pages website. As our focus is on the general practice rather than the GP, it was necessary to identify one GP per practice to be included in the sample frame. Therefore, where there was more than one GP listed at the same address, all GPs were removed except one. Also if there were two addresses for the one GP (two practice addresses or a home and practice address), one of the addresses was removed from the sample frame. At this stage, there were 1501 general practice addresses in the sample frame. A survey instrument pack, comprising a cover-letter, questionnaire and FreePost envelope, was sent to all 1501 general practices.[59] 84 questionnaires were returned due to incomplete addresses or retired or deceased GPs. Therefore, the final sampling frame

[58] The Golden Pages, the equivalent of the Yellow Pages in the UK, is the Irish telephone directory for businesses.
[59] This includes the 50 pilot study questionnaires.

consisted of 1417 general practices. Table 5.1 illustrates these different stages in constructing the sample frame.

Table 5.1: Stages of Sample Frame Construction

	Number of Units
Target population elements identified for sample frame	2,363
Duplicates of target population elements in sample frame	862
Target Population Sample Frame	**1501**
Ineligible units – questionnaires returned unanswered	84
Final Sample Frame	**1417**

5.4.2 Administering the Pilot Study

On February 16th 2010, the survey instrument pack was sent to 50 GP practices in the Cork region selected for inclusion in the pilot study. It was decided to pilot GPs in proximity to UCC, as it was more likely that they would contact either Prof. Bradley or Ms. Bourke if they had any issues or concerns with the questionnaire. The survey instrument pack contained the cover letter, the *Medical Equipment and IT in General Practice questionnaire* and a stamped-addressed envelope.

A response rate of 56% (28 returned questionnaires) was achieved with the pilot study. In general, all questions were completed. Some minor changes were made to the questionnaire following discussion of the pilot study responses. All changes discussed in this section were implemented in the final questionnaire (Appendix 4).

In the pilot study, the frequency of visits from drug company representatives question comprised of four responses categories. All respondents answered that drug company representatives visited the practice 6 or more times a year (see Figure 5.3). In light of this, an additional category was included (9 or more) in the final questionnaire (see Appendix 4).

Figure 5.3: Pilot Study Questions

Q17. On average, approximately how many times a year do the following visit your practice?

	None	1 or 2	3 to 5	6 or more
Suppliers of Medical Equipment				
Suppliers of IT equipment				
Drug Company Representatives				

Q18. Finally, how important are the following in informing your decision to prescribe a new drug for the first time?

	Not Important			Very Important	
Other GPs/Primary Care Professionals	1	2	3	4	5
Internet	1	2	3	4	5
Hospital Consultants	1	2	3	4	5
Pharmaceutical Co. Reps.	1	2	3	4	5
Conferences/CME meetings	1	2	3	4	5
Other, please specify					

The final question of the questionnaire regarding the importance of a number of factors in informing prescribing decisions was amended following the pilot study. A number of respondents to the pilot study had included 'journals' as important in informing their prescribing decision in the 'Other, please specify' category (see Figure 5.3). Therefore, 'journals' was included in the response categories in the final questionnaire.

The pilot study omitted to ask a question regarding the year the practice was established. This was included in the final questionnaire. The 26 respondents to the pilot study were contacted regarding this missing information, with 20 respondents providing us with the year their practice was established.

5.4.3 Administering the Survey

In March 2010, the survey instrument pack, which included the amended questionnaire, was mailed to all general practices identified in the sample frame. As discussed in section 5.4.1, the final sample frame consisted of 1417 general practices. In total, 601 completed questionnaires were returned.[60] An overall response rate of 42 per cent was achieved. Prior to administration of the survey, we were advised that GPs can receive a number of questionnaires every week. Therefore we expected that a substantial amount of time would be required to devote to follow-up mailings and phone-calls to achieve an adequate sample. Our sample size of 601 proved an adequate number of observations for the required analyses in Chapters 6 and 7. Also, given the reasonable representativeness of the sample by HSE region it was decided that no follow up surveys were required.[61]

[60] This figure includes the 28 completed pilot study questionnaires.

[61] Previous innovation surveys attain much lower response rates. For instance, the Open Innovation survey conducted by the UK Innovation Research Centre achieved a response rate of approximately 10 per cent(Cosh et al., 2011)."

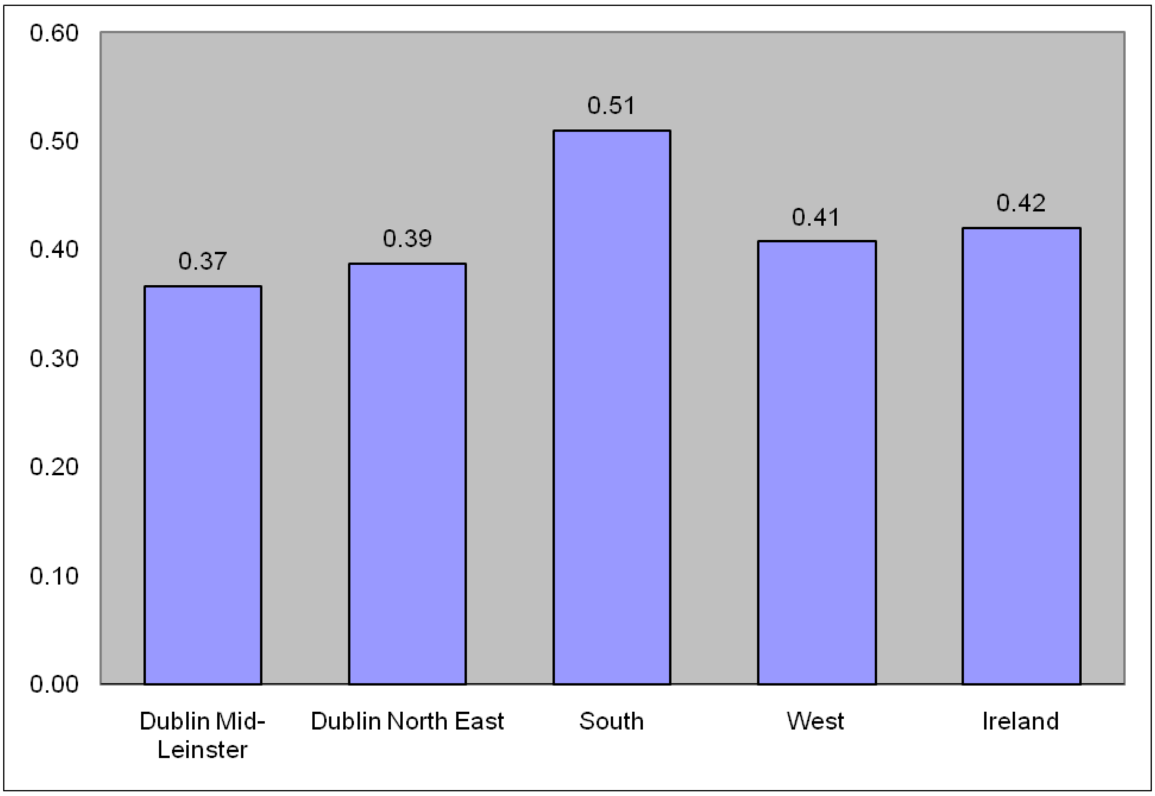
Table 5.2: Response Rates by HSE Region and County

	Distributed Questionnaires	Returned Questionnaires	Response Rate
Dublin Mid-Leinster			
Kildare	48	21	44%
Dublin South	210	69	33%
Wicklow	35	17	49%
Longford	11	6	55%
Westmeath	30	13	43%
Laois	14	6	43%
Offaly	37	9	24%
	385	**141**	**37%**
Dublin North-East			
Dublin North	139	44	32%
Meath	33	11	33%
Louth	26	19	73%
Cavan	24	11	46%
Monaghan	13	6	46%
	235	**91**	**39%**
South			
Cork	226	122	54%
Kerry	44	26	59%
Tipperary South	29	14	48%
Wexford	37	18	49%
Waterford	38	15	39%
Kilkenny	20	8	40%
Carlow	18	8	44%
	412	**211**	**51%**
West			
Galway	106	46	43%
Mayo	56	21	38%
Roscommon	19	8	42%
Limerick	74	33	45%
Clare	33	17	52%
Tipperary North	20	6	30%
Donegal	44	15	34%
Sligo	20	8	40%
Leitrim	13	3	23%
	385	**157**	**41%**
Total	**1417**	**601***	**42%**

*One questionnaire was returned without a county identifier. The respondent removed the unique identifier.

Table 5.2 presents the response rates by HSE region and county. In the HSE Dublin Mid-Leinster and HSE Dublin North-East regions response rates of 37 and 39 per cent respectively were achieved. A higher response rate of 51 per cent was achieved in the HSE South region where UCC is located. A response rate of 41 per cent was achieved in the HSE West region. These response rates by HSE region are presented in Figure 5.4.[62]

Figure 5.4: HSE Executive Region Response Rates



[62] A Chi- Square Goodness of Fit test was conducted to determine if the responses by HSE region were representative geographically. There is slight over-response from the HSE South region; potentially as a result of the survey's association with UCC and its location in the south of Ireland. The extent of over-response is small. However, if 11 fewer responses had been received from the HSE South, the sample would have been representative.

This section outlined the administration of the *Medical Equipment and IT in General Practice* questionnaire. The following section describes the data collected from the 601 general practices who returned completed questionnaires.

5.5 Description of Survey Data

The objective of this section is to provide the reader with an in-depth description of Irish general practices in 2010.[63] Firstly, we discuss the adoption and use of medical equipment (5.5.1) and ICT (5.5.2) in general practices, followed by a discussion of the structure of general practices and their interaction with external agents (5.5.3).[64] [65]Where possible, we endeavour to compare this study's findings with previous research.[66]

5.5.1 Medical Equipment Adoption Variables

A European study reported that Irish GPs provide a comprehensive mix of services, in fact, to a greater extent than many of their European counterparts. Consequently, Irish general practices are well equipped with respect to their portfolio of medical equipment (Boerma and Dubois, 2006). Therefore, it is not surprising that our survey results indicate that a high proportion of general practices use the items of medical equipment included in our survey (Table 5.3). Specifically, 83 per cent of practices

[63] See Bourke and Bradley (2010) for the *Medical Equipment and IT in General Practice* survey report.

[64] The explanatory variables, which measure equilibrium, disequilibrium and learning-by-using concepts, used in the empirical analysis of use and extent of use of medical equipment and ICT are described in Chapters 6 and 7.

[65] In the cover letter in the survey instrument pack, we request that a principal in the practice completes the questionnaire. While we cannot confirm that this was the case, given the information required to complete the survey and the low levels of item non-response, we are reasonably confident that practice principals completed this survey.

[66] It is not always possible to make direct comparisons due to differences in research objectives and the survey instruments used.

have an ECG machine, 80 per cent have a 24 hour blood pressure monitor, 64 per cent have a spirometer, 84 per cent have cryotherapy equipment, 76 per cent have minor surgery equipment, 2 per cent have dexas scanning equipment[67], and 81 per cent have foetal monitor equipment.

Table 5.3: GP Practices with Medical Equipment

Item of Medical Equipment	Total Observations	Positive Observations	Percentage
ECG Machine	601	498	82.86%
24 Hr Blood Pressure Monitor	601	478	79.53%
Spirormeter	601	384	63.39%
Cryotherapy Equipment	601	505	84.03%
Minor surgery Equipment	601	455	75.71%
Dexas Scanning Equipment	601	12	2.00%
Foetal Monitor	601	486	80.87%

When compared to previous surveys of general practices in Ireland, our results also indicate the proportion of general practices investing in equipment is increasing. For instance, in 2005 less than 60 per cent of GPs had ultrasound equipment in their practices, whereas 80 per cent of practices have this equipment in 2010. In 2005, 65 per cent of GPs had a 24 hour blood pressure monitor in their practices; this figure has increased to 80 per cent of practices having this equipment. Similarly, in 2010 more general practices have minor surgery and cryotherapy equipment and ECG machines than in 2005 (O'Dowd et al., 2006).

[67] Dexas scanners are a relatively new item of equipment within general practices. GPs can refer patients for bone density scans to secondary care centres.

Table 5.4 outlines, on average, the year each item of equipment was obtained by practices. It is important to note that not all practices provided the year their practice obtained this equipment. The average year of adoption of ECG machines is 1997, with ECG machines being first adopted in 1964. These variables enabled the drawing of diffusion curves illustrating the level of adoption of each item of equipment over time (see Chapter 6, Figures 6.1a-f).

Table 5.4: Year of Adoption of Medical Equipment

Variable Name	Observations	Year of Adoption	Std. Dev.	Min	Max
ECG Machine	439	1997.27	8.34	1964	2010
24 Hr Blood Pressure Monitor	410	2002.96	4.45	1986	2010
Spriormeter	312	2001.84	6.68	1977	2010
Cryotherapy	413	1997.67	7.07	1980	2010
Minor surgery equipment	348	1993.69	10.18	1960	2010
Dexas Scanning	10	2003.80	4.26	1998	2009
Foetal Monitor	391	1998.35	7.18	1965	2009

In relation to all seven items of medical equipment, respondents were asked how the purchase of this equipment was funded – by the practice, the HSE, a private company or another source. Across all seven items of equipment, they are predominately funded by the practice (Table 5.5), ranging from 58 per cent of practices funding dexas scanning equipment to 94 per cent of practices funding cryotherapy and minor surgery equipment.

Table 5.5: Purchase of Medical Equipment

	ECG	24 Hr BPM	Spiro-meter	Cryo-therapy	Minor Surgery	Dexas Scanning	Foetal Monitor
Practice	79.07%	55.65%	67.72%	94.23%	94.26%	58.33%	75.76%
HSE	10.66%	13.81%	4.99%	3.38%	1.10%	-	3.93%
Practice & HSE / Co.	2.81%	4.81%	1.84%	0.99%	1.10%	8.33%	2.19%
Co. / HSE & Co.	5.83%	23.64%	23.09%	1.00%	0.66%	33.33%	1.75%
Other	0.60%	0.84%	1.57%	-	-	-	0.44%
Missing	1.01%	1.26%	0.79%	0.10%	2.87%	-	15.94%
Total	497	478	381	503	453	12	458

Note: Co. = Private Company, HSE = Health Service Executive

Respondents were also asked to rate the importance of a number of different factors in informing their decision to purchase medical equipment. The majority of respondents (62 per cent) consider other GPs and primary care workers to be important in the decision to purchase medical equipment (see Table 5.6). Likewise, a large number of respondents (57 per cent) considered conferences and/or Continuing Medical Education meetings to be important in the decision to purchase medical equipment.

Table 5.6: Factors influencing Medical Equipment Purchase Decisions

	Not Important 1	2	3	4	Very Important 5	Total Responses
Other GPs/ Primary Care Workers	10.27%	6.37%	22.12%	34.87%	26.37%	565
Internet	39.69%	20.61%	24.05%	13.17%	2.48%	524
Flyers in the Post	18.35%	22.84%	33.27%	19.24%	6.29%	556
Medical Equipment Suppliers	18.35%	22.84%	33.27%	19.24%	6.29%	556
Conferences/ CME	8.66%	8.13%	26.33%	39.93%	16.96%	566

5.5.2 ICT Use Variables

A European-wide survey of ICT use among general practices categorised Irish general practices as 'average' performers in terms of ICT use (Dobrev et al., 2008). Our survey results indicate that levels of use of the different ICT applications is generally high, although there are variations in use. For example, in relation to patient care ICT applications, high levels of use (89 and 84 per cent) are reported in relation to repeat prescriptions and consultation records. 84 per cent use of computerised consultation records indicates a marked improvement on 2003 figures, when 51 per cent of GPs kept the majority of their notes on a computer, with 49 per cent of GPs in general using paper records (Irish College of General Practitioners, 2003).

However, there is also evidence of low levels of use in relation to patient care ICT applications, with approximately 40 and 41 per cent of practices using ICT for coding of diseases and audit/quality assurance purposes respectively. This means that only four in ten general practices in Ireland use ICT to classify patient's diseases and conditions and identify patterns in the practices population, and to review and evaluate current practices.

Table 5.7: General Practice's ICT Use for patient care and administrative purposes

Variable Name	Observations	Percentage
Patient Care Functions		
Repeat Prescriptions	601	88.85%
Consultation Records	601	84.40%
Download Lab Reports	601	80.20%
Internet Research	601	75.71%
Scan Correspondence	601	74.38%
Recall of Items	601	73.38%
Audit/Quality Assurance	601	41.76%
Coding of Diseases	601	40.10%
Administrative Functions		
Patient Registration	601	90.35%
Referral Letters	601	88.52%
Word Processing	601	87.69%
Email	601	79.53%
Appointment	601	77.54%
Accounts	601	63.89%
Billing	601	59.40%
Calendar	601	39.77%
Practice Website	601	28.12%

There are similar variations with respect to ICT use for administrative purposes. For example, more than 87 per cent of practices use ICT for word processing, patient registration and referral letters, although only 29 per cent of practices in Ireland have a practice website. Therefore, more than seven in ten general practices in Ireland do not use the internet to promote their practices. However, this does indicate an increase from 2003 when only 16 per cent of GPs had a practice website (Irish College of General Practitioners, 2003).

Respondents were also asked the importance of different factors in informing how they use ICT for both administrative and patient care purposes. Most respondents identify other GPs and primary care workers, conferences/CME meetings and the General Practice Information Technology (GPIT) group as important with respect to informing their ICT use. The GPIT group, among other functions, provides advice and support to GPs on all issues relating to IT in General Practice (Irish College of General Practitioners, 2004).

Table 5.8: Factors influencing Extent of ICT Use

	Not Important 1	2	3	4	Very Important 5	Total Responses
Other GPs/ Primary Care Workers	8.50%	5.06%	21.88%	37.25%	27.31%	553
Internet	33.46%	22.24%	24.41%	14.96%	4.92%	508
Flyers in the Post	55.82%	26.10%	15.46%	1.81%	0.80%	498
IT Suppliers	18.71%	19.28%	32.14%	22.12%	7.75%	529
Conferences/CME	8.12%	8.67%	30.07%	36.53%	16.61%	542
GPIT	13.12%	12.74%	25.67%	34.03%	14.45%	526

5.5.3 Practice and GP Characteristics

This section briefly describes the structure of the general practices surveyed, in relation to practice staff, practice location, practice size and interaction with external agents.

On average, there are 2.7 GPs per practice (Table 5.9). However, one in four practices is a solo-practitioner practice. This is approximately a 10 per cent reduction from 2005, when 35 per cent of GPs were categorised as solo-practitioners (O'Dowd et al., 2006), and in line with the Primary Care Strategy proposals (Department of Health and Children, 2001). In fact, more than one in eight practices comprise of 5 or more GPs.

Respondents were also asked approximately how many public and private patients are on the practice list. As presented in Table 5.9, the average number of public patients per practice is 1,399, with the average number of private patients per practice being 2,800. The average year of establishment of the practices surveyed is 1984.

With respect to the gender profile of GPs in the practices surveyed, on average, there are 1.4 male full-time equivalent (FTE) GPs in the practices surveyed, with 1.14 female FTE GPs per practice (see Table 5.9). In 18.5 per cent of practices, there is a gender balance with an equivalent number of male and female GPs in the practice. In 51.2 per cent of practices, there is a higher proportion of male GPs to female GPs, and in 30.4 per cent of practices, there is a higher proportion of female GPs to male GPs. These figures reflect current trends of more females entering the profession than ever before, In fact, 70 per cent of GP graduates were female between 1997 and 2003 (Competition Authority, 2010). On average, there are more male principals (1.2) than female principles (0.7) per practice (Table 5.9). [68]

Respondents were asked to specify how many GPs in their practice are in four age categories. The majority of general practices comprise of GPs within the 30-59 age categories, with a slightly higher percentage in the 30-40 age category (78 per cent) compared to the 40-49 (73 per cent) and 50-59 (73 per cent) age categories (Table 3.9). Approximately, 11 per cent of general practices include GPs of less than 30 years of age. One-third of general practices include GPs of more than 60 years of age.

31 per cent of general practices deem a city to be the main location of the practice, with 21 and 29 percent of general practices located in large and small towns respectively. 18 per cent of practices report the main location of their practice to be a village or rural location. 12 per cent of practices are in receipt of a rural practice allowance (Table 5.9). O'Dowd et al. (2006) also report that one in eight practices are in receipt of this allowance.

[68] A practice principal usually owns (or part-owns) the practice and holds the GMS contract in the practice

Table 5.9: Profile of General Practices

Variable Name	Observations	Percentage
Size of Practice & Year of Establishment		
GPs per practice (average number)	596	2.70
Solo Practitioner Practice	596	25.17%
2 GP Practice	596	29.1%
3 GP Practice	596	22.2%
4 GP Practice	596	11.5%
5+ GP Practice	596	11.9%
Public Patients (average number)	583	1399.32
Private Patients (average number)	564	2800.09
Year of Establishment (average number)	555	1984.28
Gender of GPs and Principals		
Male GPs per practice (average number)	600	1.40
Female GPs per practice (average number)	600	1.14
Male Principles per practice (average number)	595	1.20
Female Principles per practice (average number)	595	0.72
Male Dominated Practice	600	50.92%
Female Dominated Practice	600	30.28%
Gender Balance Practice	600	18.80%
Age of GPs		
Less than 30 years	597	10.64%
30-39 years	596	77.60%
40-49 years	597	72.86%
50-59 years	597	73.70%
60 years plus	597	35.18%
Location of Practice		
City	601	31.45%
Large Town	601	21.13%
Small Town	601	28.95%
Village/Rural	601	18.47%
Rural Practice Allowance	593	12.48%
Nursing and Administrative Support		
Nurse Support	597	80.74%
Clerical Support	593	87.35%
Managerial Support	595	53.78%
Administrative Support	601	91.35%
Professional & Academic Involvement		
Committee Member	597	41.21%
Academic Affiliation	590	37.80%
Research Project	597	23.62%
ICGP Course	592	31.25%
Additional Practice Characteristics		
Training Practice	595	29.08%
Dispensing Practice	561	7.13%
Primary Care Team	592	46.79%
Co-Location	273	20.51%
Practice holds clinic(s)	595	49.42%

In relation to support staff, 80 per cent of practices employ nursing support. 54 per cent of practices employ a practice manager. This is a significant increase from 2005 when approximately 30 per cent of practices employed a practice manager (O'Dowd et al., 2006). 87 per cent of practices employ clerical support. As some practices may employ either a clerical worker or a practice manager but not both, the administrative support variable captures whether a practice has administrative support in the form of either a clerical worker or a practice manager. 91 per cent of practices employ some form of administrative support (Table 5.9).

In the last three years, 41 per cent of respondents have been or are currently a committee member of a professional organisation, such as the ICGP or the Irish Medical Organisation (IMO). 38 per cent of respondents are affiliated with an academic department, with 24 per cent of respondents actively involved in research projects. While these figures for academic and research involvement are high, 44 per cent of recent graduates work at least one non-clinical session a week, undertaking teaching, research and continuing education; and 24 per cent of recent graduates combine general practice with another area of medicine, usually in the area of academic activity (O'Kelly et al., 2008). As is evident from Table 5.9, 31 per cent of respondents are completing or have completed an ICGP course or its equivalent in the last three years.

29 and 7 per cent of practices act as a training practice for postgraduate GP trainees and as a dispensing practice respectively. 49 per cent of practices hold at least one clinic, such as physiotherapy and dietetics. 46 per cent of practices surveyed

participate in a primary care team and, of those, one-fifth of practices are co-located with the primary care team (Table 5.9).

Within the sample, attendance at CME meetings is high, with 91 per cent of respondents attending six or more such meetings each year (see Table 5.10). Pharmaceutical representatives are frequent visitors, with 93 per cent of practices visited by pharmaceutical company representatives six or more times a year. In hindsight, it may have been more prudent to ask respondents how many times a month, or even a week, they see pharmaceutical representatives. Visits from suppliers of medical equipment and IT are less frequent, in fact, 55 and 41 per cent of practices report no visits from suppliers of medical equipment and IT equipment respectively (see Table 5.10).

Table 5.10: Frequency of Attendance at CME meetings and Supplier Visits

	Number of Responses	None	1 to 2	3 to 5	6 +
CME Meetings	601	8.49%	7.15%	30.45%	53.91%
Suppliers of Medical Equipment	589	55.01%	36.50%	7.30%	1.19%
Suppliers of IT Equipment	591	40.78%	36.55%	15.74%	6.94%
Drug Company Representatives	598	3.85%	0.84%	1.84%	93.48%

Finally, respondents were also asked how important they consider a number of different factors in informing their decision to prescribe a new drug for the first time. As is evident from Table 5.11, there is a wide distribution across most factors in terms of their influence on prescribing decisions. However, in general, other GPs and primary care workers, hospital consultants, conferences and/or CME meetings and journals are deemed more important than the internet and pharmaceutical company representatives in terms of influencing the decision to prescribe a new drug for the first time.

Table 5.11: Factors influencing the Decision to Prescribe a New Drug

	Not Important 1	2	3	4	Very Important 5	Total Responses
Other GPs/ Primary Care Workers	7.26%	11.36%	25.33%	34.45%	21.60%	537
Internet	54.25%	20.85%	16.22%	6.56%	2.12%	518
Hospital Consultants	3.29%	5.20%	25.30%	46.27%	19.93%	577
Drug Representatives	13.39%	25.22%	38.61%	17.57%	5.22%	575
Conferences/CME	3.42%	3.76%	18.46%	51.28%	23.08%	585
Journals	4.80%	7.20%	26.75%	43.36%	17.90%	542

It is worth mentioning that an ideal scenario would be to link this survey data to the prescribing dataset discussed in Chapters 3 and 4, which would enable many of the rank and epidemic effects variables collected in this primary data collection to be included in our prescribing analysis. However, this is not possible given the lack of identifiers common to both datasets.

5.6 Conclusion

This chapter describes the design and administration of the *Medical Equipment and IT in General Practice* questionnaire. Completed questionnaires were received from

601 general practices, and a description of the survey data is presented in the previous section.

We estimate that our sample size of 601 represents about one-third of the general practice population (Wren, 2003). As discussed in Section 5.4.3, our sample of 601 is also reasonably representative by HSE region. We also compare our survey characteristics with population characteristics for Irish GPs and general practices, obtained from a number of different sources, to further illustrate the representativeness of our survey sample (see Table 5.12).

From our survey data, it is possible to form a view of what constitutes a 'typical' general practice in Ireland in 2010 from the survey data. Such a practice comprises of 2½ GPs, one of which is female, within the age bracket of 30-59. An urban practice with nursing and administrative support, it serves over 4,000 patients, a third of which are public patients. The practice is well equipped with medical equipment, and uses a broad range of administrative and patient care ICT applications. Pharmaceutical representatives regularly visit the practice; whereas the practice is rarely visited by IT suppliers and never by suppliers of medical equipment.

The *Medical Equipment and IT in General Practice* survey data is employed in the analysis of the use of medical equipment and intensity of ICT use in Irish general practice in Chapters 6 and 7 respectively.

Table 5.12: Representativeness of Survey Sample

	Survey Characteristics	Population Characteristics
Rural Practice Allowance	One in eight general practices are in receipt of a rural practice allowance.	This is in line with ICGP estimates (O'Dowd et al., 2006) and our GP characteristics database described in Chapter 3.
Gender	With respect to practice composition, the breakdown between male and female GPs is 55 to 45 per cent (1.40 male FTE/1.14 female FTE).	According to recent ICGP data, approximately 40 per cent of GPs are female (ICGP, 2008).
Age Profile of GPs	The majority of GPs in the practices surveyed are between the ages of 30 to 59.	O'Dowd et al. (2006) report that most GPs are between the ages of 35 and 60 years of age.
Academic Affiliation & Research Involvement	A high proportion of respondents to our survey indicate an academic affiliation (38%) and involvement in a research project (24%)	A recent report finds that 44 per cent of recent graduates work are involved in teaching, research and continuing education, and 24 per cent of recent graduates combine general practice with some element of academic activity (O'Kelly et al., 2008).
Solo-Practitioner Practices	One in four practice are solo-practitioner practices	O'Dowd et al. (2006) reported that, in 2005, approximately one in three practices were solo-practitioner practices. However, a key change in general practice is a move away from solo-practitioner to multi-partner practices (Competition Authority, 2010; Thomas and Layte, 2009), as proposed by the Primary Care Strategy (Department of Health and Children, 2001). Therefore, we would expect to see a decline in the proportion of such practices since 2005.
Public (GMS) Patients	53 per cent of practices have between 500 and 1500 public patients	In 2005, 57 per cent of practices had between 500 and 1500 public patients.

CHAPTER 6: USE OF MEDICAL EQUIPMENT IN IRISH GENERAL PRACTICES

6.1 Introduction

In our exploration of innovative behaviour in general practices in Ireland, our overall objective is to explain the adoption, use and intensity of use of innovations by GPs. In chapter 4, we determine the influence of practice heterogeneity (rank effects), strategic behaviour (stock and order effects), experience from previous adoption decisions (learning-by-using effects), and learning and knowledge spillovers (epidemic effects) on the timing of first prescription of new drugs by Irish GPs. Using the *Medical Equipment and IT in General Practice* survey data described in Chapter 3, this chapter addresses our second research question: what influences the use of medical equipment in Irish general practices?

In previous chapters, particular aspects of the Irish general practice environment have been described in detail, such as the prescribing autonomy of Irish GPs. However, an additional important characteristic of general practice in Ireland is the strong gate-keeper role of Irish GPs. In fact, along with Denmark, the Netherlands and the UK, Ireland is identified as one of the European countries where GPs are predominately the first point of contact with health care services (Boerma and Dubois, 2006). Therefore, Irish GPs provide a comprehensive mix of services, in fact, to a greater extent than many of their European counterparts (Boerma and Dubois, 2006). Consequently, general practices in Ireland require a broad range and mix of medical equipment to provide these services. In the mid-1990's, a survey of European GPs asked them to indicate, from a list of 25 types of medical equipment, whether their practice used such equipment. Ireland was included in the second highest group in terms of GPs' range of medical equipment (Boerma and Dubois, 2006). As discussed in Chapter 5, a high proportion of general practices surveyed use the items of medical equipment examined in our survey.[69] There is also evidence that, since 2005, increasingly more practices are investing in medical equipment (O'Dowd et al., 2006; Bourke and Bradley, 2010). However, as outlined in Chapter 5, there still remains variation across general practices in terms of their uptake of medical equipment.

Along with the discretion which Irish GPs have concerning the nature and location of their practice, they also have considerable autonomy in terms of how they equip and staff their practices. The commercial autonomy which characterise Irish general practice suggests that decisions to invest in medical equipment may reflect both medical and commercial factors. Acquiring new medical technologies may enable GPs to provide more effective treatment to their patients, but may also influence their attractiveness to mobile and commercially valuable private and public patients. These distinguishing characteristics of Irish general practice, as well as our empirical findings presented in Chapter 4, validate the extension of our encompassing equilibrium, disequilibrium and learning-by-using theoretical model to an examination of what influences the use of medical equipment.

[69] Dexas-scanning equipment being the exception, with only 12 practices investing in this equipment.

This study is the first to examine the adoption of multiple medical technologies by small health care practices. The empirical approach is to apply multivariate Probit analysis to a group of medical technologies to try to identify commonalities in the determinants of the probability of use of such equipment. Primary data, through a self-administered postal questionnaire, was collected, which provides us with information relating to practice characteristics and medical equipment for a sample of 601 general practices in Ireland. This survey data is discussed in detail in Chapter 5.

The rest of the chapter is organised as follows. Section 6.2 briefly revisits the main influences on adoption decision-making, as discussed in detail in Chapter 2. This section also discusses previous empirical studies of adoption and use of medical equipment by GPs, as well as emphasising the potential for informational, commercial, strategic and learning-by-using influences on the adoption of medical equipment by general practices. Section 6.3 describes our primary data source, presents diffusion curves for the items of medical equipment examined, and outlines our econometric approach. Section 6.4 presents and discusses the econometric results, and Section 6.5 concludes this chapter.

6.2 Theoretical & Empirical Research on Adoption and Use of Technologies & Medical Equipment

Our unit of analysis here is the general practice, and our focus is on the factors which influence the use of medical equipment by general practices. The medical equipment being examined comprises of ECG machines, 24 hour blood pressure monitors, spirometers, cryotherarpy equipment, minor surgery equipment, and foetal monitors.[70] This section will briefly revisit the theoretical models of adoption, and discuss previous empirical research on the adoption and use of technologies and medical equipment by firms and general practices. We also justify the use of these models in relation to examining the use of medical equipment in general practices.

As discussed in Chapter 2, three complementary theoretical approaches have been used to explain the timing of innovation decisions.[71] Disequilibrium models reflect the learning and informational influences on timing of adoption (Rogers, 2003), whereas equilibrium models take account of how organisational characteristics and strategic interactions, specifically rank, stock and order effects, influence timing of adoption (Karshenas and Stoneman, 1993); and learning-by-using effects reflect cumulative learning experience from previous adoption decisions influencing timing of adoption (McWilliams and Zilbermanfr, 1996).

Previous studies have empirically tested the influence of rank, stock, order, epidemic and learning-by-using effects on the adoption of new technologies (Karshenas and Stoneman, 1993; McWilliams and Zilbermanfr, 1996; Baptista, 1999; Battisti and Stoneman, 2005). These studies are discussed in Chapter 2. However it is useful to briefly recall their findings in the context of this empirical chapter. There is substantial evidence of rank effects influencing timing of adoption of new technologies. Specifically there is evidence that firm size, R&D investment and human capital positively influence the adoption of new technologies (Karshenas and Stoneman, 1993; Baptista, 2000; Battisti et al., 2007). There is some evidence of

[70] These six technologies were identified following a literature review and expert interviews (see Chapter 5). A description of each item of medical equipment is provided in Section 5.2.
[71] See Table 2.1 for a summary of the influences on timing of adoption.

stock and order effects influencing adoption of new technology, particularly in relation to adoption of multiple technologies (Karshenas and Stoneman, 1993; Baptista, 2000). Specifically, Stoneman and Kwon (1994) find evidence of both stock and order effects, although greater support for order effects, in relation to the adoption of complementary technologies. Stoneman and Toivanen (1997), in an examination of multiple technology adoption, find mixed evidence of stock effects and no evidence of order effects.[72]

There is a substantial diffusion and adoption literature which highlight the influence of epidemic learning effects on the adoption of new innovations (Hall and Khan, 2003; Rogers, 2003). Many studies examined the influence of equilibrium effects on the adoption of new technologies, simultaneously test for the influence of epidemic effects. There is considerable empirical evidence of epidemic learning effects positively influencing the adoption of new technologies (Karshenas and Stoneman, 1993; Stoneman and Kwon, 1994; Stoneman and Toivanen, 1997; Baptista, 2000; Burton et al., 2003). Likewise, there is empirical evidence of learning-by-using effects, i.e. learning from previous adoption decisions, influencing adoption of new technologies (Stoneman and Kwon, 1994; Colombo and Mosconi, 1995; McWilliams and Zilbermanfr, 1996; Stoneman and Toivanen, 1997; Arvantis and Hollenstein, 2001).

To reiterate, empirical studies report evidence of equilibrium, disequilibrium and learning-by-using effects influencing the adoption of new technology. Previous

[72] Stoneman and Kwon (1994) examined the adoption of numerically controlled machine tools and coated carbide tools, two complementary goods, in the UK. Stoneman and Toivanen (1997) also examined the adoption of these two technologies, in addition to computer numerically controlled machine tools, computers and microprocessors, in the UK.

studies examining the adoption of medical equipment by general practices have not used these theoretical influences on adoption as a conceptual framework for their empirical analyses (Bosanquet and Leese, 1988; Baker and Thompson, 1995; Leese and Bosanquet, 1995; Boerma et al., 1998; O'Dowd et al., 2006; Nic Gabhainn et al., 2001; Ni Shuilleabhain et al., 2007). In fact, previous studies are distinctly atheoretical. Nonetheless, empirical studies have reported how GP and practice characteristics, which are identified as rank effects in the equilibrium models, have influenced a practice's portfolio of medical equipment. There is also evidence that practice location and whether the practice is a training practice, factors generally identified as epidemic or learning effects in the disequilibrium models, impact on the adoption of medical equipment. These studies are discussed below.

A study of UK GPs outlines how practice characteristics can influence 'innovative' behaviour (Bosanquet and Leese, 1988). Bosanquet and Leese (1988) subdivided practices as innovative, traditional or intermediate, according to whether they employed a nurse and participated in the cost rent scheme and the vocational training scheme. Practices were defined as being innovative if they fulfilled at least two of these criteria, traditional if they fulfilled none, and the remainder were classified as intermediate. Bosanquet and Leese (1988) report that innovation is related to the size of the practice. Practices with four or more partners were more likely to be innovative than those with fewer partners. Innovative practices were more common in partnerships with a younger partner average age. Innovative practices were also much more likely to employ practice managers. GPs in the innovative practices were also more likely to have further qualifications and to be members of professional bodies. This study was not conducted within the framework of the equilibrium model of adoption; however it identifies practice characteristics, which could be considered rank effects, as impacting on innovative behaviour in general practice. However, it must be observed that this study reported no statistical analysis, and merely presented the study's findings in cross-tabulations.

In a study of 30 European countries, Boerma et al. (1998) report that the availability of medical equipment and ancillary staff are positively related, with practices with nursing and administrative support more likely to obtain medical equipment. Boerma et al. (1998) found that the proportion of GPs working in solo practices was greater in rural practices in all 30 countries. Leese and Bosanquet (1995) report that in the UK in the mid-1990s fewer singlehanded GPs employed a practice nurse than group practices. Both these studies highlight evidence of rank effects (support staff and practice size) impacting directly and indirectly on the use of medical equipment. However, neither study is testing the equilibrium model of adoption, nor conducting complex statistical analysis. Leese and Bosanquet (1995) use descriptive statistics and crosstabulations to identify differences between categories of general practices, and in Boerma et al. (1998) t-tests are used to determine if the differences reported between categories are significantly different.

While previous studies have not explicitly tested whether rank effects impact on general practices' adoption and use of medical equipment, there is evidence that practice characteristics, such as the number of GPs, the qualification and age mix of GPs in the practice and whether the practice employs nursing and administrative support, influence this decision (Bosanquet and Leese, 1988; Leese and Bosanquet, 1995; Boerma et al., 1998). There is also evidence that these practice characteristics may influence Irish GPs' willingness to embrace preventative programmes. A study examining attitudes of Irish GPs on screening for cervical cancer found that if a national prevention programme was introduced the majority of GPs would participate (McDonald et al., 2001). Those who were less likely to participate included those were in single-handed practice, aged over 44 years, with no ancillary staff, no computer and in rural practice.

Previous studies have not examined the adoption of medical equipment through the lens of the disequilibrium model of adoption. However, previous studies have examined the influence of practice location and interaction with external agents, factors which can be considered measures of epidemic effects, on adoption and use of medical equipment in general practice. These studies will now be discussed. A study examining the range of services provided by GPs in 30 European countries reports that the variation in services provided is not only related to personal characteristics and features of the country's health care system but also to practice location (Boerma et al., 1998). In relation to the range of services provided by GPs, Boerma et al. (1998) specifically examined procedure tasks (the application of minor surgery and medical techniques) and treatment tasks (the treatment and follow-up of diseases). Scores of procedure and treatment tasks were higher for rural GPs and those practicing furthest from the nearest hospital.

Boerma et al. (1998) report a higher availability of medical equipment in rural practices, and found that rural practices provided more comprehensive services regardless of the type of health care system. Boerma et al. (1998) state that GPs with an estimated overrepresentation of socially deprived people and elderly in the practice population provide a wider range of services. Nic Gabhainn et al. (2001) found that medical equipment, namely ECG machines, oxygen, defibrillator, minor surgery instruments, ambulatory blood pressure monitor, foetal Doppler, glucometer and cryosurgery equipment, was more frequently available in rural practices in Ireland. Smaller, more rural practices may be acquiring this equipment to recompense for less access to secondary care services (Ni Shuilleabhain et al., 2007), although there is evidence that rural practitioners report a higher level of contact with hospital services (Nic Gabhainn et al., 2001). Nic Gabhainn et al. (2001) report that rural GPs, in comparison with their urban counterparts, work longer hours, have more socio-economically deprived patients, and participate more in, and depend financially to a greater extent on, the public health system. Nic Gabhainn et al. (2001) stress that their study cannot describe the quality of care provided by this equipment. It is also worth noting that analyses consisted of descriptive statistics and t-tests.

Baker and Thompson (1995) examined whether training practices in the UK developed faster than non-training practices between 1982 and 1990. They found that training practices were more likely to develop than non-training practices in relation to personnel, aspects of practice organisation, educational activities, clinical activities and equipment. Baker and Thompson (1995) put forward three reasons that may explain the different rates of innovation among the two practice groups. Firstly, the doctors and staff in training practices may be inherently more innovative. Secondly, they may face fewer obstacles to the introduction of innovations. Finally, the accreditation procedure that training practices undertake may serve as a stimulus for innovation. Whether a practice engages in training or not may be considered a proxy for learning or epidemic effects, and therefore Baker and Thompson's (1995) findings may suggest evidence of epidemic effects in the adoption of medical equipment. However, it is must be noted that Baker and Thompson (1995) conducted logistic regression analysis on a relatively small sample of 124 practices.

The studies discussed above do not explicitly test the disequilibrium model of adoption, we can deduce that their findings, in relation to practice location and training practices, suggests the likelihood of an epidemic effect influencing use of medical equipment (Baker and Thompson, 1995; Boerma et al., 1998; Nic Gabhainn et al., 2001). Previous research reports that rural practices have a wider portfolio of medical equipment. Therefore, better equipped rural practices suggest a negative epidemic effect. However, the positive influence of training practices on innovative behaviour emphasises the potential importance of informational effects. Our survey data includes a number of measures of informational effects which will allow us to empirically test the use of medical equipment in Irish general practices within the disequilibrium model of adoption framework.

In addition to disequilibrium influences on use of medical equipment, the commercial autonomy of Irish GPs suggests the potential for equilibrium influences on the adoption of medical equipment. In Chapter 4, our findings support the application of the equilibrium model of adoption to an examination of timing of prescribing innovation. As discussed previously, GPs are self-employed professionals, who engage in service commitments with the HSE to provide care and treatment to public patients and provide services directly to private patients. They have considerable autonomy concerning where they set up practice, who they employ and any additional services they provide (Caulfield, 2001; Wren, 2003; Department of Health and Children, 2001; Thomas and Layte, 2009). A European study reports that in countries where GPs are largely self-employed they have greater involvement in disease management and in applying medical techniques than in those countries where they are employees (Boerma et al., 1997). Boerma et al. (1997) suggest that this independence may encourage doctors to develop services in addition to those basic to general practice. Therefore, we would expect practice characteristics to influence the decision to obtain medical equipment.

Given the commercial autonomy of general practice in Ireland, it also seems appropriate to test whether stock and order effects impact on the decision-making concerning practice development. In Chapter 4, we find that strategic behaviour, measured as stock and order effects, strongly and consistently influences first prescription of new drugs. In line with these findings and given that the costs incurred from medical equipment investments are borne by the practice, we expect that stock and order effects influence use of medical equipment. Unfortunately, due to the nature of our survey data, we do not model stock effects.[73] However, we include order effects in our empirical analysis, that is, we examine whether adopting medical equipment later in the adoption order adversely impacts on the benefit from adoption.

There is a distinct lack of literature in relation to learning-by-using effects from other innovations within health care organisations. Nonetheless, given the strong evidence of such effects within other industries and sectors (Stoneman and Kwon, 1994;

[73] In Section 6.3.1, the difficulties with constructing a stock effects variable are discussed.

Colombo and Mosconi, 1995; McWilliams and Zilbermanfr, 1996; Stoneman and Toivanen, 1997; Arvantis and Hollenstein, 2001), we expect cumulative learning-by-using to positively influence use of medical equipment. In fact, Colombo and Mocsoni (1995), in their examination of adoption patterns within the Italian metalworking industry, highlighted that technological interdependencies and cumulative learning-by-using effects are important determinants of firms' adoption decisions. Colombo and Mosconi (1995) concluded that "interactions among different innovations and learning-by-using effects arising from experience with previously available technologies are a pervasive phenomena that significantly shape the pace and direction of technical change".

6.3 Data and Methods

Section 6.3.1 identifies the six items of medical equipment to be included in our empirical analysis, and presents diffusion curves graphically depicting the uptake of these items of medical equipment by general practices over time. Our empirical analysis is based on survey data, collected through a self-administered postal questionnaire - *Medical Equipment and IT in General Practice*- distributed to all general practices in Ireland in February and March 2010. The survey data is discussed in detail in Chapter 5.[74] Nonetheless, a description of the survey data employed in this empirical analysis is presented in Section 6.3.1. Section 6.3.2 describes the econometric analysis employed to address our research question.

[74] Chapter 5 describes the survey questions used to measure use of medical equipment in general practices, and provides a detailed description of the data obtained.

6.3.1 Description of Survey Data

As discussed in Chapter 5, the following items of medical equipment were identified for inclusion in the *Medical Equipment and IT in General Practice* questionnaire. Respondents were asked if they have the following medical equipment: ECG machine, 24 hour blood pressure monitor, spirometers, cryotherapy equipment, minor surgery equipment, and foetal monitors; and the year in which it was obtained.[75] These items of medical equipment were chosen to include in our examination of what influences the use of medical equipment in Irish general practices, and were identified from previous surveys and literature and also from interviews with Prof. Bradley and Dr. Ryan. Both Prof. Bradley and Dr. Ryan advised that these six items of medical equipment would be widely available and used in general practices in Ireland, although they expected variation in use across practices. This expectation was realised when our questionnaires were returned with high proportions of general practices confirming that their portfolios of medical equipment included these six items of medical equipment (see Table 6.1). Consideration was also given to the fact that these six items of equipment are used to diagnose, monitor and treat different therapeutic conditions and their inclusion in the analysis should eliminate any potential inter-relationships between adoption patterns which might stem from individual GPs having a particular interest in a certain therapeutic area or medical condition.

Table 6.1 briefly summarises the adoption patterns in relation to these six items of medical equipment: the year the equipment was first adopted by a practice in our sample, the average year the equipment was adopted across all 601 general practices

[75] A description of these items of medical equipment is presented in Chapter 5. Dexas-scanning equipment was also included in the questionnaire. However, only twelve practices had adopted this equipment, so it is not included in the analysis.

examined, and the percentage of users in 2010. Our survey results clearly indicate that by 2010 a high proportion of Irish general practices use a wide range of medical equipment: 83 per cent of practices have ECG machines, 80 per cent have 24 hour blood pressure monitors, 63 per cent have spirometers, 84 per cent have cryotherapy equipment, 76 per cent have minor surgery equipment, and 81 per cent have foetal monitors (Table 6.1).

Table 6.1: Medical Equipment Adoption Patterns

Medical Equipment	**Year of First Adoption**	**Average Year of Adoption**	**% of Users in 2010**
ECG Machine	1964	1997	82.86%
24Hr Blood Pressure Monitor	1986	2003	79.53%
Spirometer	1977	2002	63.39%
Cyrotherapy Equipment	1980	1998	84.03%
Minor Surgery Equipment	1960	1994	75.71%
Foetal Monitor Equipment	1965	2004	80.87%

However, there is clear variation with respect to initial adoption and the year most practices adopted these six items of medical equipment (Table 6.1). It is generally accepted that the contribution of new technology to economic welfare is only realised when and if the new technology is widely diffused and used. Diffusion results from a series of individual decisions to begin using the new technology, i.e. to adopt the new technology (Hall and Khan, 2003). Given the nature of our survey data, we are able to derive diffusion curves for our sample of general practices, which are presented in Figures 6.1a-f. Diffusion curves and what they represent is briefly revisited and described below.

As discussed in Chapter 2, the epidemic models of adoption generally assume that a potential user will adopt a new technology upon learning of its existence. Rogers (2003) found that when the number of adopters of a new product or technology is plotted on a cumulative frequency basis over time, the resulting distribution is an S-shaped curve. Stoneman (1983), examining adoption within the equilibrium model, also states "if one can explain the date of adoption by individual firms, then by aggregation one should have the inter-firm or intrasectoral diffusion curve". These 'diffusion curves' generally follow an S-shaped pattern, whether examining the adoption of agricultural innovations, a new prescription drug or public health initiatives (Rogers, 2003). At first, only a few individuals/households adopt the innovation in each time period. Soon the diffusion curve begins to climb, as more and more entities adopt the innovation in each succeeding time period. Eventually, the trajectory of the curve begins to level off, as fewer and fewer entities remain who have not adopted the innovation. Given that our survey asked respondents the year they adopted each of the six technologies examined, we can also derive diffusion curves for our sample. Rogers' (2003) S-shaped curve is evident in the diffusion curves depicting the level of adoption of the six types of medical equipment among the sample of general practices over time (Figure 6.1a-f).

Figure 6.1a: Proportion of General Practices with ECG Machines

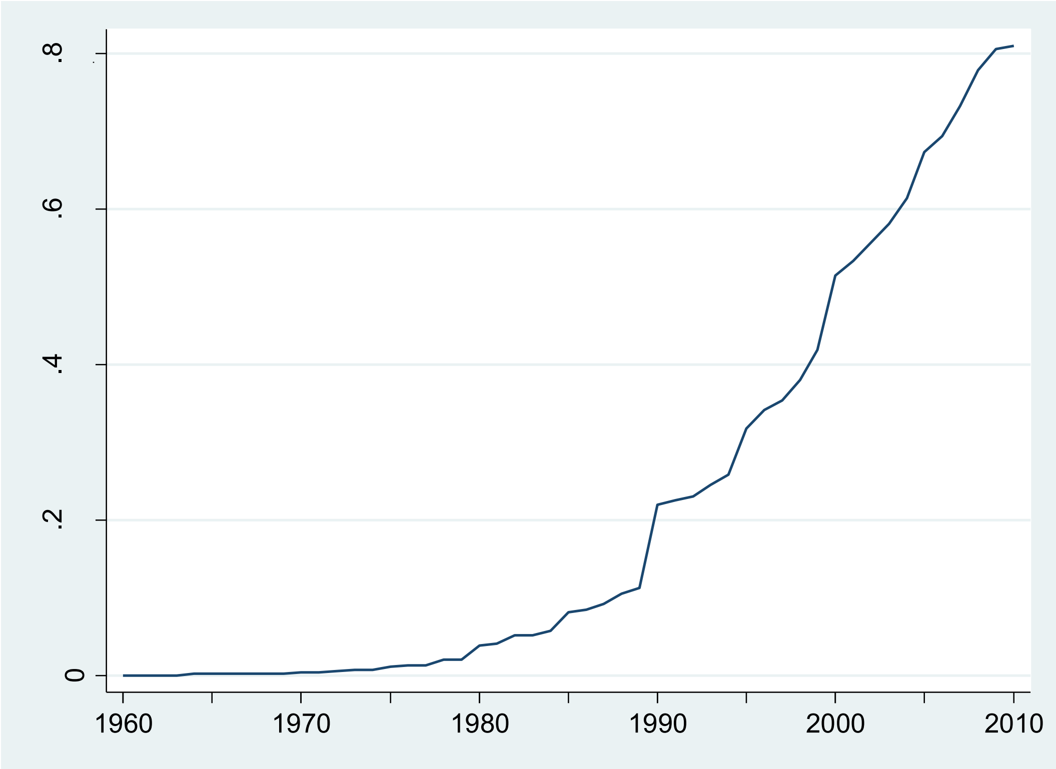


Figure 6.1b: Proportion of General Practices with 24Hr BP Monitors

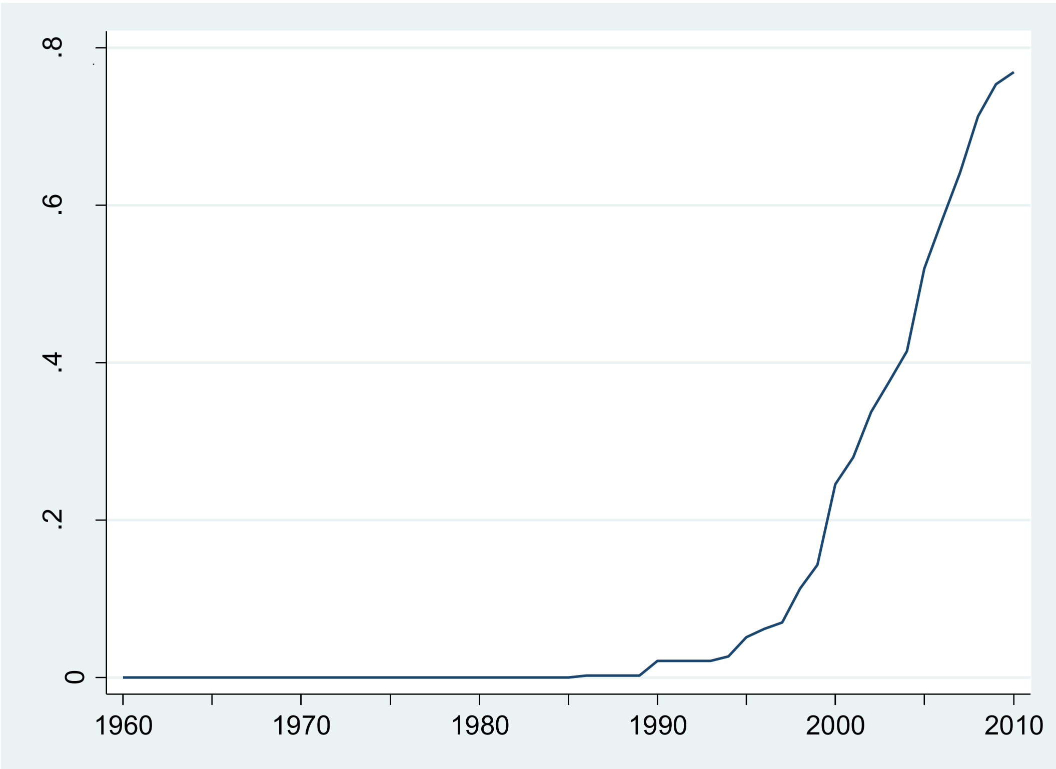


Figure 6.1c: Proportion of General Practices with Spirometers

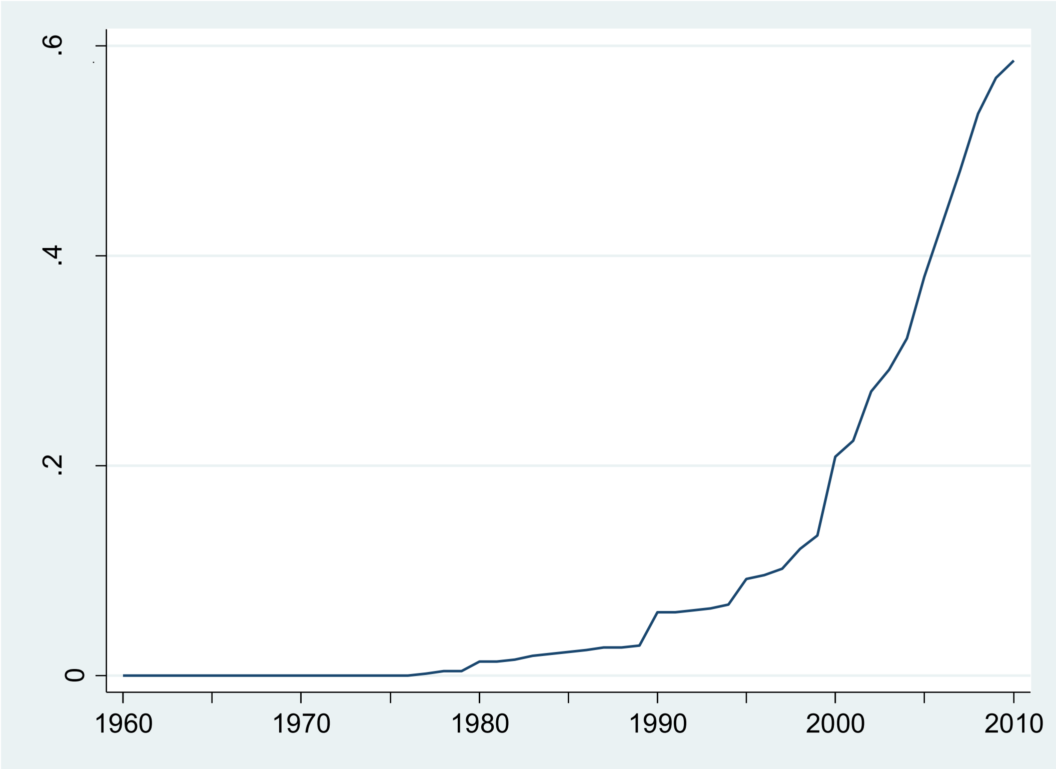


Figure 6.1d: Proportion of General Practices with Cryotherapy Equipment

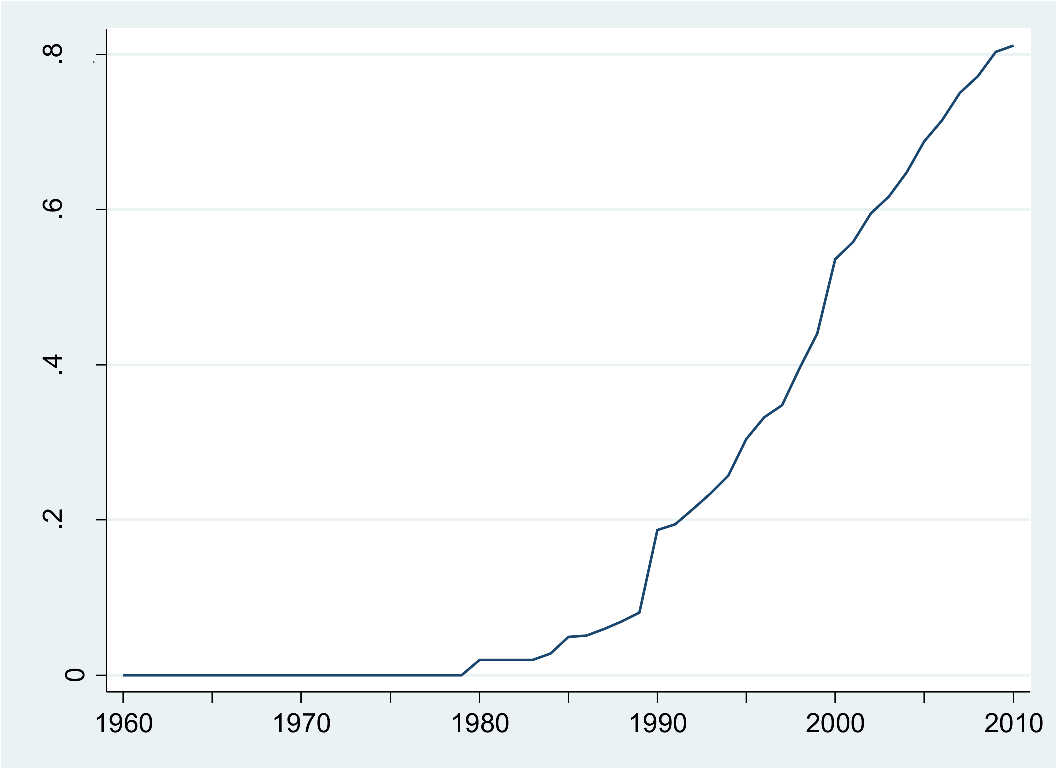


Figure 6.1e: Proportion of General Practices with Minor Surgery Equipment

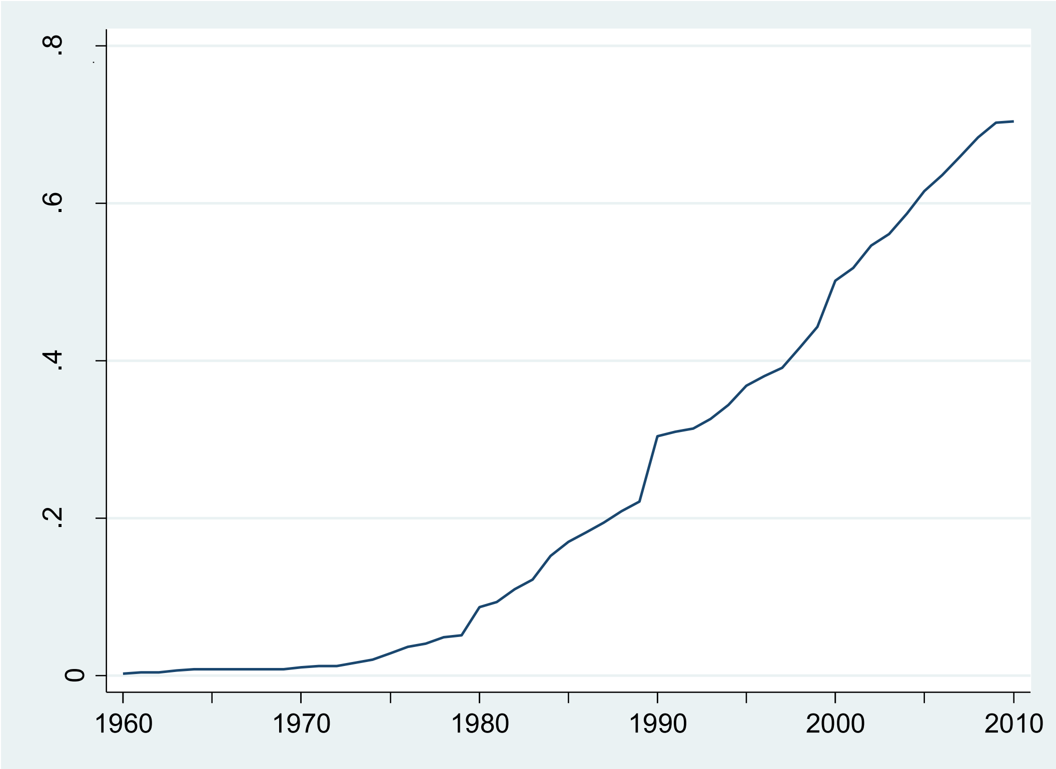
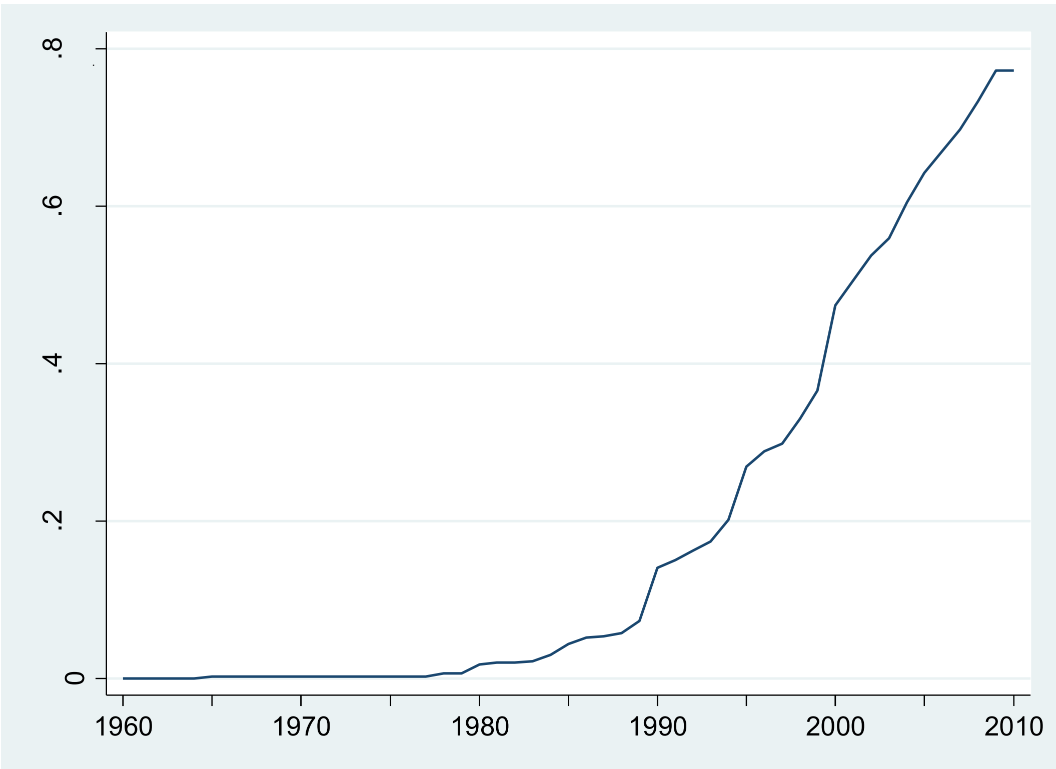


Figure 6.1f: Proportion of General Practices with Foetal Monitors



To elucidate, a description of the diffusion curve illustrating the uptake of ECG machines is described. As previously established from Table 6.1, ECG machines were first adopted in 1964. As illustrated in Figure 6.1a, take-up of ECG machines was initially slow among practices, with less than 10 per cent of practices adopting ECG machines in the first 20 years of their adoption. However, by 2000, approximately 50 per cent of the practices examined had adopted ECG machines, with adoption of ECG machines increasing to more than 80 per cent by the end of the time period. There is also some evidence of a levelling-off of the diffusion curve in the last two years of the time period. The diffusion curves for the 24hr blood pressure monitor (Figure 6.1b), the spirometer (Figure 6.1c), cryotherapy equipment (Figure 6.1d), minor surgery equipment (Figure 6.1e) and foetal monitor equipment (Figure 6.1f) depict similar patterns, with low levels of adoption initially, followed by a 'take-off' in adoption rates, and eventually a levelling off as fewer non-adopter practices remain.[76]

As previously discussed, general practices bear the monetary cost of acquiring medical equipment. While there may be variation in the prices of individual items of equipment as well as variation in price due to the timing of adoption of the equipment, we assume that the monetary cost of purchasing the equipment is constant across practices. However, it is important to note that the cost of acquiring these six items of medical equipment can vary across the range of items of medical equipment, with the cost of purchasing equipment such as 24hr blood pressure monitors being greater relative to equipment such as minor surgery kits. Therefore,

[76] In these graphs, there appears to be an increase in the adoption of all six items of medical equipment around 1990. This is a result of the data collection process. A number of respondents provide answers such as 'circa. 1990' or '20 years ago' when asked the year their practice obtained each item of equipment.

the uptake of an item of medical equipment is likely to be influenced by the monetary cost to the practice of acquiring that equipment. The purpose of this analysis is to identify commonalties in the use of medical equipment. However, given the range of medical equipment being examined, we also consider how the cost of these individual items of medical equipment may influence uptake in the interpretation of our econometric results, particularly in relation to factors such as practice size.

The diffusion curves in Figure 6.1 clearly depict a similar adoption pattern across all six items of medical equipment, in line with Rogers' S-shaped diffusion curve (Rogers, 2003). In Chapter 4, the diffusion curves illustrating GPs adoption of six new prescription drugs also demonstrate a similar pattern. In Chapter 4, we explore the factors which shape the timing of the first prescription of six new drugs by GPs. Our analysis is based on a dataset which matches prescription data with survey data on GP characteristics. The survey data allows us to match GP characteristics collected in 2001, the midpoint of the 54 month panel data, with prescribing patterns. However, the practice characteristics obtained in the *Medical Equipment and IT in General Practice* survey relate to the practice in 2010 and may vary substantially from the date the equipment was obtained. As a result, dynamic analysis of the adoption of medical equipment is ill-advised. A cross-sectional analysis of the determinants of the use of medical equipment by general practices is considered more appropriate.

Empirically, we will examine the determinants of the probability of a practice obtaining these six items of medical equipment. Dummy variables are used for the six dependent variables, which take a value of one if the general practice has the medical equipment. These binary dependent variables are necessary as multivariate Probit analysis is employed to estimate the probability of a practice adopting these six items of medical equipment. The rationale for choosing this technique is discussed in detail in Section 6.3. As is evident from Table 6.2, these six dependent variables are positively related to each other, although the relationship is generally weak in magnitude.

Table 6.2: Correlation Matrix of Equipment Use

	ECG	24Hr BPM	Spirometer	Cryotherapy Equipment	Minor Surgery	Foetal Monitor
ECG	1.0000					
24Hr BPM	0.3712	1.0000				
Spirometer	0.3052	0.3251	1.0000			
Cryotherapy Equipment	0.2476	0.1953	0.1967	1.0000		
Minor Surgery	0.3087	0.2127	0.1978	0.3355	1.0000	
Foetal Monitor	0.1604	0.1726	0.1221	0.1805	0.1880	1.0000

Next, the explanatory variables, in the context of equilibrium, learning-by-using and disequilibrium models, are discussed. In the equilibrium model of adoption tradition, rank effects are measured by a number of variables as outlined in Table 6.3. On average there are 2.7 GPs per practice. The average number of patients is 4218, and on average 37 per cent of those patients are public patients. Nursing and administrative support are reported in 81 and 91 per cent of practices respectively. We also include the GP age and gender profile of the practice. Two dummy variables were created; the first which takes a value of one if all GPs in the practice are 40 years of age or older, and the second which takes a value of one if there are more male than female GPs in the practice. In 25 per cent of practices, all GPs are 40 years or older. In 51 per cent of practices, there are more male than female GPs. These variables are included to capture practices' heterogeneity which have been identified as one of the key drivers in explaining technology adoption decisions (Karshenas and Stoneman, 1993; Bosanquet and Leese, 1988; Boerma et al., 1998). In our analysis of prescribing new drugs, we found that nursing and secretarial support, as well as a GPs' increasing age, positively influenced the decision to prescribe a new drug for the first time (Chapter 4). Therefore, we expect these rank effect variables to positively influence the use of medical equipment in general practices. There is also evidence that practices with large patient numbers are more extensive users of new drugs (Tamblyn et al., 2003), so it is likely that practices with large patient numbers will positively influence use of medical equipment. In general, investments in practice development are borne by the practice, therefore, it is also likely that practices with more GPs have a greater capacity to invest in medical equipment. Table 6.4 provides a symbolic summary of our anticipated results.

Table 6.3: Descriptive Statistics of Explanatory Variables

Variable Name	N	Mean	St. Dev.
Rank Effects			
Number of GPs	596	2.701	1.667
Log of Patients	559	8.072	0.749
Public Patients/ Total Patients	559	0.375	0.201
Nursing Support	597	0.807	0.395
Administrative Support	601	0.914	0.281
Age >40	601	0.250	0.433
Male Dominated	601	0.509	0.500
Learning-by-using Effects			
Portfolio	601	0.899	0.302
Order Effects			
Order ex. ECG	601	0.306	0.461
Order ex. BPM	601	0.293	0.455
Order ex. Spirometer	601	0.311	0.463
Order ex. Cryotherapy	601	0.293	0.455
Order ex. Minor Surgery	601	0.300	0.458
Order ex. Foetal Monitor	601	0.301	0.460
Epidemic Effects			
Rural	601	0.185	0.388
Town	601	0.501	0.500
City	601	0.315	0.465
HSE Dublin Mid-Leinster	600	0.235	0.424
HSE Dublin North East	600	0.152	0.359
HSE South	600	0.352	0.478
HSE West	600	0.262	0.440
Training Practice	595	0.291	0.455
Clinic	601	0.494	0.500
Supplier Visits = 0	589	0.408	0.492
Supplier Visits = 1.5	589	0.366	0.482
Supplier Visits = 4	589	0.157	0.364
Supplier Visits = 7	589	0.039	0.194
Supplier Visits = 10	589	0.031	0.172
Committee Member	597	0.412	0.493
Academic Department	590	0.378	0.485
Research Project	597	0.236	0.425
ICGP Course	592	0.313	0.464
CME Meetings = 0	601	0.085	0.279
CME Meetings = 1.5	601	0.072	0.258
CME Meetings = 4	601	0.305	0.461
CME Meetings =7	601	0.539	0.499

Note: The Supplier Visits variable consists of 5 numeric categories, which represent midpoints of ordered categories: 0, 1.5, 4, 7 and 10. The CME Meetings variable consists of 4 numeric categories which represent midpoints of ordered categories: 0, 1.5, 4 and 7. N differs due to item non-response.

Within the equilibrium model of adoption, strategic behaviour is measured by stock and order effects. As mentioned in the previous section, we do not model stock effects in this empirical study. Given the cross-sectional nature of our survey data, we are unable to construct a stock effects variable, which is a time-variant measure of the stock of previous adopters.[77] However, we are able to construct an order effects variable, as respondents provided the year their practice obtained each item of medical equipment.

Six order variables were constructed for each medical technology being examined. The order effects variable takes a value of one if a practice is a first-mover, i.e. in the first 16 per cent of adopters, in at least one of the other five items of medical equipment. Rogers (2003) identifies five adopter categories based on the relative speed at which an innovation is adopted by members of the social system: innovators, early adopters, early majority, late majority and laggards. When the rate of adoption is plotted along a normal distribution, the first 16 per cent of adopters are classified as innovators (2.5 per cent) and early adopters (13.5 per cent), and so for the purposes of this study, we deem the first 16 per cent of adopters as 'first-movers'. Across all six items of medical equipment, approximately 30 per cent of practices are 'first-movers' in at least one of the remaining five technologies.

Order effects capture strategic behaviour reflecting trade-offs between the costs and benefits of adoption by co-related agents. Previous studies report conflicting evidence in relation to order effects: some studies have found no evidence of order effects (Karshenas and Stoneman, 1993; Stoneman and Toivanen, 1997), some have

[77] In Chapter 4, in our panel prescribing dataset, the stock effects variables were time-variant. The survey data, which provided the GP characteristics, was collected in 2001 – the midpoint of our panel data.

found some evidence of such effects (Stoneman and Kwon, 1994; Baptista, 2000) and others have chosen not to include such variables in their models (Burton et al., 2003; Hollenstein, 2004). In view of the free-market elements of general practice in Ireland, in which practice development costs are borne by the practice, we expect evidence of strategic behaviour with respect to decision-making where GPs incur a monetary cost from adoption. Also, in relation to order effects and prescribing innovation, we find that GPs who are early adopters of at least one drug are early adopters of other drugs. Therefore, we can hypothesise it is probable that a positive relationship exists between order effects and use of medical equipment.

To model learning-by-using effects, a portfolio variable was created, which takes a value of 1 if the practice has adopted three or more of the six items of medical equipment. Ninety per cent of practices have adopted three or more of this range of medical equipment (Table 6.3). Previous theoretical and empirical studies have highlighted the impact of cross-technology effects and cumulative learning-by-using from other or previous technologies on technology adoption (Stoneman and Kwon, 1994; Colombo and Mosconi, 1995; McWilliams and Zilbermanfr, 1996; Arvantis and Hollenstein, 2001). In Chapter 4, learning-by-using effects are also examined. Slower adoption is found for GPs with narrower prescribing portfolios. This finding is strongly statistically significant and consistent across all six drugs examined. Therefore, we expect to find positive learning-by-using effects in relation to use of medical equipment.

Table 6.4: Symbolic Summary of Anticipated Effects on Medical Equipment Use

Rank Effects	
Number of GPs	+
Log of Patients	+
Prop. of Public Patients	+
Nursing Support	+
Admin Support	+
All GPs > 40	-
Male Dominated	+
Order Effects	
Order Effects	+
Learning-By-Using Effects	
Portfolio	+
Epidemic Learning Effects	
Town	+
Rural	-
HSE Dublin North East	+
HSE South	-
HSE West	-
Clinic	+
Training Practice	+
Supplier Visits	+
Committee Member	+
Academic Department	+
Research Project	+
ICGP Course	+
CME Meetings	+

Notes: '+' denotes a positive and significant effect on use of medical equipment, '-' denotes a negative and significant effect on use of medical equipment.

In the disequilibrium model of adoption tradition, epidemic effects are measured by practice location in terms of urban and rural classifications and HSE region. 31 per cent of practices are located in a city, 50 per cent in a town, and 19 per cent in a rural location. 24 and 15 per cent of practices are located in the HSE Dublin Mid-Leinster and Dublin North East regions respectively, and 35 and 26 per cent of practices are located in the HSE South and HSE West regions respectively. Epidemic effects are also measured by whether the practice is a training practice or holds a clinic, and how often it is visited by suppliers of medical equipment. 29 per cent of practices are training practices and 49 per cent of practices hold a clinic delivered by a health care professional. 55 per cent of practices receive no visits from suppliers of medical equipment, 36 per cent receive 1.5 visits per year, and the remainder receive 4 or more visits a year.

Respondents were also asked if they are a committee member of a professional organisation, such as the ICGP or IMO, affiliated with an academic department, involved in research projects and have completed or are completing an ICGP course or its equivalent. 41 per cent of respondents are committee members, 38 per cent are affiliated with an academic department, 23 per cent are involved in research projects, and 31 per cent have completed or are completing an ICGP course or its' equivalent. Respondents were also asked how many CME meetings they attend each year. Eight per cent attend no CME meetings, seven per cent attend between one and two, 30 per cent attend between three and five, and 54 per cent attend six or more. These variables are also included to measure epidemic learning effects.

In line with previous studies, we expect epidemic effects to impact on the adoption of medical technologies (Baker and Thompson, 1995; Boerma et al., 1998; Nic Gabhainn et al., 2001). In line with previous studies it is more likely that rural practices will have the items of medical equipment examined (Boerma et al., 1998; Nic Gabhainn et al., 2001).[78] We also expect interaction with other health care professionals and suppliers of medical equipment and continuing education and research to positively influence medical equipment use.

6.3.2 Econometric Methodology for Multiple Technology Adoption

Previous econometric studies examining technology adoption have employed duration analysis (Stoneman and Kwon, 1994; Baptista, 2000).[79] Duration, or failure-time, analysis focuses on the factors which determine the probability that a household or a firm will adopt a new technology by a specific point in time, and also allows researchers to model the S-shaped diffusion curves discussed earlier. However, duration analysis requires panel data. As previously discussed, given the cross-sectional nature of our data, we focus on the determinants of the probability of a practice using these items of medical equipment, rather than time to adoption. McWilliams and Zilbermanfr (1996), also using cross-sectional survey data, attempt to overcome this constraint by employing a tobit model. In their study, the dependent variable takes a value of zero for non-adopters and a positive value, which is the number of years since first adoption, for the adopters. Their survey instrument determines the time of adoption of a new technology, if adopted, and both adopter and non-adopter characteristics. However, the implicit assumption of this approach is

[78] We find evidence of epidemic effects in relation to prescribing patterns, in that; rural practices are less likely to be early adopters of new drugs. However, we do not expect a similar relationship in relation to use of medical equipment, as there is substantial evidence in the literature that rural practices are often better equipped than their urban counterparts.
[79] In Chapter 4, we employ duration analysis to examine time to adoption of six prescription drugs.

that individual characteristics do not differ from when the technology was adopted and the present, when these characteristics are documented through the survey process. This raises questions about the direction of causality as adopter characteristics may change following the adoption of a new technology. Therefore, we do not employ such a technique as the adopter characteristics at time of adoption, in some cases decades prior to data collection, may differ fundamentally from the practice characteristics collected through the survey process in 2010. Therefore, we consider the adoption decision as a binary process whereby a practice chooses 'use' or 'non-use'. Probit models are an appropriate estimation methodology to investigate the effects of explanatory variables on dichotomous dependent variables (Greene, 2003).

A probit model is a binary choice model:

$$prob\ (Y_i = 1|X_i) = \int_{-\infty}^{X'\beta} \emptyset\,(t)\mathrm{d}t = \Phi(X_i'\beta) \qquad \text{[Eqn. 6.1]}$$

where the practice either adopts the medical equipment ($Y_i = 1$) or does not adopt the medical equipment ($Y_i = 0$) and the choice depends on a vector of independent variables (*X*). The standard normal distribution is notated as $\Phi(\cdot)$. The coefficients are estimated using the method of maximum likelihood.

Therefore, it would be possible to run six adoption regressions where the binary dependent variable (Y_i) takes a value of one if one particular type of medical equipment is adopted and zero if that specific medical equipment is not adopted. To illustrate, a Probit model is presented below specifically for the ECG machine adoption equation:

$$prob\ (Y_i = 1|X_i) = \int_{-\infty}^{X'\beta} \emptyset\,(t)\mathrm{d}t = \Phi(X_i'\beta) \qquad \text{[Eqn. 6.2]}$$

where the practice either adopts an ECG machine ($Y_i = 1$) or does not adopt an ECG machine ($Y_i = 0$) and the choice depends on a vector of independent variables (*X*).

However, suppose the random components of all six adoption equations are correlated. This means that potentially there are unobservable factors that influence the adoption of all six types of medical equipment. Hence, it is necessary to take into account the unobservable individual-specific heterogeneity in the estimation procedure in order to ensure consistent estimates of the coefficients (Greene, 2003).The general specification for a multivariate probit is:

$$\begin{aligned} y_1* &= \beta'_1\ x_1 + \varepsilon_1, \qquad y_1 = 1(y_1 *> 0) \\ y_2* &= \beta'_2\ x_2 + \varepsilon_2, \qquad y_2 = 1(y_2 *> 0) \\ &\dots \\ y_M* &= \beta'_M\ x_M + \varepsilon_M,\ y_M = 1(y_M *> 0) \end{aligned}$$

[Eqn. 4.3]

$$\begin{pmatrix} \varepsilon_1 \\ \varepsilon_2 \\ \dots \\ \varepsilon_M \end{pmatrix} \sim N_M \left[\begin{pmatrix} 0 \\ 0 \\ \dots \\ 0 \end{pmatrix}, \begin{pmatrix} 1 & \rho_{12} & \cdots & \rho_{1M} \\ \rho_{12} & 1 & \cdots & \rho_{2M} \\ \cdots & \cdots & \cdots & \cdots \\ \rho_{1M} & \rho_{2M} & \cdots & 1 \end{pmatrix} \right]$$

[Eqn. 4.4]

Therefore, given the likelihood that the random components of the six Probits suggested above are correlated, we model the use of these six items of medical equipment using a multivariate Probit analysis. The dependent variables in the multivariate probit model are:

y_1 = 1 if practice has an ECG machine, 0 otherwise.

y_2 = 1 if practice has a 24Hr blood pressure monitor, 0 otherwise.

y_3 = 1 if practice has a spirometer, 0 otherwise.

y_4 = 1 if practice has cryotherapy equipment, 0 otherwise.

y_5= 1 if practice has minor surgery equipment, 0 otherwise.

y_6 = 1 if practice has a foetal monitor, 0 otherwise.

This econometric technique allows for the extension of our encompassing theoretical model to an analysis of multiple technology adoption. Variables which measure the equilibrium, learning-by-using and disequilibrium effects, which have previously been discussed, form the independent variables in the multivariate Probit analysis. The coefficients are estimated using the Geweke-Hajivassilou Keane simulator for probabilities and a maximum simulated likelihood procedure.[80] The results of the multivariate Probit are presented in Section 6.4.

6.4 Econometric Results for Use of Medical Equipment

A multivariate Probit model is used to examine the probability of a general practice using six items of medical equipment: ECG machines, 24 hour blood pressure

[80] The Stata command 'mvprobit' is used to obtain the multivariate Probit regression.

monitors, spirometers, cryotherapy equipment, minor surgery equipment, and foetal monitors.[81] As discussed in Section 6.3.2, we adopt this econometric approach as we assume the random components of all six adoption equations are correlated. The variance covariance matrix presented in Table 6.5 provides justification for this approach, as the statistically significant covariance coefficients illustrate that these dependent variables vary together. The multivariate Probit regression results are presented in Table 6.6. In interpreting the multivariate Probit estimates, we are restricted to interpreting the sign and significance of the coefficients (Greene, 2003). The overall model is statistically significant.

Table 6.5: Variance Covariance Matrix

	ECG	**24Hr BPM**	**Spirometer**	**Cryotherapy Equipment**	**Minor Surgery**	**Foetal Monitor**
ECG	1	0.03	-0.03	-0.08	0.20*	0.26*
24 Hr BPM	0.03	1	0.26**	-0.37**	-0.34***	-0.13
Spirometer	-0.03	0.26**	1	-0.13	-0.03	0.00
Cryotherapy	-0.08	-0.37**	-0.13	1	0.35***	-0.08
Minor Surgery	0.20*	-0.34***	-0.03	0.35**	1	0.06
Foetal Monitor	0.26*	-0.13	0.00	-0.08	0.06	1

[81] Initially, six Probit models were estimated including all explanatory variables. Subsequently, in a 'stepwise' fashion, variables with z-statistics of less than |0.5| were excluded from the models. We tested the robustness of the preferred models by ensuring that the significant variables did not differ in terms of sign or significance from the initial models. The explanatory variables from the preferred Probit models are included in the multivariate Probit model. The baseline and preferred Probit models are presented in Appendices 5 and 6.

Table 6.6: Multivariate Probit of Medical Equipment Use

	ECG	24 Hr BPM	Spiro-meter	Cryo-therapy	Minor Surgery	Foetal Monitor
Equilibrium Effects – Rank Effects						
Number of GPs		0.280***	0.077	0.041	0.067	-0.064
		(0.088)	(0.066)	(0.080)	(0.070)	(0.063)
Log of Patients	0.261*	-0.195	0.291**	0.452***	-0.083	0.227
	(0.155)	(0.164)	(0.145)	(0.169)	(0.152)	(0.153)
Proportion of Public Patients	0.935*	0.715	0.479	0.418	-0.792**	0.302
	(0.498)	(0.435)	(0.376)	(0.431)	(0.404)	(0.394)
Nursing Support	0.465**	1.033***	0.274	-0.505**	0.331	0.113
	(0.226)	(0.204)	(0.192)	(0.240)	(0.203)	(0.205)
Administrative Support			-0.428	0.11	0.339	0.327
			(0.276)	(0.288)	(0.266)	(0.261)
All GPs > 40	0.22				-0.175	-0.222
	(0.224)				(0.190)	(0.190)
Male Dominated	0.382**	-0.059	0.292**	-0.263	0.383**	-0.186
	(0.188)	(0.164)	(0.133)	(0.163)	(0.151)	(0.146)
Equilibrium Effects – Order Effects						
Order	0.318	0.135	0.426***	0.223	0.239	-0.239
	(0.209)	(0.179)	(0.141)	(0.186)	(0.160)	(0.155)
Learning-By-Using Effects						
Portfolio	1.908***	1.407***	1.567***	1.503***	1.516***	1.128***
	(0.279)	(0.267)	(0.327)	(0.253)	(0.259)	(0.240)
Disequilibrium Effects – Epidemic Effects						
Town	0.288	-0.318*			0.2	0.349**
	(0.176)	(0.190)			(0.160)	(0.162)
Rural		-0.336			0.129	0.354
		(0.246)			(0.224)	(0.231)
HSE Dublin North East			-0.327	-0.139	-0.273	
			(0.213)	(0.256)	(0.218)	
HSE South	0.386*	-0.346*	-0.145	0.172	0.267	0.366**
	(0.202)	(0.190)	(0.180)	(0.215)	(0.192)	(0.172)

Table 6.6 (continued): Multivariate Probit of Medical Equipment Use

	ECG	24 Hr BPM	Spiro-meter	Cryo-therapy	Minor Surgery	Foetal Monitor
HSE West	0.825***	0.198	0.091	0.135	0.223	0.326*
	(0.256)	(0.213)	(0.193)	(0.228)	(0.204)	(0.186)
Clinic	0.578***	0.231	0.07		0.133	0.126
	(0.185)	(0.161)	(0.131)		(0.145)	(0.152)
Training Practice	0.684**		0.384**	0.143	-0.13	-0.162
	(0.282)		(0.169)	(0.221)	(0.186)	(0.185)
Supplier Visits	0.078			0.172**		-0.076
	(0.071)			(0.082)		(0.048)
Committee Member		-0.063		0.193	-0.186	0.189
		(0.162)		(0.168)	(0.146)	(0.148)
Academic Department	0.211		0.144	0.17	0.226	0.084
	(0.207)		(0.147)	(0.191)	(0.166)	(0.166)
Research Project		0.564**	0.131	0.103	0.203	0.128
		(0.227)	(0.164)	(0.216)	(0.183)	(0.183)
ICGP Course		-0.238	0.212	0.159	0.194	-0.282*
		(0.176)	(0.146)	(0.194)	(0.161)	(0.154)
CME Meetings	-0.033		-0.024	0.024		
	(0.040)		(0.028)	(0.034)		
	Chi- Square = 600.633			P value = 0		

Notes: Coefficients are reported with standard errors in parentheses. *** denotes significance at the 1 per cent level; ** at the 5 per cent level and * at the 10 per cent level. Variable definitions are given in Table 6.3. The explanatory variables included are taken from the preferred Probit models presented Appendix 6. Explanatory variables with z-statistics of less than |0.5| were removed from the initial 'baseline' Probit models.

In the model we represent potential rank effects using a series of variables reflecting the characteristics of general practices. The number of GPs in a practice is found to positively impact on the probability of a practice obtaining a 24 hour blood pressure monitor. Therefore, the more GPs in the practice, the more probable it is for the practice to have this equipment. This finding is statistically significant at the 1 per cent level. This finding is not particularly surprising as a 24 hour blood pressure monitor is a particularly expensive piece of equipment, and a larger practice would be able to share the cost of purchasing this equipment between a number of GPs. Previous studies have also reported that firm size impacts on adoption of technologies (Karshenas and Stoneman, 1993; Baptista, 2000). There is no evidence that the number of GPs in a practice influences the use of the other items of medical equipment examined.

When examining the effect of the number of patients on the probability of a practice obtaining medical equipment, we find that the log of the number of patients positively impacts on the probability of a practice having spirometry and cryotherapy equipment. This finding is statistically significant at the 5 and 1 per cent levels for spirometers and cryotherapy equipment respectively. Larger practices, with respect to the number of patients, are likely to be seeing patients with a greater variety of conditions and illnesses, and therefore may be more likely to see the need to invest in equipment to cater for their patients' needs. Given that most practices have both public and private patients, we also include a variable to determine the proportion of public patients to total patients in each practice. A higher proportion of public patients negatively impacts on the likelihood of a practice having minor surgery equipment. This result is statistically significant at the 5 per cent level for minor surgery equipment. Minor surgery often involves elective procedures which public patients are entitled to access in hospitals free of charge. Private patients are required to pay, directly or through their private health insurance providers, for elective procedures in hospitals. Therefore, practices with a large proportion of public patients may not consider a minor surgery kit an integral part of their service provision, as they can direct their public patients to secondary care, either through Accident and Emergency (A&E) or as a referral to a consultant.

A practice which employs a nurse is more likely to have both an ECG machine and a 24 hour blood pressure monitor. These findings are statistically significant at the 5 and 1 per cent levels respectively. Previous studies have also reported that human capital impacts on the adoption of technologies (Karshenas and Stoneman, 1993; Baptista, 2000), and specifically that nursing support positively impacts on the use of medical technologies (Boerma et al., 1998). In Chapter 4, we also find that nursing support positively influences the decision to prescribe a new drug for the first time. Contrastingly, a practice with the support of a nurse is less likely to have cryotherapy equipment. This finding is significant at the 5 per cent level. Administrative support does not influence the use of medical equipment by general practices.

We also examine the age and gender profile of GPs in the practices surveyed, and their influence on use of medical equipment. The age profile variable takes a value of one if all GPs in the practice are 40 years of age or older. There is no evidence of a relationship between this variable and the use of medical equipment in general practices. However, the GP gender profile in general practices does influence the use of medical equipment. Practices that have more male GPs than female GPs are more likely to obtain ECG machines, spirometers and minor surgery equipment. These findings are statistically significant at the 5 per cent level. Previous studies examining ICT use among doctors report higher levels of use among male doctors in comparison with their female counterparts (Masters, 2008; Meade et al., 2009).

To recap, there is some evidence of rank effects influencing the use of medical equipment by general practices. In general, the number of GPs positively influences the use of medical equipment. Likewise, nursing support appears to positively impact on the use of medical equipment; this finding relates to two of the technologies. Also, practices with more male GPs than female are more likely to use medical equipment. This relationship is reported in relation to three of the six items of medical equipment examined. Therefore, rank effects in the form of patient numbers, nursing support and male dominated practices positively impact on the adoption of medical equipment by general practices. However, it is worth noting that the proportion of public patients and nursing support negatively impact on the use of at least one type of medical equipment. It is also apparent that no one rank effects variable influences the use of all six technologies. While previous studies examining the adoption of one particular technology report evidence of rank effects (Karshenas and Stoneman, 1993; Baptista, 2000), it is worth noting that Stoneman and Kwon's (1994) study of multiple technology adoption report little evidence of rank effects.

As previously discussed, we include a 'portfolio' variable to capture learning-by-using effects. The 'portfolio' variable is consistently signed and significant across all six items of medical equipment. Practices that have adopted at least three items of medical equipment are more likely to adopt each type of medical equipment examined.[82] Evidence of this relationship is consistent across all six items of medical equipment and consistent at the 1 per cent level. Therefore, it is clear that general practices are likely to differ in the probability of adopting a new technology given differences in their previous adoption decisions. Although there is a limited body of

[82] We initially included a ratio portfolio variable which measured how many of the six medical equipments each practice had in its portfolio of equipment. However, inclusion of this variable meant that the Multivariate Probit model did not converge.

empirical work examining the influence of learning-by-using effects on the uptake of new technologies, the research to date provides strong evidence of learning-by-using effects positively influencing the adoption of technologies, particularly when examining multiple technology adoption (Stoneman and Kwon 1994, Colombo and Mosconi 1995, McWilliams and Zilbermanfr 1996, Stoneman and Toivanen 1997, Arvantis and Hollenstein 2001). In Chapter 4, we also find evidence of learning-by-using effects positively influencing prescribing innovation.

An order effect variable was constructed to determine if early adoption of at least one item of medical equipment positively influences use of other items of medical equipment. Evidence of order effects is somewhat indeterminate in relation to the adoption of medical equipment, as there is only one statistically significant relationship observed. Being a 'first-mover' positively impacts on the probability of a practice obtaining a spirometer. This finding is significant at the 1 per cent level. However, our somewhat indeterminate evidence of order effects is in line with previous empirical studies, with some studies reporting no evidence of order effects (Karshenas and Stoneman, 1993; Stoneman and Toivanen, 1997) and others reporting some evidence of such effects (Stoneman and Kwon, 1994; Baptista, 2000).

In the multivariate Probit model, we represent potential epidemic effects using a series of variables reflecting location and interaction effects. We categorise practices as being located in a city, town or rural location, and also in which HSE region they are located: HSE Dublin Mid-Leinster, HSE Dublin North East, HSE South, and HSE West. Practices located in the HSE West regions are more likely to have foetal monitors than practices located in the HSE Dublin Mid Leinster and the HSE Dublin North East region. It is worth mentioning that the HSE West region has a greater proportion of small, rural practices than the HSE Dublin Mid-Leinster and HSE Dublin North East regions. Also there are fewer hospitals in these regions. Previous studies examining general practices' use of medical equipment also report that rural practices are more likely to obtain medical equipment (Boerma et al., 1998; Nic Gabhainn et al., 2001). It may be the case that smaller, more rural practices acquire this equipment to compensate for reduced access to secondary care services (Ni Shuilleabhain et al., 2007), and therefore the HSE West variable may, in fact, be capturing 'compensation' effects. There is a direct financial incentive for general practices to acquire foetal monitors. The Maternity and Infant Care Scheme (MIS) provides an agreed programme of care to all expectant mothers (public and private patients) who are ordinarily resident in Ireland. This service is provided by a GP and a hospital obstetrician, and even those who do not have a medical card are entitled to this service. In general, the scheme allows for seven GP visits during pregnancy and two post-natal GP visits (Department of Health and Children, 2001).

We also include the following variables in the model to capture epidemic effects: practices that hold a clinic, training practices, supplier visits, committee member, affiliation with an academic department, involvement in research projects, participation in ICGP courses, and attendance at CME meetings. Practices that hold a clinic delivered by a health care professional are more likely to have an ECG machine. This finding is statistically significant at the 1 per cent level. Training practices are also more likely to have an ECG machine, and more likely to have spirometers. These findings are statistically significant at the 5 per cent level. Both these findings indicate evidence of epidemic learning effects. A UK study also reported that training practices were more likely to use medical equipment than their non-training counterparts (Baker and Thompson, 1995).

Surprisingly, frequency of visits from suppliers of medical equipment only influences the use of one item of medical equipment, cryotherapy equipment. As the frequency of supplier visits increases, practices are more likely to obtain cryotherapy equipment. This finding is statistically significant at the 5 per cent level. Also, practices involved in research projects are more likely to obtain a 24 hour blood pressure monitor. This finding is statistically significant at the 5 per cent level. None of the other epidemic effects variables influence the use of the six items of medical equipment examined. Therefore, practices in which at least one of the GPs is a committee member of a medical organisation, affiliated to an academic department, completing an ICGP course and regularly attending CME meetings are no more likely to use medical equipment than other practices. Interestingly, a mid-1990s study reported that Irish GPs collaboration with other GPs and health care professionals was low relative to their European counterparts (Boerma and Dubois, 2006).

Therefore, in relation to the influence of epidemic learning effects on the use of the six items of medical equipment examined, we find limited evidence of location and interaction effects influencing the use of medical equipment. In relation to the practice location variables, there appears to be a ‘compensation’ effect, whereby GPs located in the HSE West region are more likely to adopt medical equipment, perhaps to recompense for less access to secondary care. However, the ‘interaction’ variables have little influence on the use of the items of medical equipment examined; with the exception being training practices, which positively influence the use of two items of medical equipment.

6.6 Conclusion

The purpose of this chapter is to explain the determinants of use of medical equipment in general practices. The Irish primary health care system provides a distinctive setting for such an examination. Firstly, the commercial autonomy which characterise Irish general practice suggests that investment decisions concerning medical equipment may reflect both medical and commercial factors. Secondly, in relation to their European counterparts, Irish GPs provide a more comprehensive mix of services (Boerma and Dubois, 2006) and, therefore, require a broad range and mix of medical equipment to provide these services. As is evident from our survey data, a high proportion of general practices surveyed use the six items of medical equipment examined in our survey, although considerable variation remains across general practices in terms of their uptake of medical equipment.

Within a multiple technology adoption framework, we examine the use of six items of medical equipment across Irish general practices through the lens of equilibrium, disequilibrium and learning-by-using models of adoption, specifically modelling the influence of rank, order, learning-by-using and epidemic effects on medical equipment use. The *Medical Equipment and IT in General Practice* survey provides the data for this study, and a multivariate Probit is employed to estimate the influence of the aforementioned factors on the use of six items of medical equipment.

We find some evidence of rank effects. The number of patients, the proportion of public patients, nursing support and male (GP) dominated practices positively influence the use of medical equipment. However, it is clear these effects are not consistent across all six items of medical equipment, indicating the benefit to examining the adoption of a range of technologies rather than one technology in isolation (Stoneman and Kwon, 1994). There is consistent evidence of learning-by-using effects in relation to all six items of medical equipment examined. Therefore, practices that have a broader portfolio of medical equipment are more likely to use another medical technology. There is little evidence of order effects, with being a 'first-mover' positively influencing the use of only one item of medical equipment. We find little evidence of epidemic learning effects, although training practices are more likely to use medical equipment. Table 6.7 provides a symbolic summary of these results.

As previously outlined, this study is the first to examine the adoption of multiple medical technologies by small health care practices. Our results provide evidence of some commonalties in the determinants of medical equipment use in Irish general practices. However neither the equilibrium (rank and order) nor the disequilibrium (epidemic) effects are consistent in their influence of medical equipment use. A possible reason for this finding is that the use of medical equipment in general practices is technology-specific. Therefore, it is necessary to examine adoption and use of technologies within a multiple-technology framework as it may be imprudent to make generalisations with respect to findings concerning use of a single technology.

Table 6.7: Symbolic Summary of Effects on Medical Equipment Use

	Anticipated Effects	A	B	C	D	E	F
Equilibrium Effects – Rank Effects							
Number of GPs	+		+				
Log of Patients	+	+		+	+		
Prop. of Public Patients	+	+	+			-	
Nursing Support	+	+	+		-		
Admin Support	+						
All GPs > 40	-						
Male Dominated	+	+		+	-	+	
Equilibrium Effects – Order Effects							
Order Effects	+			+			
Learning-by-using Effects							
Portfolio	+	+	+	+	+	+	+
Disequilibrium Effects – Epidemic Effects							
Town	-		-				+
Rural	+						
HSE Dublin North East	-						
HSE South	+						+
HSE West	+	+					+
Clinic	+	+					
Training Practice	+	+		+			
Supplier Visits	+						
Committee Member	+						
Academic Department	+						
Research Project	+						
ICGP Course	+			+			-
CME Meetings	+				+		

Table Key: A – ECG; B – 24Hr Blood Pressure Monitor; C – Spriometer; D - Cryotherapy Equipment; E – Minor Surgery Equipment; F – Foetal Monitor. **Notes**: '-' denotes a negative and significant effect (at the 10 per cent level or above); '+' denotes a positive and significant effect.

However, our empirical results reveal that learning-by-using effects consistently influence the use of all six items of medical equipment; practices with a broader portfolio of medical equipment are more likely to use another medical technology. This finding is strongly statistically significant and consistent across all six items of medical equipment examined. This finding is also consistent with the positive relationship reported between learning-by-using effects and adoption of new drugs by GPs (Chapter 4).

Our empirical findings in relation to use of medical equipment by Irish GPs, as well as our empirical results pertaining to prescribing innovation in Chapter 4, support the application of our encompassing theoretical model to examining Irish GPs innovative behaviour. Our empirical findings, as presented in this chapter, also support the extension of our theoretical model to multiple technology adoption. We further explore GP's innovative behaviour in Chapter 7, with an examination of the determinants of ICT use in general practices. The results from all three empirical exercises are discussed collectively in Chapter 8.

CHAPTER 7: INTENSITY OF ICT USE IN IRISH GENERAL PRACTICES

7.1 Introduction

The general aim of this thesis is to explain the timing and intensity of adoption of innovations in general practices in Ireland. In our previous empirical exercises, we identified the influence of equilibrium, disequilibrium and learning-by-using effects on timing of prescribing innovation (Chapter 4) and use of medical equipment (Chapter 6) by Irish GPs. This chapter continues our exploration of innovative behaviour amongst Irish GPs, focusing on the determinants of intensity of ICT use in Irish general practices. General practices use ICT for a variety of reasons ranging from billing patients and writing referral letters to keeping consultation records and coding diseases. Therefore, practices differ in terms of the intensity of their ICT use, and, this in turn, influences practice management and patient care. This chapter addresses our third research question: what factors influence intensity of ICT use in Irish general practices?

In previous chapters, the autonomy enjoyed by Irish GPs with respect to prescribing new drugs and investing in new equipment has been discussed in detail. In addition, general practices in Ireland also enjoy considerable autonomy in terms of their use of ICT. The national Health Information Strategy (NHIS) commits to modernise ICT infrastructure in the health sector and to optimise development and utilisation of health information (Department of Health and Children, 2004). However, a European-wide survey of ICT use among general practices categorised Irish general practices as 'average' performers in terms of ICT use (Dobrev et al., 2008). In fact, almost all general practices who responded to our survey use ICT, although the variation in the extent of ICT use is considerable.[83] It is this variation in ICT use that we are concerned with and the purpose of this chapter is to identify the determinants of intensity of ICT use.

Recent innovation literature has argued that an understanding of the extent of use of new technologies is of as much importance as understanding the initial decision to use the technology (Mansfield, 1963; Battisti and Stoneman, 2003; Hollenstein, 2004; Battisti and Stoneman, 2005; Battisti et al., 2007). Conversely, there is limited data on within firm use of a new technology over time, resulting in few empirical studies of intra-firm diffusion (Battisti et al., 2007). However, a small number of studies examining the extent of use of new technologies by firms report that 'use' and 'intensity of use' are driven by different factors (Hollenstein, 2004; Battisti et al., 2007). Such empirical results indicate that when examining the diffusion of new technologies, it is necessary to examine the overall adoption process, i.e. the adoption decision and, following this decision, intensity of use.

As discussed in Chapter 2, there is a substantial body of theoretical and empirical literature examining decision making concerning the use of new technologies and innovations. The main theoretical approaches to timing of adoption have been extended to examinations of intensity of adoption. Drawing on the complementary disequilibrium, equilibrium and learning-by-using approaches, these studies report that intensity of use is partly determined by learning from previous adoption

[83] Fifteen of the 601 general practices surveyed did not use ICT at all. The variation with respect to extent of use is discussed in more detail later in the chapter.

decisions and interaction with external agents and partly determined by profitability considerations (Battisti et al., 2007; Hollenstein, 2004; Battisti and Stoneman, 2005). We also adopt this approach, and investigate the influences of rank, epidemic and learning-by-using effects on the intensity of ICT use in Irish general practices.

As previously mentioned, general practices use ICT for a variety of purposes, ranging from administrative to patient care purposes. Therefore, using ICT for accounts and billing purposes may influence the efficient running of the practice as a business, whereas using ICT for coding of diseases and audit/ quality assurance reasons clearly influences health care provision. This suggests that decisions concerning ICT use may reflect both medical and commercial factors, and implies the value of considering both informational and commercial factors as determinants of intensity of ICT use by general practices.

To our knowledge, this study is the first to examine intensity of ICT use by small health care organisations. We examine general practices' ICT use for both administrative functions and patient care functions, and categorise practices as being 'basic', 'intermediate' or 'enhanced' users of ICT for both these purposes. We apply ordered Probit analysis to both types of ICT use and identify the determinants of the probability of practices being extensive ICT users. The data source used in this study is the *Medical Equipment and IT in General Practice* survey data. Described in Chapter 5, this survey data provides information relating to practice characteristics and ICT use for a sample of 601 general practices in Ireland.

The rest of the chapter is organised as follows. Section 7.2 outlines the potential for extending our encompassing theoretical model to intensity of ICT use by general practices. This section also describes previous studies examining intensity of ICT use, as well as focusing on empirical research on ICT use by GPs. Section 7.3 describes our primary data source and outlines our econometric approach. Section 7.4 presents and discusses the econometric results, and Section 7.5 concludes this chapter.

7.2 Theoretical & Empirical Influences on Intensity of Adoption

Our aim here is to examine the determinants of intensity of ICT use among general practices. As discussed in Chapter 2, there is an argument presented in the innovation literature that an understanding of the extent of use by adopting firms is of as much importance as understanding the decision to adopt an innovation in the first instance (Mansfield, 1963; Battisti and Stoneman, 2003; Hollenstein, 2004; Battisti and Stoneman, 2005; Battisti et al., 2007). In the diffusion literature, the extent of use of an innovation is referred to as intra-firm diffusion, whereas the decision to adopt an innovation initially is referred to as inter-firm diffusion. Battisti and Stoneman (2003) stress that inter-firm diffusion patterns alone are a poor indicator of overall diffusion and argue that much greater emphasis should be placed on intra-firm issues in future diffusion research. A number of studies argue that the theoretical propositions made in the inter-firm diffusion literature should also be applied to studies of intra-firm diffusion (Battisti, 2000; Battisti and Stoneman, 2003; Hollenstein, 2004; Battisti and Stoneman, 2005). In general, there is a paucity of intra-firm diffusion studies, however, there are a small number of studies that examine intensity of ICT use (Hollenstein, 2004; Battisti et al., 2007).

Battisti et al. (2007) examined intensity of ICT use among UK and Swiss firms, measured as ICT use at a basic or enhanced level.[84] Specifically, Battisti et al. (2007) categorise firms as non-users, basic users and enhanced users in relation to their adoption of the internet. Drawing on an integrated equilibrium and disequilibrium model of diffusion, Battisti et al. (2007) report evidence of positive epidemic learning effects and organisational factors, such as the introduction of process innovations and conducting R&D, in relation to enhanced internet usage. Interestingly, firm size does not impact on intra-firm diffusion in either the UK or Switzerland, indicating that smaller firms, having adopted ICT, use it to the same extent as larger firms.

Using the same Swiss survey data as Battisti et al. (2007), Hollenstein (2004) also examined intensity of ICT use among Swiss firms. Hollenstein (2004), focusing on the adoption of nine ICT elements, examines both the timing and intensity of ICT adoption.[85] Hollenstein (2004) calculated a four-level ordinal measure of intensity of ICT use: level 0 for less than three ICT elements (including zero), level 1 for three or four elements, level 2 for five or six elements, and level 3 for seven to nine elements. Hollenstein (2004) also examined the extent of internet usage, measured as the proportion of employees regularly using the internet. Hollenstein (2004) drawing on a conceptual framework incorporating both rank and epidemic learning effects, uses an ordered Probit model to examine intensity of ICT and internet usage. In relation

[84] The UK data derives from the Community Innovation Survey (CIS) which surveyed businesses with 10 or more employees across a broad range of industries (10-74 of the SIC 92 industrial classification). The Swiss data derives from a survey conducted on businesses with five or more employees across 28 industries.
[85] The specific ICT elements include digital assistants, laptop, PCs, Workstations, terminals, E-mail, Internet, EDI, LAN/WAN, intranet, and extranet.

to firm size, Hollenstein (2004) report positive size effects in relation to overall ICT intensity; however, there is hardly any size dependence in relation to intensity of internet usage. In fact, the propensity to adopt seems to be highest in the case of medium-sized firms in relation to internet usage. Hollenstein (2004) report that the capacity to absorb external knowledge is important in relation to intensity of ICT use, distinctly more important than its' impact on adoption in the first instance. Hollenstein (2004) purports the plausibility of this finding given the more complex problems to be solved when a large set of ICT elements have already been adopted.

Hollenstein (2004) also reports that know-how deficiencies, managerial problems and costs of ICT are the most important obstacles to the introduction of ICT. There is no evidence of a negative impact from uncertainty and switching costs. Hollenstein (2004), acknowledging that these results differ from previous studies of technology adoption, concludes that the relative importance of the explanatory variables are technology-specific. Hollenstein (2004) reports that absorptive capacity, firm size, cost of technology and anticipated benefits from improved internal processes are more important with respect to intra-firm diffusion, whereas quality-orientated and customer-related advantages are more relevant for timing decisions. Hollenstein (2004) reasons that a firm's resource commitment may be low at earlier stages of adoption (inter-firm diffusion) than later stages (intra-firm diffusion).

To date, we are not aware of previous empirical research examining the influences of learning-by-using effects on intensity of ICT use. However, Battisti and Stoneman (2005) report positive learning-by-using effects on the intensity of use of CNC machines. They found that learning-by-using effects, reflecting stock of knowledge and technical skills, positively influence the benefit a firm obtains from use of a new technology.

In line with the empirical research discussed above, we incorporate the equilibrium, disequilibrium and learning-by-using models of adoption to our examination of intra-practice diffusion of ICT. To our knowledge, this encompassing theoretical model has not previously been applied to intensity of ICT use in small health care practices. However, there are a number of examinations of ICT use among GPs, some of which are documented below.

In 2007, the European Commission surveyed primary care physicians regarding their use of ICT for eHealth purposes (Dobrev et al., 2008). In this study, 6,789 interviews were conducted across all 27 Member States of the European Union, Norway and Iceland. Dobrev et al. (2008) report that basic ICT infrastructure consisting of computers and internet connections is available in most GP practices in Europe. They also report that the electronic storage of administrative and medical patient data, the use of a computer during consultation with patients and other uses of ICT in the health area are becoming more and more a daily experience in practices.

Dobrev et al. (2008) report that 87 per cent of GP practices in the EU use a computer, with larger practices more likely to have a computer (93 per cent) compared to smaller practices (84 per cent). 69 per cent of practices have an internet connection, increasing from 61 per cent for single GP practices to 81 per cent among practices with four or more GPs. Dobrev et al. (2008) also report that European GPs believe that ICT use in general practices improves the quality of healthcare services. Similarly, a qualitative study examining the attitudes of Irish and Northern Irish GPs towards computerisation reported an overall positive attitude towards computerisation, particularly in terms of ease of access to information, legibility, increased efficiency, and increased quality of care (Lordan and Normand, 2005).

Dobrev et al. (2008) categorise Ireland's general practices as 'average' performers in terms of ICT use.[86] However, in terms of infrastructure, Ireland scores slightly below the European average. Approximately two-thirds of Irish GP practices store administrative patient data and use local electronic health records (EHR). However, a relatively low proportion of Irish GPs transfer electronic patient data (40 per cent) or administrative data (17 per cent).

A recent Irish study specifically examined the use of electronic patient records (EPR) by Irish GPs (Meade et al., 2009). Following surveys conducted in 2000 and 2003, Meade et al. (2009) report a significant increase in the use of EPRs by Irish GPs over this three year time interval.[87] Table 7.1 summarises the findings in relation to ICT use presented in Meade et al. (2009). For example, in 2000 half of all GPs surveyed always use a computer to write repeat prescriptions; however, by 2003 almost three-quarters of GPs were always using a computer to complete this task.

In terms of identifying which GPs are more likely to use ICT, Meade et al. (2009) report that young, male GPs and those working in group practices are most likely to use EPRs. Also, GPs based in a rural location and involved in GP vocational training

[86] Interviews were conducted with 206 Irish GPs.
[87] The sample sizes for 2000 and 2003 were 1543 and 1408 respectively.

are most likely to use EPRs. While most GPs accept the benefit of EPR systems over manual ones, the major perceived obstacle preventing the migration from manual to electronic records by GPs was lack of time rather than lack of financial resources.

Table 7.1: Computer Use for Common Clinical Tasks

Task Always Carried out on a Computer	2000	2003
Patient Registration	66%	79%
Vaccination records	59%	73%
Repeat Prescriptions	50%	74%
Referral Letters	39%	53%
Consultation Notes	39%	52%
Acute Prescriptions	36%	56%
Administration	30%	56%
Accounts	27%	30%
Recall	23%	30%

Source: Meade et al. 2009

A previous Irish study also collected survey data on the structure of Irish general practices, and presented some rudimentary statistics in relation to ICT use (O'Dowd et al., 2006). However, there was no attempt to differentiate between users and non-users or low- and high-users. Meade et al.'s (2009) study is the most in-depth study to date of ICT use among Irish GPs, however it is worth noting that the study is atheoretical and mainly descriptive in nature.

Masters (2008) also identifies similar patterns to Meade et al. (2009) in relation to ICT use, specifically internet usage, among doctors.[88] Masters (2008) reports that

[88] In a systematic review of the literature, Masters (2008) examined the purpose and reasons for which doctors use the internet. All of the studies reviewed were in the developed world, primarily North America. Masters (2008) reports that most internet activity among doctors focuses on email and searching in journals and databases. Professional email with colleagues and patients is low.

males use the internet more than females, young more than old, and specialists more than generalists. However, these differences are not across the board and there is variation between studies (Masters, 2008).

In summary, Irish general practices are not considered frontrunners in terms of ICT use for administrative and patient care purposes (Dobrev et al., 2008). However, there is a commitment to modernise ICT infrastructure in the health sector as outlined in the national Health Information Strategy (NHIS) (Department of Health and Children, 2004). Part of the NHIS's strategy includes the introduction of an Electronic Health Record by 2009. However, such a system has not been implemented largely because there is no agreement between IT providers on sharing information (Information Society Commission, 2004). Dobrev et al. (2008) criticised the long-term planning of the strategy as being a possible reason as to why ICT use among Irish GPs is currently at an average level.

7.3 Data and Methods

The data (7.3.1) and econometric methodology (7.3.2) employed in our analysis of intensity of ICT use by general practices are discussed in this section.

7.3.1 Description of Survey Data

Our empirical analysis is based on survey data, collected through a self-administered postal questionnaire - *Medical Equipment and IT in General Practice*- distributed to all general practices in Ireland in February and March 2010. The purpose of our data collection was to collect data relating to the structure of the practice, support staff, educational and training activities, clinics, and use of medical equipment and ICT. A response rate of 42 per cent resulted in a sample size of 601.

The purpose of this chapter is to examine the factors impacting on the intensity of ICT use in general practices, i.e. the intra-practice ICT diffusion. Battisti and Stoneman (2003) highlight a paucity of studies in the area of intra-firm diffusion, due in part to the limited data available. However, our survey data allows us to measure the extent of ICT use. As discussed in Chapter 5, our survey asked respondents for which administrative and patient care functions their practice uses ICT. With respect to administrative functions, respondents were asked for which of the following functions their practice uses ICT: accounts, word processing, billing, patient registration, referral letters, appointments, staff calendar, email, and practice website. Respondents were also asked for which patient care functions their practice uses ICT: recall of items, repeat prescriptions, download hospital laboratory reports, coding of diseases, consultation records, internet research, scan hospital and/or consultant correspondence, and audit/quality assurance.[89]

These variables allow us to measure intensity of ICT use for both administrative and patient care functions. As previously discussed in Section 2.4, the costs of a practice incorporating additional ICT applications to their current system is likely to vary substantially given the individual ICT applications. The costs of adoption of additional ICT applications(s), in terms of time, effort and money, will differ relative to the individual ICT application(s) being adopted and also relative to the practice's current ICT use. Similarly the benefits of adopting different ICT applications to the

[89] See Chapter 5 for a full description of practices' ICT use for both administrative and patient care functions.

patient and the practice are likely to be dependent on the individual ICT application. Consequently, we decided to rescale the count data into ordered categories, as the various ICT applications are not equivalent in economic terms. Hollenstein (2004), in the examination of intensity of ICT use among Swiss firms, also grouped a range of ICT applications into an ordinal measure of intensity of ICT use.

Therefore, practices are categorised within a three-level ordinal measure of intensity of ICT use for administrative purposes, basic, intermediate, and enhanced users. Basic users use ICT for between zero and four administrative functions, intermediate users for five to seven functions, and enhanced users for eight or nine functions. As presented in Table 7.2, 21 per cent of practices are categorised as basic users of ICT for administrative purposes, 45 per cent as intermediate users, and 34 per cent as enhanced users. Similarly, practices are categorised as basic, intermediate, and enhanced users of ICT for patient care purposes. Basic users use ICT for between zero and four functions, intermediate users for five or six functions, and enhanced users for seven or eight patient care functions. 24 per cent of practices are basic users of ICT for patient care purposes, 33 per cent are intermediate users and 43 per cent are enhanced users (Table 7.2). [90]

[90] The pattern of explanation from estimates with an alternative number of response levels were similar for both types of ICT use, and the threshold parameters presented in Tables 7.9a and 7.9b indicate the appropriateness of these ordered categories of the dependent variables.

Table 7.2: Intensity of ICT Use for Administrative and Patient Care Purposes

	Number of ICT Elements	Positive Observations	Percentage of Users
Intensity of ICT Use for Administrative Purposes			
Basic Users	0-4	126	20.97%
Intermediate Users	5-7	273	45.42%
Enhanced Users	8-9	202	33.61%
		601	100.00%
Intensity of ICT Use for Patient Care Purposes			
Basic Users	0-4	146	24.29%
Intermediate Users	5-6	197	32.78%
Enhanced Users	7-8	258	42.93%
		601	100.00%

Table 7.3 presents a cross-tabulation of these two dependent variables, indicating that 15.8 per cent of practices are basic users of ICT for both purposes, 21.6 per cent of practices are intermediate users of ICT for both purposes, and 25.8 per cent of practices are enhanced users of ICT for both administrative and patient care purposes.

Table 7.3: Crosstabulation of ICT User Categories for Administrative and Patient Care Purposes – Percentage of Total Practices

		Administrative ICT Use		
		Basic User	***Intermediate User***	***Enhanced User***
Patient Care ICT Use	***Basic User***	15.8%	7.5%	1.0%
	Intermediate User	4.3%	21.6%	6.8%
	Enhanced User	0.8%	16.3%	25.8%

Next, the explanatory variables used in this analysis, presented in Table 7.4, are briefly discussed. The rank effect variables used in our examination of intensity of ICT use are consistent with those used in our medical equipment use analysis. As before, these variables include nursing and administrative support, size of practice with respect to number of GPs and patients, the proportion of public patients to total patients, and the age and general profile of GPs in the practice. These rank effects variables have previously been discussed in Section 6.3.1; descriptive statistics are presented in Table 7.4.

Table 7.4: Descriptive Statistics of Explanatory Variables

Variable Name	N	Mean	St. Dev.
Rank Effects			
Number of GPs	596	2.701	1.667
Log of Patients	559	8.072	0.749
Public Patients/ Total Patients	559	0.375	0.201
Nursing Support	597	0.807	0.395
Administrative Support	601	0.914	0.281
Age >40	601	0.250	0.433
Male Dominated	601	0.509	0.500
Learning-by-using Effects			
ICT Use for Patient Care Purposes (3 or more patient care ICT functions)	601	0.875	0.331
ICT Use for Administrative Purposes (3 or more administrative ICT functions)	601	0.905	0.293
Epidemic Effects			
Rural	601	0.185	0.388
Town	601	0.501	0.500
City	601	0.315	0.465
HSE Dublin Mid-Leinster	600	0.235	0.424
HSE Dublin North East	600	0.152	0.359
HSE South	600	0.352	0.478
HSE West	600	0.262	0.440
Training Practice	595	0.291	0.455
Clinic	601	0.494	0.500
Supplier Visits = 0	591	0.408	0.492
Supplier Visits = 1.5	591	0.366	0.482
Supplier Visits = 4	591	0.157	0.364
Supplier Visits = 7	591	0.039	0.194
Supplier Visits = 10	591	0.031	0.172
Committee Member	597	0.412	0.493
Academic Department	590	0.378	0.485
Research Project	597	0.236	0.425
ICGP Course	592	0.313	0.464
CME Meetings = 0	601	0.085	0.279
CME Meetings = 1.5	601	0.072	0.258
CME Meetings = 4	601	0.305	0.461
CME Meetings =7	601	0.539	0.499

Note: The Supplier Visits variable consists of 5 numeric mid-point categories: 0, 1.5, 4, 7 and 10. The CME Meetings variable consists of 4 midpoint numeric categories: 0, 1.5, 4, and 7.

These variables are included to capture practices' heterogeneity which has been identified as an explanatory factor in intensity of technology and ICT use among firms, although findings reported are not consistent (Hollenstein, 2004; Battisti and Stoneman, 2005). In our previous empirical exercises we find support staff and practice size positively influence innovative behaviour. Therefore, we expect nursing and administrative support to positively impact on intensity of ICT use. However, previous studies have reported little evidence of size effects in relation to intensity of adoption, therefore we do not expect practice size with respect to number of GPs or number of patients to influence intensity of ICT use in general practices. In relation to medical equipment use, we find a positive relationship between the proportion of public patients and use of medical equipment. It is likely that a similar relationship exists in relation to intensity of ICT use. In relation to the age and gender of GPs, in previous chapters, we find male-dominated practices are more likely to use medical equipment and older GPs are slower to adopt new drugs. Also, there is previous Irish evidence that ICT use is greater among younger, male GPs (Meade et al., 2009),therefore we anticipate similar findings in relation to this study.[91] Table 7.5 provides a symbolic summary of our anticipated results in relation to intensity of ICT use. Given the nature of the survey data, i.e. we do not ask the time of practices' adoption of ICT applications, we are unable to capture stock and order effects.

[91] However, we are aware that the factors influencing adoption and use of innovations in general practices may differ with respect to their influence on intensity of ICT use.

Table 7.5: Symbolic Summary of Anticipated Effects on Intensity of ICT Use

Rank Effects	
Nursing Support	+
Number of GPs	-
Prop. of Public Patients	+
(Log) Number of Patients	-
Administration Support	+
All GPs >40 years	-
Male (GP) Dominated	+
Learning-by-Using Effects	
ICT Use for 3 or more Patient Care Functions	+
Medical Equipment Portfolio	+
Epidemic Learning Effects	
HSE Dublin Northeast	-
HSE South	+
HSE West	+
Town Practice	-
Rural Practice	+
Training Practice	+
Visits from It Suppliers	+
Practice Holds a Clinic	+
Committee Member	+
Academic Department	+
Research Projects	+
ICGP Course	+
CME Meetings	+

Notes: '-' denotes a negative and significant effect; '+' denotes a positive and significant effect.

There is little evidence of learning-by-using effects being incorporated in intra-firm diffusion studies, although Battisti and Stoneman (2005) report that use of complementary technologies impacts on firms' extent of use with respect to CNC machines. There is also evidence that learning-by-using effects impact on inter-firm diffusion of technologies (Stoneman and Kwon, 1994; Colombo and Mosconi, 1995; McWilliams and Zilbermanfr, 1996; Stoneman and Toivanen, 1997; Arvantis and Hollenstein, 2001), and previous studies have argued that the theoretical propositions made in the inter-firm diffusion literature should also be applied to studies of intra-firm diffusion (Battisti, 2000; Battisti and Stoneman, 2003). Therefore, we include learning-by-using effects in our examination of intensity of ICT use for administrative and patient care purposes. To that end, we create two dummy variables, which measure if practices are using ICT for at least three administrative functions and at least three patient care functions. The learning-by-using ICT for administrative purposes variable will be included in the analysis examining the factors impacting on the probability of the extent of ICT use for patient care purposes. 90 per cent of practices use ICT for three or more administrative functions. Similarly, the learning-by-using ICT for patient care purposes variable will be used in the analysis examining the factors impacting on the probability of the extent of ICT use for administrative purposes. 87 per cent of practices use ICT for three or more patient care functions. The portfolio of medical equipment variable was strongly significant and consistently signed in relation to use of medical equipment (see Chapter 6). Therefore, we include this variable to examine if learning-by-using a portfolio of medical equipment impacts on intensity of ICT use. 90 per cent of practices use three or more of the six items of medical equipment.

As in our medical equipment use analysis, epidemic effects are measured by variables relating to practice location and interaction and education factors. Practice location is provided for with respect to urban and rural classifications and HSE region. Epidemic effects variables also included whether the practice is a training practice, holds clinic and is frequently visited by suppliers of IT. Factors such as being a committee member of a professional organisation, affiliated with an academic department, involved in research projects, completing an ICGP course and attendance at CME meetings are also considered. These variables are described in detail in Section 6.3.1. Descriptive statistics for these variables are also included in Table 7.4.

There is a lack of consensus in the literature in terms of the impact of epidemic learning effects on intra-firm diffusion (Hollenstein and Woerter, 2004; Battisti and Stoneman, 2005). However, we would expect interaction with external agents to have some positive influence on extent of ICT use among general practices, and it is likely that rural, training practices use ICT to a greater extent (Meade et al., 2009). Also, in our medical equipment study, we find that practices located in HSE West are more likely to invest in medical equipment. Therefore, it is likely that these practices are also more intensive users of ICT.

Interestingly, in 2001, the Southern Health Board developed an ICT strategy to improve service delivery, for which it received the European Commission's "Best Practices in eService Delivery" award. It is likely that knowledge spillovers from this strategy may positively influence intensity of ICT use among general practices in the HSE South.[92][93]

[92] Prior to January 2005, the Irish health care system comprised of eight regional health boards. In 2005, the Southern Health Board was subsumed into the HSE South region.
[93] This ICT Strategy is discussed in more detail in Section 8.4.1, where policy implications of this thesis are discussed.

As previously discussed in Section 2.4, intensity of adoption decision-making differs from adoption decision-making with respect to costs and benefits. The cost of adopting ICT in the first instance would be considerable for an individual practice. However, the cost of becoming a more intensive user of ICT, in terms of time, effort and money, is likely to be very much dependent on the individual ICT applications and the practice's current portfolio of ICT applications. For example, if a practice chooses to use additional ICT applications from their current software package, the costs of such decision-making are likely to be relatively low. On the other hand, use of some ICT applications, such as coding of diseases, would require considerable effort regardless of whether or not the application was readily available to the practice. Likewise, in order for some practices to move from being 'basic' or 'intermediate' ICT users to 'enhanced' ICT users may require the purchase of new software. Similarly, the development of a practice website may incur considerable monetary and effort costs.

It is important to note that although more intensive ICT use may require additional investments and training; in general, risks of adoption reduce with ownership and use of technologies. Therefore, we assume costs of intensity of ICT use to be constant across practices in our econometric analysis. However, we do consider the cost implications of adoption when interpreting our empirical results.

A correlation matrix of all variables used in this analysis is also presented in Table 7.6, illustrating that the explanatory variables, in general, are not strongly correlated with each other. We also present descriptive statistics for all explanatory variables in relation to the three categories of ICT users for both administrative and patient care purposes (see Tables 7.7 and 7.8).

Table 7.6: Correlation Matrix of Dependent and Independent Variables

	Admin ICT Use	Patient Care ICT Use	Nurse Support	No. of GPs	Public Patients	No. of Patients	Admin Support	All GPs > 40yrs	Male	≥ 3 Admin ICT	≥ 3 PC ICT	Med. Eq. Portfolio
Patient Care ICT Use	0.64	1.00										
Nurse Support	0.26	0.29	1.00									
No. of GPs	0.38	0.36	0.28	1.00								
Public Patients	-0.14	-0.06	0.14	-0.06	1.00							
No. of Patients	0.36	0.33	0.35	0.70	-0.31	1.00						
Admin Support	0.19	0.18	0.27	0.13	0.02	0.27	1.00					
All GPs >40 yrs	-0.37	-0.42	-0.20	-0.53	0.06	-0.39	-0.15	1.00				
Male	-0.13	-0.18	-0.01	-0.05	0.15	-0.08	-0.10	0.18	1.00			
≥ 3 Admin ICT	0.47	0.42	0.21	0.21	-0.08	0.28	0.19	-0.26	-0.07	1.00		
≥ 3 PC ICT	0.67	0.91	0.34	0.38	-0.05	0.36	0.24	-0.42	-0.16	0.55	1.00	
Med. Eq. Portfolio	0.28	0.26	0.37	0.22	-0.01	0.31	0.23	-0.22	-0.01	0.25	0.30	1.00
HSE Northeast	0.02	-0.01	0.08	-0.01	-0.08	0.13	0.03	-0.04	-0.03	0.05	0.00	0.02
HSE South	0.09	0.10	0.10	0.09	0.08	-0.01	0.05	-0.06	-0.04	0.04	0.08	-0.03
HSE West	-0.07	-0.07	-0.14	-0.14	0.19	-0.21	-0.10	0.08	0.07	-0.07	-0.05	0.00
Town	0.02	0.05	0.18	0.20	0.07	0.21	0.06	-0.07	0.04	0.02	0.07	0.07
Rural	-0.09	-0.09	0.00	-0.24	0.12	-0.28	0.03	0.17	0.04	-0.02	-0.09	0.04
Training	0.31	0.33	0.24	0.41	0.01	0.27	0.08	-0.40	-0.07	0.15	0.33	0.18
Supplier Visits	0.23	0.21	0.09	0.17	0.02	0.21	0.10	-0.05	-0.12	0.17	0.24	0.17
Clinic	0.13	0.14	0.18	0.23	-0.01	0.19	0.12	-0.11	0.01	0.15	0.14	0.21
Committee	0.07	0.14	0.06	0.02	0.05	-0.02	0.01	-0.08	0.03	-0.03	0.13	0.11
Academic	0.29	0.28	0.17	0.22	-0.09	0.14	0.04	-0.23	-0.09	0.13	0.26	0.16
Research Projects	0.20	0.23	0.11	0.14	-0.04	0.09	0.03	-0.15	0.07	0.10	0.24	0.15
ICGP course	0.17	0.19	0.08	0.10	-0.10	0.08	0.07	-0.11	-0.10	0.08	0.18	0.11
CME	0.02	0.13	0.06	0.08	0.04	0.02	0.03	-0.02	0.06	0.07	0.12	0.11

Table 7.6 (continued): Correlation Matrix of Dependent and Independent Variables

	HSE Northeast	HSE South	HSE West	Town	Rural	Training	Supplier Visits	Clinic	Committee	Academic	Research Projects	ICGP Course	CME
HSE Northeast	1.00												
HSE South	-0.31	1.00											
HSE West	-0.25	-0.46	1.00										
Town	0.02	0.02	-0.01	1.00									
Rural	-0.08	-0.01	0.18	-0.48	1.00								
Training	0.04	-0.08	0.03	0.12	-0.02	1.00							
Supplier Visits	-0.04	0.05	-0.06	0.01	-0.07	0.06	1.00						
Clinic	0.11	0.01	-0.07	0.08	0.14	0.15	0.10	1.00					
Committee	-0.02	-0.02	0.01	0.00	-0.05	0.14	0.04	-0.04	1.00				
Academic	0.06	0.01	-0.05	-0.06	-0.01	0.36	0.12	0.11	0.17	1.00			
Research Projects	0.02	-0.03	0.03	-0.02	0.07	0.28	0.03	0.08	0.16	0.31	1.00		
ICGP course	0.03	-0.05	0.03	0.04	0.00	0.11	0.08	0.10	0.17	0.21	0.18	1.00	
CME	-0.18	0.05	0.00	0.05	-0.06	0.05	0.00	0.03	0.10	0.08	0.06	0.10	1.00

Table 7.7: Descriptive Statistics of Explanatory Variables for ICT User Categories for Administrative Purposes

	Basic Use	Intermediate Use	Enhanced Use
Variable Name	Mean	Mean	Mean
Rank Effects			
Nursing Support	0.58	0.85	0.89
Number of GPs	1.76	1.42	3.50
Public Patients/ Total Patients	0.42	0.20	0.34
Log of Patients	7.60	8.04	8.37
Administrative Support	0.77	0.22	0.96
Age >40	0.74	0.50	0.25
Male Dominated	0.63	0.50	0.48
Learning-by-using Effects			
ICT Use for Patient Care Purposes (3 or more administrative ICT functions)	0.49	0.20	1.00
Portfolio of Medical Equipment (3 or more medical equipments)	0.71	0.25	0.97
Epidemic Effects			
HSE Dublin Mid-Leinster	0.26	0.23	0.22
HSE Dublin North East	0.16	0.35	0.15
HSE South	0.29	0.48	0.39
HSE West	0.29	0.44	0.23
City	0.29	0.28	0.37
Rural	0.21	0.42	0.11
Town	0.50	0.50	0.51
Training Practice	0.06	0.45	0.45
Clinic	0.33	0.50	0.55
Supplier Visits = 0	0.61	0.38	0.32
Supplier Visits = 1.5	0.33	0.39	0.35
Supplier Visits = 4	0.05	0.16	0.22
Supplier Visits = 7	0.00	0.03	0.07
Supplier Visits = 10	0.01	0.03	0.05
Committee Member	0.31	0.41	0.47
Academic Department	0.21	0.31	0.53
Research Project	0.13	0.15	0.36
ICGP Course	0.19	0.26	0.43
CME Meetings = 0	0.11	0.07	0.09
CME Meetings = 1.5	0.08	0.07	0.07
CME Meetings = 4	0.33	0.32	0.28
CME Meetings =7	0.48	0.55	0.55

Table 7.8: Descriptive Statistics of Explanatory Variables for ICT User Categories for Patient Care Purposes

	Basic Use	Intermediate Use	Enhanced Use
Variable Name	Mean	Mean	Mean
Rank Effects			
Nursing Support	0.59	0.84	0.91
Number of GPs	1.77	2.59	3.32
Public Patients/ Total Patients	0.37	0.41	0.35
Log of Patients	7.66	8.02	8.32
Administrative Support	0.79	0.95	0.95
Age >40	0.75	0.46	0.23
Male Dominated	0.62	0.51	0.44
Learning-by-using Effects			
ICT Use for Administrative Purposes (3 or more administrative ICT functions)	0.64	0.98	1.00
Portfolio of Medical Equipment (3 or more medical equipments)	0.74	0.92	0.97
Epidemic Effects			
HSE Dublin Mid-Leinster	0.25	0.23	0.23
HSE Dublin North East	0.17	0.15	0.14
HSE South	0.27	0.38	0.38
HSE West	0.31	0.25	0.25
City	0.30	0.29	0.34
Rural	0.23	0.22	0.13
Town	0.47	0.49	0.53
Training Practice	0.08	0.22	0.46
Clinic	0.36	0.51	0.56
Supplier Visits = 0	0.59	0.39	0.32
Supplier Visits = 1.5	0.35	0.36	0.37
Supplier Visits = 4	0.06	0.17	0.20
Supplier Visits = 7	0.00	0.05	0.02
Supplier Visits = 10	0.01	0.03	0.05
Committee Member	0.31	0.41	0.47
Academic Department	0.21	0.31	0.53
Research Project	0.13	0.15	0.36
ICGP Course	0.19	0.26	0.43
CME Meetings = 0	0.12	0.09	0.06
CME Meetings = 1.5	0.11	0.07	0.05
CME Meetings = 4	0.30	0.33	0.29
CME Meetings =7	0.47	0.51	0.60

7.3.2 Econometric Methodology for Intensity of ICT Use

Intensity of ICT use for both administrative and patient care functions are ordered categorical variables and, in line with Hollenstein (2004), can be analysed using the ordered probit model. The ordered probit model can be used to model a discrete dependent variable that takes ordered multinomial outcomes for each individual *i*, for example y_i = 1, 2......, m (Jones et al., 2007). This applies to our measure of ICT use, which has categorical outcomes: basic user, intermediate user, and enhanced user.

The ordered probit model can be expressed as:

$$y_i = j \ if \ \mu_{j-1} < y_i^* < \mu_j, \ \ j = 1, \dots \dots, m.$$

[Eqn. 7.1]

where the latent variable, y^* , is assumed to be a linear function of a vector of explanatory variables *x*, plus a random error term Ɛ:

$$y_i^* = x_i\beta + \varepsilon_i, \qquad \varepsilon_i \sim N(0,1)$$

[Eqn. 7.2]

and $\mu_0 = -\infty, \mu_j \leq \mu_{j+1}, \ \mu_m = \infty$. Given the assumption that the error term is normally distributed, the probability of observing a particular value of *y* is:

$$P_{ij} = P(y_i = j) = \Phi(\mu_j - x_i\beta) - \Phi(\mu_{j-1} - x_i\beta)$$

[Eqn. 7.3]

where $\Phi(.)$ is the standard normal distribution function. It is important to note that the coefficient values from the ordered probit model should not be given a quantitative interpretation (Jones et al., 2007). However, marginal effects can be calculated for each of the categorical outcomes which can be interpreted quantitatively.

It is also worth noting that the dependent variables being examined show a high level of correlation with each other (ρ =0.6395; see Table 7.5) indicating that a simultaneous equation model should perhaps be considered. However, given that both dependent variables are ordered categorical variables, we are not aware of an estimation technique that would allow us to estimate these models simultaneously while retaining the current structure of the variables. It is also likely that there may be endogeneity issues with some of the explanatory variables such as nursing support or administrative support. An instrumental variables approach would overcome such an issue, however, from the survey data it would be extremely difficult to identify appropriate instruments. It is also worth noting that these explanatory variables, indeed all explanatory variables in the models, are not strongly correlated with each other (see Table 7.6).

7.4 Econometric Results for Intensity of ICT Use

Ordered probit models are used to examine the determinants of intensity of ICT use for administrative and patient care purposes in Irish general practices. The ordered probit model estimations are presented in Tables 7.9a and 7.9b. Initial baseline models were estimated. Subsequently, in a 'stepwise' fashion, variables with z-statistics of less than |0.5| were excluded from the models.[94] The ordered probit models examining intensity of ICT use for administrative and patient care purposes are statistically significant and with R-squared values of 24 and 22 per cent respectively. Also, the statistical significance of the threshold parameters in the preferred ordered Probit models indicate the appropriateness of the model given ordered categories of the dependent variables (see Tables 7.9a and 7.9b). Given the restrictions in interpreting the ordered probit model coefficients (Jones et al., 2007), these results will be discussed briefly in Section 7.4.1. Subsequently, marginal effects will be presented and discussed in detail in Section 7.4.2.

[94] In a robustness check, comparison of significant coefficients in initial models and preferred models suggests that the exclusion of a number of insignificant variables has no effect on direction of significant coefficient values (see Tables 7.9a and 7.9b).

Table 7.9a: Intensity of ICT Use for Admin Functions – Ordered Probits

	Saturated Model	Model (ii)	Model (iii)	Preferred Model
	b/se	b/se	b/se	b/se
Rank Effects				
Nursing Support	0.171	0.172	0.182	0.183
	(0.170)	(0.170)	(0.167)	(0.166)
Number of GPs	0.118**	0.118**	0.127***	0.131***
	(0.054)	(0.054)	(0.043)	(0.043)
Proportion of Public Patients	-1.042***	-1.041***	-1.078***	-1.081***
	(0.321)	(0.321)	(0.294)	(0.294)
Log of Number of Patients	0.037	0.037		
	(0.125)	(0.124)		
Administration Support	0.32	0.32	0.335	0.335
	(0.243)	(0.243)	(0.237)	(0.237)
All GPs >40 years	-0.183	-0.184	-0.182	-0.181
	(0.135)	(0.134)	(0.134)	(0.134)
Male (GP) Dominated	-0.064	-0.063	-0.063	-0.062
	(0.112)	(0.111)	(0.111)	(0.111)
Learning-by-using Effects				
IT Use for Patient Care Functions	1.842***	1.842***	1.843***	1.836***
	(0.251)	(0.251)	(0.251)	(0.250)
Portfolio of Medical Equipment	0.383*	0.384*	0.393*	0.403*
	(0.224)	(0.224)	(0.222)	(0.221)
Epidemic Effects				
HSE Dublin Northeast	0.175	0.175	0.18	0.188
	(0.186)	(0.186)	(0.186)	(0.185)
HSE South	0.376**	0.375**	0.372**	0.372**
	(0.152)	(0.152)	(0.152)	(0.152)
HSE West	0.308*	0.308*	0.305*	0.300*
	(0.165)	(0.165)	(0.165)	(0.164)
Town Practice	-0.215	-0.215	-0.213	-0.205
	(0.130)	(0.130)	(0.130)	(0.129)
Rural Practice	-0.276	-0.277	-0.283	-0.263
	(0.178)	(0.178)	(0.177)	(0.172)

Table 7.9a (continued): Intensity of ICT Use for Admin Functions – Ordered Probits

Training Practice	0.292**	0.293**	0.292**	0.293**
	(0.141)	(0.141)	(0.141)	(0.141)
Visits from It Suppliers	0.074***	0.074***	0.075***	0.075***
	(0.026)	(0.025)	(0.025)	(0.025)
Practice Holds a Clinic	0.055	0.055	0.054	
	(0.114)	(0.114)	(0.114)	
Committee Member	0.01			
	(0.114)			
Academic Department	0.255**	0.256**	0.252**	0.254**
	(0.125)	(0.124)	(0.124)	(0.124)
Research Projects	0.219	0.22	0.219	0.22
	(0.136)	(0.136)	(0.136)	(0.136)
ICGP Course	0.153	0.155	0.154	0.156
	(0.121)	(0.121)	(0.120)	(0.120)
CME Meetings	-0.021	-0.02	-0.021	-0.021
	(0.024)	(0.024)	(0.024)	(0.024)
Summary Statistics				
Threshold Parameter 1	1.858*	1.852*	1.596***	1.593***
	(0.961)	(0.959)	(0.405)	(0.404)
Threshold Parameter 2	3.620***	3.614***	3.358***	3.355***
	(0.966)	(0.964)	(0.419)	(0.418)
N	523	523	523	523
Chi-Square	270.223	270.215	270.128	269.906
P - value	0	0	0	0
Bayesian Information Criterion	973.108	966.857	960.684	954.647

Notes: Coefficients are reported with standard errors in parentheses. *** denotes significance at the 1 per cent level; ** at the 5 per cent level and * at the 10 per cent level.

Table 7.9b: Intensity of ICT Use for Patient Care Functions Ordered Probits

	Saturated Model b/se	Model (ii) b/se	Model (iii) b/se	Preferred Model b/se
Rank Effects				
Nursing Support	0.387**	0.389**	0.375**	0.389**
	(0.166)	(0.166)	(0.161)	(0.158)
Number of GPs	0.059	0.058	0.055	0.054
	(0.055)	(0.055)	(0.054)	(0.054)
Prop. of Public Patients	-0.117	-0.108		
	(0.320)	(0.318)		
(Log) Number of Patients	0.084	0.086	0.103	0.11
	(0.125)	(0.125)	(0.115)	(0.114)
Administration Support	0.183	0.179	0.173	0.181
	(0.245)	(0.245)	(0.244)	(0.243)
All GPs >40 years	-0.417***	-0.418***	-0.418***	-0.424***
	(0.134)	(0.134)	(0.134)	(0.133)
Male (GP) Dominated	-0.281**	-0.282**	-0.287**	-0.287**
	(0.114)	(0.114)	(0.113)	(0.113)
Learning-by-using Effects				
IT Use for 3 or more Admin Functions	1.710***	1.709***	1.717***	1.725***
	(0.284)	(0.284)	(0.284)	(0.283)
Medical Equipment Portfolio	0.107	0.105	0.106	
	(0.218)	(0.217)	(0.217)	
Epidemic Effects				
HSE Dublin Northeast	0.045			
	(0.186)			
HSE South	0.311**	0.293**	0.289**	0.289**
	(0.152)	(0.132)	(0.132)	(0.132)
HSE West	0.2	0.182	0.174	0.178
	(0.166)	(0.147)	(0.145)	(0.145)
Town Practice	-0.13	-0.13	-0.135	-0.133
	(0.132)	(0.132)	(0.132)	(0.131)
Rural Practice	-0.267	-0.268	-0.271	-0.264
	(0.180)	(0.180)	(0.180)	(0.179)

Table 7.9b (continued): Intensity of ICT Use for Patient Care Functions – Ordered Probits

Training Practice	0.367**	0.366**	0.364**	0.362**
	(0.145)	(0.145)	(0.145)	(0.145)
Visits from It Suppliers	0.052**	0.051**	0.051**	0.052**
	(0.025)	(0.025)	(0.025)	(0.025)
Practice Holds a Clinic	0.085	0.088	0.089	0.096
	(0.116)	(0.115)	(0.115)	(0.115)
Committee Member	0.202*	0.201*	0.200*	0.205*
	(0.116)	(0.116)	(0.116)	(0.116)
Academic Department	0.116	0.118	0.121	0.125
	(0.127)	(0.127)	(0.127)	(0.126)
Research Projects	0.348**	0.349**	0.351**	0.356**
	(0.142)	(0.141)	(0.141)	(0.141)
ICGP Course	0.234*	0.235*	0.239*	0.239*
	(0.125)	(0.125)	(0.124)	(0.124)
CME Meetings	0.040*	0.039*	0.038*	0.039*
	(0.024)	(0.023)	(0.023)	(0.023)
Summary Statistics				
Threshold Parameter 1	2.400**	2.393**	2.540***	2.544***
	(0.989)	(0.988)	(0.889)	(0.888)
Threshold Parameter 2	3.686***	3.679***	3.826***	3.829***
	(0.994)	(0.993)	(0.894)	(0.893)
N	523	523	523	523
Chi-Square	253.217	253.159	253.045	252.808
P – value	0	0	0	0
Bayesian Information Criterion	1006.45	1000.25	994.1	988.077

Notes: Coefficients are reported with standard errors in parentheses. *** denotes significance at the 1 per cent level; ** at the 5 per cent level and * at the 10 per cent level.

7.4.1 Ordered Probit Estimations for Intensity of ICT Use

This section discusses the ordered probit estimations for intensity of ICT use for administrative and patient care purposes, firstly, with respect to rank effects, then, learning-by-using effects and, finally, epidemic effects. There is evidence that the equilibrium model rank effects variables impact on intensity of ICT use for both administrative and patient care functions. However, different rank effect variables impact on intensity of use for both purposes. For instance, as the number of GPs in a practice increases, intensity of ICT use for administrative purposes increases. Also, as the proportion of public patients in the practice relative to the total number of patients increases, intensity of ICT use for administrative purposes decreases. Both these relationships are statistically significant at the 1 per cent level. Neither of these variables impact on intensity of ICT use for patient care purposes. Nursing support positively impacts on intensity of ICT use for patient care purposes. However, practices dominated by male GPs and by older GPs negatively impact on the intensity of ICT use for patient care purposes. None of these three variables impact on intensity of ICT use for administrative purposes. The remaining rank effect variables, the number of patients and administrative support, do not impact on either type of ICT use.

There are more consistent findings for both types of ICT use in relation to learning-by-using effects. As discussed in the previous section, we use a variable measuring learning-by-using ICT for at least three administrative functions in the patient care ICT analysis and a variable measuring learning-by-using ICT for at least three patient care functions in the administrative ICT analysis. There is clear evidence of learning-by-using effect in both models. Practices which use

ICT for at least three patient care and administrative functions are more likely to extensively use ICT for administrative and patient care purposes respectively. These effects are statically significant at the 1 per cent level. [95]

There is also strong evidence of epidemic effects in relation to intensity of ICT use. In relation to practice location, practices located in the HSE South indicate a greater propensity to intensively use ICT for both administrative and patient care purposes relative to practices located in the HSE Dublin Mid-Leinster region. This relationship is statistically significant at the 5 per cent level for both types of ICT use. There is also evidence that practices in the HSE West region have a greater propensity to intensively use ICT for administrative purposes. This relationship is statistically significant at the 10 per cent level. Interestingly, practice location, with respect to city, town and rural location, does not impact on intensity of ICT use.

There is evidence of consistent epidemic effects with respect to both intensity of ICT use for administrative and patient care purposes. In relation to visits from IT suppliers, as the number of visits increases, propensity to intensively use ICT for both administrative and patient care purposes also increases. These findings are statistically significant at the 1 and 5 per cent levels respectively. Training practices are also more likely to intensively use ICT for both purposes. These

[95] There is evidence of a positive relationship between a practices' portfolio of medical equipment and intensity of ICT use for administrative purposes. This result indicates that learning which takes place within a practice from experience with one type of technology may positively influence adoption and intensity of adoption of seemingly unrelated technologies. However, this relationship is statistically significant at the 10 per cent level.

findings are statistically significant at the 5 per cent level. There is no evidence that practices that hold clinics are more likely to be intensive users of ICT.

There is further evidence of epidemic effects; however, they are not consistent in relation to both types of ICT use. For instance, practices affiliated with an academic department have a greater propensity to intensively use ICT for administrative purposes. This finding is statistically significant at the 5 per cent level. However, such an affiliation does not impact on intensity of ICT use for patient care purposes. Active involvement in research projects positively impacts on propensity to intensively use ICT for patient care purposes. This finding is statistically significant at the 5 per cent levels respectively. However, involvement in research projects does not influence intensity of ICT use for administrative purposes.

The ordered probit estimations for intensity of ICT use for administrative and patient care purposes illustrate interesting results in relation to rank, learning-by-using and epidemic effects. There is evidence of rank effects, however these is a clear distinction with respect to the rank effects variables influencing intensity of ICT use for administrative purposes and those influencing intensity of ICT use for patient care purposes. The number of GPs in a practice positively impacts on intensity of ICT use for administrative purposes, and the proportion of public patients relative to total patients negatively impacts on intensity of ICT use for administrative purposes. However, in relation to intensity of ICT use for patient care purposes, nursing support has a positive influence, whereas male dominated practices and practices with older GPs negatively influence intensity of ICT use. There is more consistent evidence of learning-by-using effects with respect to both types of ICT use. Learning from using ICT for administrative purposes positively impacts on intensity of ICT use for patient care purposes and, likewise, learning from using ICT for patient care purposes positively impacts on intensity of ICT use for administrative purposes.

There is also evidence of epidemic effects, some common to both types of ICT use, others relevant to only one type of ICT use. Practices in the HSE South region use ICT more intensively for administrative and patient care purposes. Visits from IT suppliers and being a training practice positively influences intensity of ICT use for both purposes. An academic affiliation positively impacts ICT use for administrative purposes. Whereas being actively involved in research projects positively impacts on intensity of ICT use for patient care purposes.

From the results discussed above, it is clear that equilibrium, disequilibrium and learning-by-using effects influence general practices' intensity of ICT use for administrative and patient care purposes. When interpreting ordered probit coefficients, we are restricted to interpreting the sign and significance of the coefficients. However, the next section presents marginal effects for the three categories of ICT user for administrative and patient care purposes, which allows us to determine the probability of a practice being in these categories of ICT use.

7.4.2 Ordered Probit Marginal Effects for Intensity of ICT Use

Marginal effects are calculated for each of the three outcomes, basic user, intermediate user, and enhanced user, for intensity of ICT use for administrative purposes and patient care purposes, and presented in Tables 7.10a and 7.10b respectively.

As discussed in the previous section, the number of GPs and the proportion of public patients influence intensity of ICT use for administrative purposes. Table 7.10a presents the marginal effects for these relationships. The more GPs in a practice, the less likely a practice is to be a basic user or intermediate user of ICT for administrative purposes and the more probable the practice is an enhanced user. However, the size of the marginal effects is relatively small indicating that the number of GPs in practice does not considerably influence intensity of ICT use. The proportion of public patients in a practice influences intensity of ICT use for administrative purposes, in that, the higher the proportion of public patients, the more likely a practice is to be a basic or intermediate user and less likely to be an enhanced user of ICT for administrative purposes. As is evident from the marginal effects, the size of this effect is relatively large.

Table 7.10a: Intensity of ICT use for Administrative Purposes – Marginal Effects

	Basic User	Intermediate User	Enhanced User
	dy/dx	dy/dx	dy/dx
Rank Effects			
Nursing Support	-0.031	-0.022	0.053
Number of GPs	-0.022***	-0.016***	0.038***
Prop. of Public Patients	0.183***	0.129***	-0.311***
Administration Support	-0.057	-0.040	0.097
All GPs >40 yrs	0.031	0.022	-0.052
Male Dominated	0.010	0.007	-0.018
Learning-by-using Effects			
Patient Care IT Use	-0.310***	-0.219***	0.529***
Medical Equip. Portfolio	-0.068*	-0.048*	0.116*
Epidemic Effects			
HSE Dublin Northeast	-0.032	-0.022	0.054
HSE South	-0.063**	-0.044**	0.107**
HSE West	-0.051*	-0.036*	0.086*
Town Practice	0.035	0.024	-0.059
Rural Practice	0.044	0.031	-0.076
Training Practice	-0.050**	-0.035**	0.084**
Visits from It Suppliers	-0.013***	-0.009***	0.022***
Academic Department	-0.043**	-0.030**	0.073**
Research Projects	0.037	-0.026	0.063
ICGP Course	-0.026	-0.019	0.045
CME Meetings	0.004	0.003	-0.006

Notes: *** denotes significance at the 1 per cent level; ** at the 5 per cent level and * at the 10 per cent level.

Table 7.10b: Intensity of ICT use for Patient Care Purposes – Marginal Effects

	Basic User	Intermediate User	Enhanced User
	dy/dx	dy/dx	dy/dx
Rank Effects			
Nursing Support	-0.077***	-0.039***	0.116***
Number of GPs	-0.011	-0.005	0.016
(Log) Number of Patients	-0.022	-0.011	0.033
Administration Support	-0.036	-0.018	0.054
All GPs >40 yrs	0.083***	0.043***	-0.126***
Male Dominated	0.056**	0.029**	-0.085**
Learning-by-using Effects			
Administrative IT Use	-0.339***	-0.174***	0.513***
Epidemic Effects			
HSE Dublin Northeast	-0.057	-0.029	0.086
HSE South	-0.035**	-0.018**	0.053**
HSE West	0.026	0.013	-0.040
Rural Practice	0.052	0.027	-0.079
Training Practice	-0.071**	-0.037**	0.108**
Visits from It Suppliers	-0.010**	-0.005**	0.154**
Practice holds Clinics	-0.019	-0.010	0.029
Committee Member	-0.040*	-0.021*	0.061*
Academic Department	-0.025	-0.013	0.037
Research Projects	-0.070**	-0.036**	0.106**
ICGP Course	-0.047*	0.024*	0.071*
CME Meetings	-0.008*	0.004*	0.017*

Notes: *** denotes significance at the 1 per cent level; ** at the 5 per cent level and * at the 10 per cent level.

As previously discussed, practice profile with respect to gender, age and nursing support influence intensity of ICT use for patient care purposes. If a practice has nursing support, it is 8 and 4 per cent less likely to be a basic and intermediate user of ICT for patient care purposes respectively, and 12 per cent more likely to be an enhanced user (see Table 7.10b). In practices where all GPs are forty years of age or older, they are 8 and 4 per cent more likely to be a basic or intermediate user of ICT for patient care purposes respectively, and 12 per cent less likely to be an enhanced user. A similar pattern is evident in relation to male dominated practices. Practices with more male than female GPs are 6 and 3 per cent more likely to be basic and intermediate users of ICT for patient care purposes respectively and 9 per cent less likely to be enhanced users (see Table 7.10b).

With respect to learning-by-using effects from ICT, the size of the marginal effects is quite large indicating a significant economic effect (Tables 7.10a and 7.10b). A practice which uses ICT for three or more administrative functions is 34 and 17 per cent less likely to be a basic or intermediate user of ICT for patient care purposes and 51 per cent more likely to be an enhanced user. Likewise, a practice which uses ICT for three or more patient care functions is 31 and 22 per cent less likely to be a basic or enhanced user of ICT for administrative purposes and 53 per cent more likely to be an enhanced user.

The epidemic effects in relation to ICT use for administrative and patient care purposes are discussed, focusing on location effects initially. As previously discussed, there is a positive relationship between HSE South practices and intensity of ICT use. Practices located in the HSE South region are 6 and 4 per cent less likely to be basic and intermediate users of ICT for administrative purposes than practices in the HSE Mid-Leinster region and 11 per cent more likely to be enhanced users. These practices located are also 6 and 3 per cent less likely to be basic and intermediate users of ICT for patient care purposes than practices in the HSE Mid-Leinster region and 9 per cent more likely to be enhanced users.

As IT supplier visits increases, so too does intensity of ICT use for both administrative and patient care purposes. The greater the number of visits from suppliers, the less likely a practice is to be a basic and intermediate user of ICT for both administrative and patient care purposes and more likely to be an enhanced user for both types of ICT use. However, it is worth noting that the size of marginal effects are quite small, indicating low economic significance in relation to interaction with suppliers and intensity of ICT use.

Being a training practice positively impacts on intensity of ICT use. If a practice is a training practice, it is 5 and 4 per cent less likely to be a basic and intermediate user of ICT for administrative purposes respectively, and 8 per cent more likely to be an enhanced user. Likewise, if a practice is a training practice, it is 7 and 4 per cent less likely to be a basic and intermediate user of ICT for patient care purposes respectively, and 11 per cent more likely to be an enhanced user.

The remaining epidemic effects are evident in relation to one or other type of ICT use. In relation to ICT use for administrative purposes, practices with an academic affiliation are 4 and 3 per cent less likely to be basic and intermediate users respectively, and 7 per cent more likely to be enhanced users. In relation to ICT use for patient care purposes, practices actively involved in research projects are 6 and 4 per cent less likely to be basic and intermediate users and 11 per cent more likely to be enhanced users.

7.4.3 Discussion of Intensity of ICT Use Estimations

The previous sections presented ordered probit estimations (7.4.1) and marginal effects (7.4.2) for intensity of ICT use for administrative and patient care purposes. There is clear evidence of equilibrium, disequilibrium and learning-by-using effects, although these effects are not always consistent in how they are revealed in the different ICT usage models. This section will discuss our results in the context of our anticipated results and previous literature.

Firstly, we will discuss the rank effects with respect to intensity of ICT use. In line with Hollenstein (2004) and Battisti et al. (2007), we find little evidence of size effects in relation to intensity of ICT use. The number of GPs in a practice does not impact on intensity of ICT use for patient care purposes, and only marginally positively impacts on intensity of ICT use for administrative purposes. The number of patients in a practice does not impact on intensity of ICT use. It is possible that once a practice adopts ICT, small and large practices use it to the same extent (Hollenstein, 2004). Interestingly, the higher the proportion of public patients a practice has, the more likely they are to be basic or intermediate users of ICT for administrative purposes. This may indicate that practices with a high proportion of public patients must fulfil certain requirements in terms of registering patients, but are not obliged to be intensive users of ICT for administrative purposes. In line with our previous findings of the positive influence of nursing support on prescription drugs and medical equipment adoption, we find that nursing support positively influences intensity of ICT use for patient care purposes.

The cost of adopting additional ICT applications has previously been discussed. The influence of these rank effects on intensity of ICT use may be capturing, to some extent, the cost of increasing intensity of ICT use. If becoming an 'enhanced' user of ICT for administrative and patient care purposes requires a considerable monetary and effort outlay, then larger practices are more likely to be able to afford to take that step. Therefore, the positive influence of the number of GPs and proportion of private patients in a practice on intensity of ICT use for administrative purposes and nursing support on intensity of ICT use for patient care purposes may be portraying the ability of such practices to afford to become 'enhanced' ICT users.

The GP age and gender profile within practices does not impact on intensity of ICT use for administrative purposes. However, practices where all GPs are older than 40 years of age and practices that are predominately male are 13 and 9 per cent less likely to be enhanced users of ICT for patient care purposes. The finding that practices where all GPs are older than 40 year or age are less likely to be intensive ICT users is intuitive and in line with previous research (Masters, 2008; Meade et al., 2009). Also, in our prescribing innovation analysis, we find that older GPs are slower to adopt new drugs. However, it is somewhat surprising that male dominated practices are less likely to be intensive users of ICT. Previous research indicated that male GPs were more likely to use ICT than female GPs (Masters, 2008; Meade et al., 2009). Also, in Chapter 6, we find that practices that are predominately male are more likely to use at least three of the six types of medical equipment examined. This finding, that male (GP) dominated practices are less likely to be intensive users of ICT, may be further evidence that drivers of use are not necessarily drivers of intensity of use.

Our empirical findings demonstrate the considerable influence of learning-by-using effects on intensity of ICT use. A practice which uses ICT for three or more administrative functions is 51 per cent more likely to be an enhanced user of ICT for patient care purposes. Likewise, a practice which uses ICT for three or more patient care functions is 53 per cent more likely to be an enhanced user of ICT for administrative purposes. Therefore, practices that use ICT for one particular purpose are significantly more likely to become extensive users of ICT for another purpose. The implication being here that practices learn and benefit from complementary ICT use in terms of becoming intensive ICT users for a different purpose. There is also strong evidence that learning-by-using from a portfolio of medical equipment positively influences intensity of ICT use for administrative purposes. This is further evidence that learning- by-using effects positively influence intra-firm diffusion. These findings are in line with Battisti and Stoneman (2005) who report positive learning-by-using effects from complementary technologies in relation to extent of use of CNC machines, and with our previous empirical exercises which also illustrate the influences of learning-by-using effects on adoption of new drugs and use of medical equipment.

This study also presents strong evidence of epidemic effects. Epidemic effects are measured by a number of variables which measure practice location and interaction and education factors. Some of the epidemic effects variables influence both types of ICT use, and others influence one or other type of ICT use. There is some evidence of location effects, in that practices located in the HSE South are more likely to be intensive users of ICT for both purposes examined. In fact, practices are between 5 and 10 per cent more likely to be enhanced users of ICT for patient care and administrative purpose than practices in the HSE Dublin Mid-Leinster region. As previously mentioned, the HSE South has an independent ICT strategy. While this strategy pertains to all aspects of health care provisions, it is probable that knowledge spillovers are influencing the intensity of ICT use in general practices in the HSE South. Potential policy implications in relation to this finding are discussed in Chapter 8.

Surprisingly, practice location with respect to city, town and rural distinctions does not influence intensity of ICT use. However, given that a high proportion of practices in the HSE South region are rural or town practices, it is likely that our findings in relation to intensity of ICT use and HSE South are capturing a rural influence. Previous empirical studies report that rural GPs were more likely to keep EPRs than their urban counterparts (Meade et al., 2009), and are better equipped than their urban counterparts, possibly to compensate for less access to secondary care services (Boerma et al., 1998; Nic Gabhainn et al., 2001).

Now, focusing on how interaction and education factors influence intensity of ICT use. Epidemic effects, measured by training practice and supplier visits variables, are evident in relation to both types of ICT use. Being affiliated with an academic institution positively influences a practice's propensity to intensively use ICT for administrative purposes, while active involvement in research projects positively influence intensity of ICT use for patient care purposes. In support of Mansfield's (1963) hypothesis that intra-firm diffusion is influenced by epidemic effects, we find evidence of epidemic effects with respect to intensity of ICT use. However, previous empirical studies, also drawing on a complementary equilibrium and disequilibrium framework, report conflicting evidence of epidemic effects (Hollenstein, 2004; Battisti et al., 2007). It is worth noting that studies use different variables to measure epidemic effects which may impact on findings (Battisti et al., 2007), and there is evidence that the importance of explanatory variables is technology-specific (Hollenstein, 2004).

In summation, there is clear evidence that rank, learning-by-using and epidemic effects influence intensity of ICT use in Irish general practices.

7.5 Conclusion

The purpose of this chapter is to examine the intensity of ICT use in Irish general practices. The commercial autonomy which characterise Irish general practice suggests that decisions concerning ICT use may reflect both medical and commercial factors. In fact, there are clear 'business' reasons for using certain ICT functions, such as patient registration and accounts, whereas the use of other ICT functions, such as coding and quality assurance, would indicate more altruistic decision-making. Extending our encompassing theoretical framework to intra-practice ICT diffusion, we examine the influence of equilibrium, disequilibrium and learning-by-using effects on intensity of ICT use.

There is clear evidence that practice heterogeneity influences intensity of ICT use, although the variables measuring rank effects are not consistent in their influence on both types of ICT use. To date, previous empirical studies have reported inconclusive evidence of rank effects with respect to intensity of use. Learning-by-using effects demonstrate a considerable influence on intensity of ICT use in this study. To date, there is little research on how learning-by-using effects impact on intensity of use, with the exception of Battisti and Stoneman (2005) who also report positive learning-by-using effects in relation to extent of use of CNC machines. In line with earlier examinations of intra-firm diffusion, we also find evidence of epidemic effects, particularly in relation to interaction with and learning from external agents. There also appears to be evidence in support of the HSE South's ICT strategy positively influencing ICT use in practices in that region. Table 7.11 provides a symbolic summary of our results in relation to intensity of ICT use.

This study contributes to a limited body of research concerning intensity of adoption. Our research findings support the extension of our encompassing theoretical model to examinations of intensity of adoption. These research findings, along with our findings in relation to prescribing innovation and medical equipment use, will be discussed in the following chapter, thereby presenting a holistic view of Irish GPs innovative behaviour.

Table 7.11: Symbolic Summary of Anticipated Effects and Results

	Anticipated Effect	Intensity of ICT Use for Administrative Purposes	Intensity of ICT Use for Patient Care Purposes
Rank Effects			
Nursing Support	+		+
Number of GPs	-	+	
Prop. of Public Patients	+	-	
(Log) Number of Patients	-		
Administration Support	+		
All GPs >40 years	-		-
Male (GP) Dominated	+		-
Learning-by-using Effects			
IT Use for 3 or more Functions	+	+	+
Medical Equipment Portfolio	+	+	
Epidemic Effects			
HSE Dublin Northeast	-		
HSE South	+	+	+
HSE West	+	+	
Town Practice	-		
Rural Practice	+		
Training Practice	+	+	+
Visits from It Suppliers	+	+	+
Practice Holds a Clinic	+		
Committee Member	+		+
Academic Department	+	+	
Research Projects	+		+
ICGP Course	+		+
CME Meetings	+		+

Notes: '-' denotes a negative and significant effect (at the 10 per cent level or above); '+' denotes a positive and significant effect.

CHAPTER 8: CONCLUSION

8.1 Introduction

The aim of this thesis is to examine the timing and use of innovations in general practices in Ireland. The influence of practice heterogeneity (rank effects); strategic behaviour (stock and order effects); cumulative learning from previous adoption decisions (learning-by-using effects); and learning and knowledge spillovers (epidemic effects) on the perceived benefits of adopting and using innovations in general practices is investigated. In order to examine the innovative behaviour of Irish GPs, we addressed the following research questions:

(i) What are the determinants of timing of adoption of new prescription drugs by Irish GPs?

(ii) What influences the use of medical equipment in Irish general practices?

(iii) What factors influence intensity of ICT use in Irish general practices?

This thesis provides us with a holistic view of the innovativeness of Irish GPs. Our research suggests that the general practice environment in Ireland facilitates and incentivises innovative decision-making with respect to practice development and health care provision. Empirically, we identify the influence of informational and learning stimuli, as well as economic and commercial motivations, on timing of adoption, multiple technology adoption and intensity of adoption of innovations in a health care setting. Furthermore, our empirical findings support the application of our encompassing theoretical model, which incorporates equilibrium, disequilibrium and learning-by-using effects, to an investigation of the timing of innovative behaviour in Irish general practices, and the extension of that model to multiple technology adoption and intensity of adoption.

This chapter outlines the contribution of this thesis to knowledge (8.2) and theory (8.3), and discusses potential policy implications arising from this work (8.4). Research limitations are discussed in Section 8.5 and, finally, future research plans and possibilities suggested by the research are discussed (8.6).

8.2 Contribution to Knowledge

This thesis provides us with a distinctive understanding of Irish GPs, with a particular focus on what influences their prescribing and practice development decision-making. An important contribution of this work is the empirical evidence of learning-by-using effects and their influence on inter- and intra-practice diffusion. We also provide considerable evidence in relation to the influence of equilibrium and disequilibrium effects on timing of adoption, multiple technology adoption and intensity of adoption in a health care setting. We discuss the importance of taking a multiple technology approach to studies of adoption decision-making. Furthermore, we employ three different econometric techniques to address our timing of adoption, multiple technology adoption and intensity of adoption research questions. This section discusses how this thesis contributes to our understanding of Irish GPs innovative capabilities and to our broader understanding of the factors influencing adoption of innovations in health care and commercial settings.

8.2.1 Irish GP's Innovative Behaviour

Our findings point to a group of health care professionals that exhibit notable innovative behaviour. In general, Irish GPs prescribe new drugs soon after they reach the Irish market, invest in a range of medical equipment, and are active users of ICT for administrative and patient care purposes. Our research demonstrates that Irish GPs respond to informational and learning stimuli in the development of their practices and prescribing behaviour. Furthermore, our findings also reveal that GPs are incentivised by commercial and market considerations.

Given the nature of general practices in Ireland, it is very likely that the autonomy enjoyed by Irish GPs facilitates the adoption of health care technologies. Irish GPs enjoy certain independence in the running and staffing of their practices. They are, in fact, operating in a market where they compete for public and private patients. Therefore, like any small business unit, decisions concerning adoption and intensity of adoption of new innovations are influenced by the expected commercial outcomes for the business. The autonomy enjoyed by Irish GPs not only influences how they respond to commercial and market incentives, but also provides them with the freedom to learn from interactions with others and previous adoption decisions and incorporate this accumulated knowledge in ensuing adoption decisions. With prescribing and practice development decision-making at the practice or individual GP level, Irish GPs are given ample incentives and opportunities to innovate. This innovative behaviour has positive consequences for their businesses and their patients.

8.2.2 Learning-By-Using Effects on Adoption and Intensity of Adoption

A particular insight from this research is the influence of learning-by-using effects on GP's innovative behaviour. The influence of learning-by-using effects is consistent and strongly significant across all innovative decision-making examined (see Table 8.1 for a symbolic summary of key empirical findings). Specifically, we find evidence of earlier adoption of new drugs by GPs with broader prescribing portfolios. Also, practices with a large portfolio of medical equipment are more likely to invest in new medical equipment. In relation to ICT use, we find that users of ICT for administrative purposes are more likely to be intensive users of ICT for patient care purposes. We also find practices that use ICT for patient care purposes and practices with a large portfolio of medical equipment are more likely to be intensive users of ICT for administrative purposes.

In essence, the extent which a practice adopts technologies and learns from that experience influences ensuing adoption decisions. Therefore, Irish GPs demonstrate a capacity for accumulating knowledge and learning from adoption decisions, which they use to make informed decisions concerning the development of their practice and the health care provided to their patients. It is likely that the autonomy enjoyed by Irish GPs in how they equip their practices and what drugs they prescribe to their patients provides them with the scope to benefit from this learning experience. The evidence of the impact of learning-by-using effects on innovative behaviour indicates that learning from experience of previously adopted technologies within the practice is as important, if not more so, as learning from interactions with those external to the practice. To date, there is a paucity of studies on the influence of cumulative learning on adoption decisions (Stoneman and Kwon, 1994; Colombo and Mosconi, 1995; Arvantis and Hollenstein, 2001) and intensity of adoption decisions (Battisti and Stoneman, 2005). Therefore, our research contributes to the broader debate of the significance of learning-by-using effects on inter- and intra-firm diffusion.

Table 8.1: Key Empirical Findings of Equilibrium, Disequilibrium and Learning-by-Using Effects on Timing of Adoption, Use and Intensity of Use of Innovations

	Equilibrium Model			Disequilibrium Model	Learning-by-Using Model
	Rank Effects	**Stock Effects**	**Order Effects**	**Epidemic Effects**	**Learning-by-Using Effects**
Timing of Prescription of New Drugs	✓	✓✓	✓✓	✓	✓✓
Use of Medical Equipment	✓			✓	✓✓
Intensity of ICT Use	✓			✓✓	✓✓

✓ indicates evidence of effect with respect to adoption of innovation. ✓✓ indicates strong evidence of effect with respect to adoption of innovation. Shaded cell indicates that relevant effect was not tested in empirical exercise.

8.2.3 Equilibrium Effects on Adoption and Intensity of Adoption

Our findings suggest the commercial elements of the Irish general practice market incentivise innovative decision-making. Within the equilibrium model of adoption, we examine the influence of rank, stock and order effects on GPs decision-making concerning adoption of innovations. In our three empirical exercises, we model the influence of rank effects, measured by GP and practice characteristics, on timing of adoption, use and intensity of use of innovations in general practices. There is considerable evidence of rank effects influencing adoption decisions (Stoneman and Kwon, 1994; Baptista, 2000; Battisti et al., 2007). In line with this literature and considering the prescribing and commercial autonomy of Irish GPs, we expected rank effects to influence such innovative decision-making. This expectation is realised as our research demonstrates the influence of rank effects on timing of first prescription of new drugs, use of medical equipment and intensity of ICT use.

In our empirical investigations, rank effects are measured by variables such as nursing and administrative support, patient numbers and GP age. It is important to note that as two datasets are used in our empirical analyses, rank effects are measured by different variables. In relation to prescribing innovation, younger GPs and those who work with the support of a nurse and secretary are early adopters of new drugs. With respect to medical equipment use, there is evidence that practices with nursing support, high patient numbers, and more male GPs are more likely to use medical equipment. Interestingly, there is no consistency in how the rank effect variables influence intensity of ICT use for administrative and patient care purposes. Increasing GP numbers and decreasing proportions of public patients in a practice positively influence intensity of ICT use for administrative purposes. Nursing support positively influences intensity of ICT use for patient care purposes; whereas practices with older, male GPs are less likely to be intensive users of ICT for patient care purposes.

Therefore, the influence of rank effects on innovative decision-making is clearly affected both by the specific innovation being examined and by how such effects are measured. However, the influence of some rank effects variables is evident in relation to a number of these decisions. For instance, nursing support positively affects innovative behaviour in relation to all three areas of decision-making considered. There may be a number of reasons why this is the case. Practices which employ nursing support may be larger, more profitable practices. It may also be the case that practices with nursing support may be more patient-focused and this may influence their prescribing and investment decisions. Previous studies also highlight the positive influence of human capital on decision-making concerning the adoption of innovations (Karshenas and Stoneman, 1993; Baptista, 2000). We also find that older GPs are less likely to prescribe new drugs and be intensive users of ICT for patient care purposes. This finding is in line with much of the literature concerning the negative influence of age on adoption of new technologies (Masters, 2008; Meade et al., 2009).

In general, our research supports the hypothesis that rank effects influence inter- and intra-practice diffusion of innovations. The significance of rank effects may reflect the fact that Irish GPs have considerable economic independence: they choose whether they work with other GPs and/or primary care professionals; what support staff, if any, they employ; and the number and type (public and/or private) of patients they see. Therefore, the independence enjoyed by Irish GPs may encourage innovative behaviour in the form of prescribing new drugs and developing their practice. Our research indicates that the free-market elements of the general practice environment in Ireland may incentivise innovative decision-making; in turn, benefitting patient care.[96]

One of the more surprising findings from this research is the influence of strategic behaviour on adoption and use of innovations by GPs. Stock and order effects are included in our analyses to reflect trade-offs between the costs and benefits of adoption by co-related agents (Karshenas and Stoneman, 1993). In view of the independence of general practices in Ireland and the prescribing and commercial autonomy enjoyed by GPs, *a priori*, we expected that these effects would be evident with respect to decision-making where GPs incur a monetary cost from adoption, such as investments in medical equipment and ICT, more so than in decision-making where GPs do not incur a monetary cost from adoption, for instance, when prescribing drugs to patients.

Due to data restrictions, we do not test for either stock or order effects in relation to intensity of ICT use or for the stock effect in relation to medical equipment use. However we do test for order effects in relation to medical equipment use and both stock and order effects in relation to the timing of prescribing innovation. Our results in relation to the strategic behaviour stock and order effects are interesting and somewhat counter-intuitive. We find little evidence of an order effect in relation to the use of medical equipment. However, in our examination of the timing of the first prescription of new drugs by GPs, we find

[96] Previous European research also reports more innovative patient care by self-employed GPs than salaried GPs (Boerma et al., 1997)

consistently strong evidence of order and stock effects: GPs who have a track record of early adoption tend also to be early adopters of other drugs; and, the larger the proportion of GPs who have already adopted a new drug the slower subsequent adoption.

Our investigation into the influence of strategic behaviour on adoption and use of health care innovations by GPs produces interesting results. Our results indicate that Irish GPs may be motivated by first-mover advantage in their prescribing decisions. Perhaps GPs perceived as being innovative are more likely to attract mobile public and private patients. Although another equally valid interpretation of this finding is that these stock and order effects may, in fact, be capturing informational and learning elements.[97] It may be the case, for instance, that the rapid adoption of the six drugs examined is due to unobserved learning effects and, therefore: early adopters of one drug have learnt the benefits of early adopting and tend to be early adopters of other drugs (order effect); and subsequent adoption may be slow as the remaining GPs primarily comprise of non-adopters (stock effect).

8.2.4 Disequilibrium Effects on Adoption and Intensity of Adoption

Our research also highlights the influence of network externalities on timing of adoption, use and intensity of use of innovations by GPs. Across the three aspects of innovative behaviour examined, we find evidence of epidemic effects.

[97] We are restricted to one measure of epidemic effects, rural practice allowance, in our prescribing innovation analysis.

However, it is important to note that as distinct datasets are used in the econometric exercises; epidemic learning effects are measured by different variables. For instance, in relation to our examination of prescribing innovation, we are constrained to measuring epidemic effects with a rural practice allowance variable; whereas in our examination of medical equipment and ICT use, we use many variables to capture epidemic learning effects. These variables include practice location, interaction with academics, suppliers and other health care practitioners, and educational measures. Given the robust empirical evidence of individuals adopting a new technology upon learning of its existence (Karshenas and Stoneman, 1993; Baptista, 2000; Burton et al., 2003; Rogers, 2003), we expect to find evidence of these 'word-of mouth' effects with respect to the adoption of health care technologies by Irish GPs.

In relation to the timing of prescribing innovation, we find slower adoption of new drugs by rural GPs. It is likely that geographically remote GPs have less opportunity to interact with others and, consequently, are less likely to hear of new drugs. We find that training practices are more likely to use medical equipment and to be intensive users of ICT. It is likely that training practices are required to be well equipped. However, it is also likely that their involvement in education increases the likelihood of hearing of new technologies. We also find that practices frequently visited by IT suppliers are more likely to be intensive users of ICT. These findings reflect an epidemic effect, with opportunities for learning about ICT from others positively influencing ICT use. There is also evidence of education, research and academic affiliations positively influencing ICT use for administrative or patient care purposes.

While there is some inconsistency in the influence of specific epidemic effect variables on ICT use for administrative and patient care functions, our research illustrates that informational factors influence intra-practice diffusion. On the whole, we find evidence of interaction and 'word-of-mouth' effects influencing if, when and to what extent Irish GPs adopt innovations.

A particularly interesting aspect of our results in relation to epidemic learning effects is that their influence on intensity of adoption (intensity of ICT use) is more compelling than their influence on adoption (timing of adoption of new drugs and use of medical equipment). This indicates that the ability of a general practice to absorb external knowledge is distinctly more important in relation to intra-practice diffusion than inter-practice diffusion. This is important in our understanding of how interaction with external agents and information acquisition can assist in how a practice uses ICT, or indeed any health care technology, to its full advantage. Enhanced use of health care innovations ensures improved practice management and patient care.

8.2.5 Adoption of Multiple Technologies

An important contribution of this thesis is centring our empirical analysis on the adoption of multiple technologies. We do not examine any one technology in isolation, but identify commonalties in the adoption process across a range of innovations. Explicitly, we examine decision-making concerning the adoption of six new drugs and six items of medical equipment. In our interpretation of our results, we do not focus on the impact of different factors on the adoption of one drug or one item of medical equipment in isolation, but attempt to identify commonalities in the adoption of the six drugs and the six items of medical equipment. The influence of rank, stock, order, epidemic and learning-by-using effects is not always consistent across innovations. Therefore, when interpreting our results, we conclude that the adoption of both new drugs and medical equipment by GPs is, to some extent, technology- specific, demonstrating the importance of examining the adoption of multiple technologies and not focusing on one technology.

In addition to considering the adoption and use of a number of health care technologies, we use a multiple technology adoption approach to our analysis of use of medical equipment (Stoneman and Kwon, 1994; Colombo and Mosconi, 1995; Stoneman and Toivanen, 1997). This multiple technology adoption approach allows us to identify commonalities in the adoption of multiple technologies, but also accounts for the unobservable factors which are common to the adoption of these items of medical equipment (see Section 6.4 for discussion of multivariate Probit model specification). Therefore, we ascertain the importance of, where possible, taking a multiple technology adoption approach to adoption and use of innovations.

8.2.6 Econometric Analysis of Timing of Adoption, Multiple Technology Adoption and Intensity of Adoption in a Health Care Setting

This thesis' overall contribution to knowledge is robust empirical evidence of the commercial and informational influences on timing of adoption, multiple technology adoption and intensity of adoption of innovations by Irish GPs. This contribution was possible due to: access to a unique prescribing dataset; the collation of a timely profile of general practices in Ireland, along with information on decision-making concerning their use of medical equipment and ICT; and the econometric techniques employed.

Our encompassing theoretical framework necessitated the application of multivariate econometric approaches. Furthermore, in our examination of timing of adoption, multiple technology adoption and intensity of adoption in Irish general practices, we apply novel econometric techniques to our empirical investigations. Ours is the first application of duration analysis to an examination of the timing of adoption of new prescription drugs by GPs. The nature of the prescribing dataset, which matches GPs prescribing history over a 4½ year time period with information on their characteristics, affords us the opportunity to employ duration analysis to determine the influences on first prescription of new drugs by Irish GPs.

In the following section, we discuss how our empirical findings support the extension of our encompassing theoretical framework to multiple technology adoption and intensity of adoption analyses. However, it is also important to note that these approaches to examining GP's decision-making necessitated the application of multivariate and ordered Probit techniques.

By applying a multivariate Probit analysis to our examination of medical equipment use, we are able to incorporate a multiple technology adoption framework to our investigation. This approach allows us to identify commonalities in the adoption of multiple items of medical equipment, but also accounts for unobservable factors which may also be common to the adoption of these technologies. Individual econometric examinations of the factors influencing the adoption of each item of medical equipment potentially may over-or-under estimate the influence of the various theoretical effects. Therefore, our integrated approach prevents misspecification bias and allows for cross-technology effects.[98]

Furthermore, extending our encompassing theoretical model to intensity of ICT use, we use ordered Probit analysis. This econometric approach allows us to identify the determinants which influence whether a practice is a basic, intermediate or enhanced user of ICT.

Drawing on our encompassing theoretical framework, using primary and secondary datasets and employing appropriate econometric techniques allowed us to make a number of contributions to knowledge as discussed above. The following section will discuss this thesis' contribution to theory.

8.3 Contribution to Theory

This section outlines the theoretical contributions of this thesis, such as support for learning-by-using effects and their influence on adoption behaviour, as well

[98] We did not take a multiple technology adoption approach in our examination of prescribing innovation as it is not possible to simultaneously model time to adoption econometric models. If a multivariate Probit approach was applied to our prescribing innovation analysis, the timing element of the analysis would be lost.

as support for examining adoption decision-making in a health care setting within a complementary equilibrium, disequilibrium and learning-by-using theoretical framework.

8.3.1 Learning-by-Using Effects on Adoption Behaviour

This study's principal theoretical contribution is the importance of experiential learning on adoption decision-making. We hypothesised that individual and corporate learning from previous adoption decisions influence subsequent decision-making concerning adoption, use and intensity of use of innovations. As discussed in section 8.2.2, our consistent empirical evidence of such effects illustrates the importance of experiential learning which takes place within the business unit on adoption and intensity of adoption.

In previous economic adoption studies, measures of learning by using effects have focused on learning from the adoption of complementary technologies and earlier technology vintages (Colombo and Mosconi, 1995; Arvantis and Hollenstein, 2001). However, in this thesis, we extend earlier conceptualisations of learning-by-using effects with a broader definition of experiential learning. Therefore, our variable measurements of learning-by-using effects include learning from an individual GP's portfolio of drugs, learning from a general practice's portfolio of medical equipment, and learning from ICT use for contrasting purposes.

The equilibrium and disequilibrium models of adoption are reasonably established in the innovation literature as a means to examining adoption decision-making. As discussed in Section 4.2, attempts have been made to integrate learning-by using effects into both the equilibrium model and the disequilibrium model. However, our consistent evidence of the influence of experiential learning on adoption and use of innovations places these learning-by-using effects at the centre of the theoretical debate.

Our evidence of the influence of learning-by-using effects on adoption decision-making is robust across the three types of innovations examined. As previously discussed, the trade-off between commercial and patient care motivations is greatly influenced by the nature of the innovation being adopted by general practices; nonetheless the influence of experiential learning is consistent for adoption decision-making concerning prescription drugs, medical equipment and ICT. Equally, there is robust evidence of the influence of learning-by-using effects on the different variants of adoption decision-making - timing of adoption, use and intensity of use.

8.3.2 Encompassing Theoretical Model of Adoption

Our empirical findings support the application of our encompassing theoretical model of adoption, incorporating the equilibrium, disequilibrium and learning-by-using models of adoption, to examining innovative behaviour in a health care setting. Previously, Karshenas and Stoneman (1993) presented a theoretical advance in the diffusion literature with a model of adoption incorporating rank, stock, order and epidemic effects. Previous empirical studies support the full or partial application of this complementary equilibrium and disequilibrium model of adoption to examinations of adoption decision-making (Stoneman and Kwon, 1994; Stoneman and Toivanen, 1997; Hollenstein, 2004; Battisti et al., 2007). Also, theoretical models incorporating aspects of Karshenas and Stoneman's (1993) model and the emerging learning-by-using models of adoption have also emerged in the adoption literature (Colombo and Mosconi, 1995; Arvantis and Hollenstein, 2001).

This is the first application of an encompassing equilibrium, disequilibrium and learning-by-using model of adoption to an examination of adoption in a health care setting. The general practice environment in Ireland provides us with a unique setting for applying our encompassing theoretical framework to gain an understanding of the adoption processes of GPs. Our research illustrates that adoption by GPs is a complex process, influenced by all of these elements. Thus, our empirical findings demonstrate the importance of incorporating all three models of adoption to theoretical frameworks in future studies of adoption decision-making in a health care setting.

Sections 8.2 and 8.3 outlined this thesis' contributions to knowledge and theory. The following section outlines potential policy implications of this research.

8.4 Implications for Policy

Our holistic examination of the adoption process in Irish general practice highlights the innovative capabilities of Irish GPs. We discuss our findings in relation to the three areas of innovative behaviour examined and their potential policy implications (8.4.1). We also discuss the likely implications of our work in the context of the proposed reforms of the Irish and UK health care systems (8.4.2).

8.4.1 Policy Implications for Adoption and Use of Prescription Drugs, Medical Equipment and ICT by GPs

The adoption of new prescription drugs is not uniform across all GPs suggesting the potential for targeted intervention to stimulate prescribing innovation. For example, older GPs and GPs practicing without the assistance of a nurse or secretary are in general slower to adopt new drugs suggesting these groups as a specific target for support. In addition, the influence of learning-by-using, stock, order and epidemic effects on prescribing of new drugs suggest the importance of GPs' ability to obtain information on new drugs. Pharmaceutical companies and continuing education provide GPs with information on new drugs. However, if policymakers want to influence the uptake of new drugs, whether new compounds to the market or generics of existing compounds, additional means of conveying information to geographically isolated GPs and GPs who do not prescribe from a large portfolio of drugs should be considered. Therefore, to encourage prescribing of specific drugs, measures which facilitate learning both within (learning-by-using effects) and outside (epidemic learning effects) the practice need to be considered. A possible means of communicating such information to GPs, who are unlikely to obtain such information due to location or limited experience, is through e-learning; whereby, GPs can access webinars or on-line tutorials which provide them with information on specific drugs. Such policy initiatives need to be considered, however, both in the light of the potential benefits of the adoption of new drugs and their potential risks (Florentinus, 2006).[99]

Within our multiple technology adoption framework, which accounts for cross-technology effects, it is difficult to identify practice or informational factors consistently influencing the uptake of medical equipment. However, we find compelling support for the influence of learning-by-using effects on the use of medical equipment in general practice. Practices with a broader portfolio of medical equipment are more likely to use an additional item of medical equipment. It is important to note that investments in medical equipment are borne by the practice, and while this may explain why some practices are more poorly equipped than others, our findings suggest that their limited experience with medical equipment negatively affects their subsequent investment decisions. If policymakers want to influence investment in medical equipment to ensure consistent service provision, they need to consider targeting poorly equipped practices who are the least likely to invest in new equipment. A potential targeted intervention would be a scheme whereby practices can borrow items of medical equipment on a short-term basis. Therefore, practices would have the benefit of learning from using such equipment, which according to our findings, would positively influence their ensuing medical equipment adoption decisions. Another approach could be to develop a practice partnering network, whereby

[99] For instance, *rofecoxib* was first licensed in Ireland on the 12th November 1999 and by March 2004; almost three-quarters of GPs in our sample were prescribing *rofecoxib* to patients (see Chapter 4). Merck & Co Inc., who produced *rofecoxib* under the brand names Voixx and Ceoxx, voluntarily recalled the drug on September 30, 2004, amidst evidence that it drastically increased users' risk of heart attack and stroke.

knowledge sharing could occur between practices at various stages of development.

The majority of Irish general practices are computerised (Bourke and Bradley, 2010); however, previous studies have categorised Irish general practices as 'average' users of ICT within a European context (Dobrev et al., 2008), indicating that Irish general practices are not utilising ICT to its full advantage. In our examination of intra-practice diffusion, the influence of learning-by-using and epidemic learning effects on intensity of ICT use in Irish general practices is convincing. We also find evidence of more intensive ICT use by practices located in the HSE South region. This finding is interesting in light of the ICT Strategy previously developed by the Southern Health Board.[100]

In 2001, the Southern Health Board developed an ICT strategy to improve service delivery. In order to meet its objective of delivering a higher quality and more effective service to its service users, a number of applications were developed. These applications include, among others, an Interactive Hospital School for school-attending patients, an integrated, interactive staff intranet and transmission of x-rays and scans. The European Commission acknowledged the HSE South's ICT Strategy with a "Best Practices in eService Delivery" award – the first time it was awarded to a health care organisation. An evaluation of the HSE South's ICT strategy demonstrates how a system-level approach to eHealth maximises the use of technology (Mathews and Barton, 2002). It is likely that this system-level strategy results in knowledge spillovers and, in turn, influences

[100] Prior to January 2005, the Irish health care system comprised of eight regional health boards. In 2005, the Southern Health Board was subsumed into the HSE South region.

how GPs use ICT in their practices. The implementation of this strategy centres on information and education; which is in line with our findings that learning-by-using and epidemic learning effects positively influence the extent to which practices use ICT. Therefore, there may be merit in extending this strategy nationwide ensuring that practices have the necessary information and know-how to gain proficiency in ICT use and to solve the complex problems that result from using numerous ICT applications.

Our research also demonstrates the beneficial influence of research and academic involvement on intensity of ICT use, particularly in relation to patient care applications. Therefore, academic-practitioner networks, which are primarily developed to engage in research and implement research evidence, may also positively influence adoption of technologies by practitioners. The Western Research and Education Network (WestREN) is a newly established collaborative network consisting of the Discipline of General Practice at the National University of Ireland (NUI) Galway and 71 West of Ireland general practices (Kavanagh et al., 2010). Therefore, consideration should be given to the possibility of positive externalities, in the form of adoption decision-making, resulting from such university-affiliated general practice research networks.

8.4.2 Potential Policy Implications in the Context of Proposed Health Care Reforms in Ireland and the UK

There are wide-ranging reforms for general practice proposed in the new Programme for Government which, if implemented, will have significant implications for Irish GPs (Department of the Taoiseach, 2011). The Irish government proposes to develop a universal, single-tier health service which guarantees access to medical care based on need, rather than income. Such health care reforms propose that more care is delivered in the community, and that health care will be paid for through Universal Health Insurance. The Universal Health Insurance System will be designed according to the European principle of social solidarity: access will be according to need and payment will be according to ability to pay. The Irish population will be obliged to purchase insurance from a public or private insurer; insurance payments will be related to ability to pay. However, the State will pay insurance premia for people on low incomes (Department of the Taoiseach, 2011).[101]

In relation to general practice, fees for GP care will be removed and GPs will be paid primarily by capitation for the care of their patients. Universal Primary Care will be implemented on a phased basis, with the recruitment of additional doctors, nurses and other primary care professionals. It is also proposed that GPs will work in Primary Care Teams with other primary care professionals. The number of practice nurses will also be increased, so that, where appropriate, work can be delegated to them (Department of the Taoiseach, 2011).

There is much discussion and debate in Ireland as to the potential impact of these health care reforms on general practice, with limited consensus to date. However, it is expected that Irish GPs will remain self-employed, private practitioners, and that the vertical integration between provider and third-party payer will be

[101] Therefore, it is not expected that this reform will have any financial impact on current GMS patients.

completely independent. It is uncertain to what extent Universal Primary Care will affect the autonomy presently enjoyed by Irish GPs. Therefore, the opportunities for innovative behaviour in relation to prescribing and medical equipment and ICT use by Irish GPs may continue. However, if the reforms take a more systems-level approach, with respect to practice development, the opportunities for innovative decision-making may be reduced.

The proposed reforms specifically identify staffing issues within general practices. The proposal to increase the number of practice nurses is encouraging, particularly, as our research finds nursing support to be a positive influence on innovative behaviour across all three areas of adoption decision-making examined. Also, in the UK where practice nurses have more established roles than in Ireland, there is evidence that appropriate trained nurses provide high quality care, and sometimes achieve similar health outcomes for patients to GPs (Horrocks et al., 2002; Laurant et al., 2005). The move towards group practices may create a setting within which epidemic and learning-by-using effects strengthen, thereby, positively influencing innovative behaviour.

In brief, it is difficult to ascertain the future policy implications of this thesis within a reformed Irish health care system; particularly given the uncertainty surrounding such reforms. Also some aspects of the proposals may facilitate innovation, whereas other elements of the proposed reforms may restrict the current incentive structures within general practice, thereby constraining innovative behaviour. On the one hand, the general practice staffing and interaction proposals bode well for GP's decision-making concerning adoption of innovations. However, if the introduction of Universal Primary Care results in a more restrictive environment than the current system, then there is likely to be counter-acting implications for primary care. For instance, if GPs no longer face incentives with respect to attracting patients and developing the commercial, private aspects of their practice, there are potentially negative implications for health care quality in the longer-term.

There are also significant changes planned in general practice in England at present. Groups of GPs and other health care professionals, or commissioning consortia, will be given budgets to commission health care on behalf of patients in their local communities. This will replace the current system where budgets are administered by Primary Care Trusts (PCTs), with varying degrees of clinician involvement. It is planned that the GP-led commissioning consortia will assess the health needs of a population; then plan, secure and monitor the health services for that population, given the resources available (Barratt, 2011).

There are clear distinctions between the mandates of the GP-led commissioning consortia in the UK and general practices in Ireland. However, the findings of this thesis may be a useful lens through which to view these NHS reforms. Our research illustrates the innovativeness of GPs and the influence of commercial and informational stimuli on decision-making concerning practice development and health care provision. Although, the GP-led commissioning consortia will be constrained by a pre-determined budget, our findings suggest that placing such decision-making in the hands of health care professionals may encourage innovative health care provision.

8.5 Limitations of this Research

This section briefly discusses some limitations of this research, primarily focusing on data restrictions and the implications of these restrictions on our empirical analysis and findings.

As discussed in Section 8.2.3, we do not model stock and order effects in all three empirical exercises, essentially due to data restrictions. In relation to medical equipment use, we do not include a stock effect in our econometric analysis. The primary reason for this is our survey data is cross-sectional. By their nature stock effects are time-variant. We do not model either stock or order effects in relation to intensity of ICT use. Our survey instrument did not ask respondents to indicate when they adopted each of the seventeen ICT applications included in the empirical analysis. It was decided that such a task would be too onerous for respondents. Ideally, we would like to model all elements of our encompassing theoretical model of adoption in all three empirical exercises.

In this thesis, we use two datasets to address our research questions. Our prescribing dataset provides us with a rich source of data, bringing together information of GPs prescribing history over a 4½ year time period with information on the characteristics of 625 GPs themselves. Our survey data, cross-sectional in nature, provides us with a profile of 601 Irish general practices in 2010, along with information on decision-making concerning practices use of medical equipment and ICT. An ideal scenario would be if, firstly, the prescribing dataset was timelier and, secondly, if it were possible to match these two datasets.

The prescribing dataset pertains to three of the eight Irish health boards, the Southern, South-Eastern and North-Eastern Health Boards, which provide health services to 34 per cent health services to of the Irish population (Department of Health and Children, 2002). The 625 GPs in this sample represent a third of all GPs who hold a contract to treat public GMS patients in Ireland. This dataset, which matches GPs characteristics with their prescribing decisions, provides us with a unique opportunity to analyse the influences on prescribing innovation by GPs.

A key limitation with the prescribing dataset is that it pertains to prescriptions dispensed from October 1999 to March 2004. Along with the Departments of General Practice and Pharmacy at University College Cork, the Department of Economics has asked for the provision of this data from April 2004 to the present. Access to more timely data would allow us to explore adoption patterns: for the large number of drugs brought to the Irish market since 2004; and also for drugs exhibiting slow adoption prior to 2004 which may reach higher adoption levels after 2004. Secondly, the structure of Irish general practices has changed since 2004 with a move towards group-practices with more support staff (O'Dowd et al., 2006; Bourke and Bradley, 2010). It would be interesting to see if the consistent and significant influence of stock, order and learning-by-using effects on timing of adoption of new drugs continues. In the previous section, we discussed the policy implications of our findings in relation to prescribing innovation. Analysis with more timely data would reinforce the importance of our policy recommendations.

Our *Medical Equipment and IT in General Practice* survey, a population survey, was administered to all general practices in Ireland; achieving a 42 per cent response rate. Geographically, the survey data provides information on practices in every county and HSE region in Ireland. As we designed the survey instrument ourselves, we were able to ensure that the data suited our needs. For instance, we have a wider range of measures of rank and epidemic effects in our survey data than in the prescribing dataset. Therefore, if we could match our survey data with the prescribing data, we would be able to model additional influences on prescribing innovation.

We must also be aware of the implications of the cross-sectional nature of our survey data. Our econometric models suggest causality; however, we could extend our understanding of adoption decision-making if we had access to longitudinal data. Furthermore, our survey data pertains to general practices in Ireland. We have discussed at length the unique context of general practice in Ireland; which potentially limits the generalisability of our results. In the next section, we discuss how issues with the cross-sectional and country-specific nature of our analysis could be reduced with additional primary data collection.

8.6 Future research plans and possibilities

Drawing on the theoretical insights from the current study and considering the existing primary and secondary datasets and possibly further primary data collection, this section outlines six potential opportunities for future research.

First, the prescribing dataset provides a rich source of data in relation to Irish GPs and their prescribing patterns. In Chapter 3, a transition matrix (see Table 3.2), reflects the transitions in the level of prescribing by GPs of all 1,137 drugs in the first year of the sample and in the final year of the sample. In our analysis, we focus on drugs which saw an increase in the proportion of GPs prescribing them over the 4½ year period. However, it may also be interesting to identify the determinants of those drugs which are now prescribed by fewer GPs than before. Do commercial and informational stimuli also influence de-adoption?

Second, our analysis of the determinants of prescribing innovation focuses on six drugs which operate on different physiological organs or systems. Opportunities for future research include a similar analysis focusing on a number of drugs from the same therapeutic class, to determine if the commonalties reported in the adoption of the drugs in this study are evident to the same or a greater extent when examining drugs prescribed for similar conditions. It may also be of interest to conduct analyses on the adoption of drugs with a relatively high degree of pharmacological innovation compared to those with a relatively low degree of innovation. We would also like to examine GPs decisions to adopt complementary drugs. Such analysis would allow for an investigation for cross drug effects similar to those identified in complementary technology diffusion studies.

Third, as discussed in Chapter 4, our prescribing data provides us with only one epidemic learning effects measure. However, it may be possible to introduce a measure of the impact of advertising in relation to prescribing decision-making. Advertising noise or impact could be measured through a citation search in medical journals or ranking the market power of the pharmaceutical companies which initially released these drugs.

Fourth, in the prescribing innovation study, our focus is on the timing of adoption, i.e. the decision to prescribe a new drug for the first time. In the future, we would like to extend our analysis to intensity of adoption. Measuring intensity of adoption of new drugs is likely to involve identifying the number of patients to whom the GP prescribes the new drug. Such an analysis would add to our existing evidence in relation to intra-practice ICT diffusion and allow us to test the hypothesis that the drivers of adoption and intensity of adoption differ.

Fifth, as previously discussed, our primary dataset was developed to specifically address this study's research questions relating to use of medical equipment and ICT. Therefore, the opportunities for future research with this data are somewhat restricted. The purpose of this study is to explore innovative decision-making in general practices; and our approach is focused on prescribing behaviour, medical equipment use and intensity of ICT use separately. Another approach is to construct an innovativeness measure which combines medical equipment and

ICT use and determine the influence of equilibrium, disequilibrium and learning-by-using effects on this encompassing innovativeness behaviour.

Sixth, as mentioned in the previous section, a limitation of this study is the cross-sectional and country-specific nature of the survey data. A possible avenue for future research is to develop a longitudinal dataset, i.e. administer a subsequent survey to the Irish GP population, providing us the opportunity to explicitly identify the causality relationships in our analysis. Given the unique setting of general practice environment in Ireland, the generalisablility of our results internationally may be questionable. Therefore, a subsequent European survey and analysis of use and intensity of use of medical equipment and ICT would strengthen our results.

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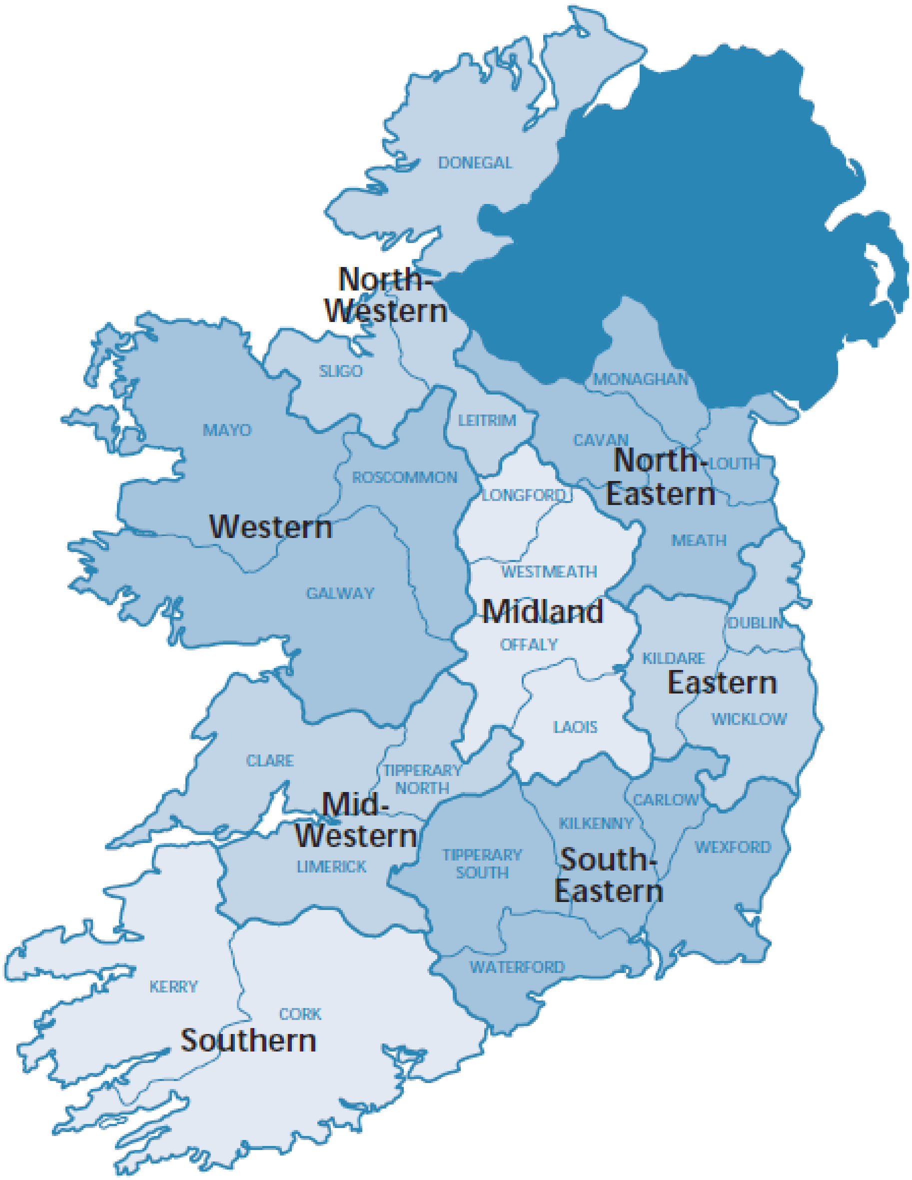
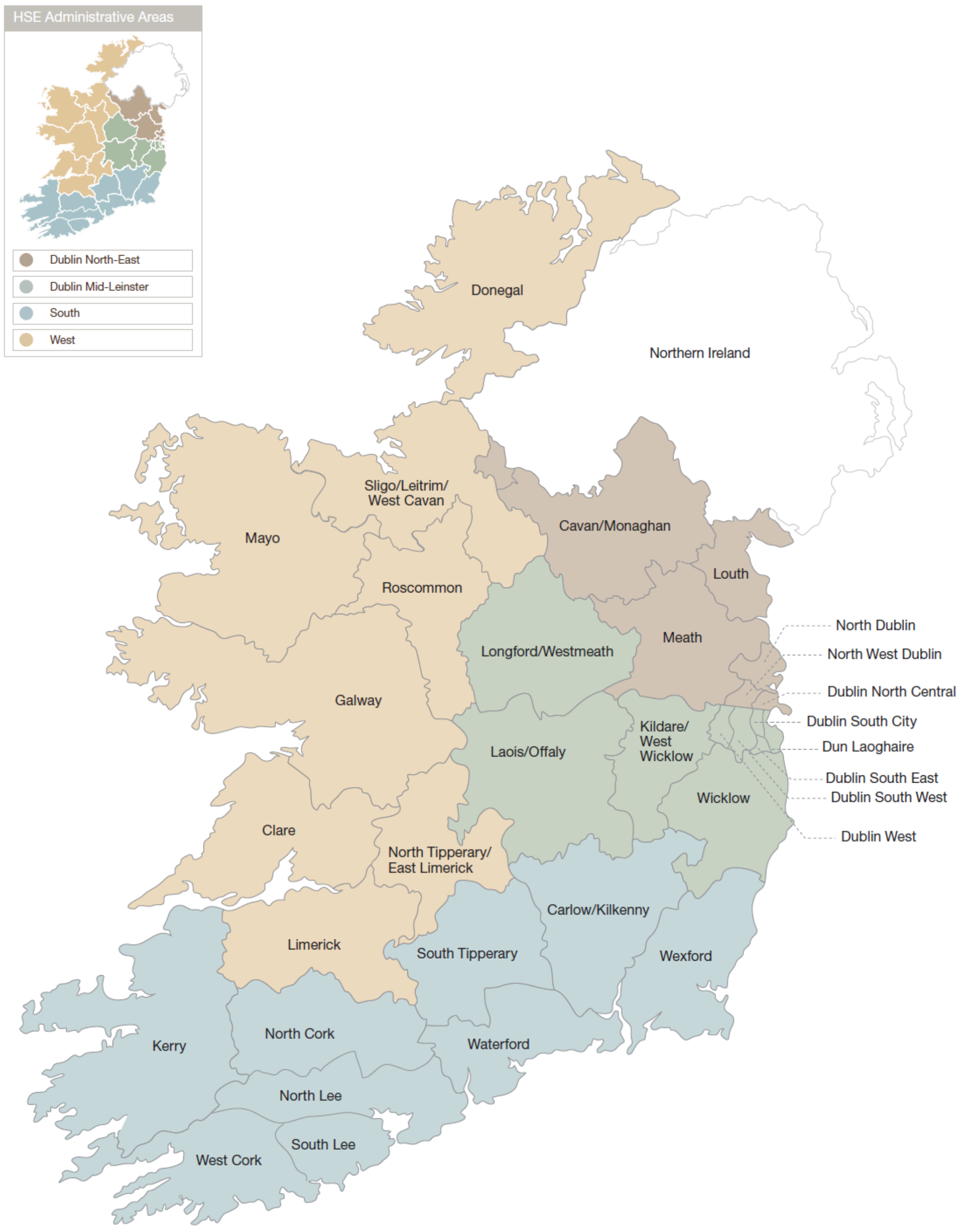
APPENDIX 1: LOCATION OF HEALTH BOARDS AND HSE ADMINISTRATIVE REGIONS IN IRELAND

Figure A1.1: Location of Health Board Regions (Pre- 2005)



Source: www.hse.ie

Figure A1.2: Location of HSE Administrative Areas



Source: www.hse.ie

APPENDIX 2: DURATION MODELS OF TIME TO FIRST ADOPTION – BASELINE MODELS

Table A2.1: Duration Models of Time to First Adoption – Baseline Models

	Esciatlopram[1] mfx/se	Esmoprazole[2] mfx/se	Rofecoxib[3] mfx/se	Desloratadine[4] mfx/se	Nicotine[5] mfx/se	Drospirenone & Estrogen[6] mfx/se
Rank Effects						
Practice Nurse	-0.253***	0.006	-0.207	-0.08	-0.002	-0.558**
	(0.062)	(0.076)	(0.188)	(0.162)	(0.114)	(0.236)
Practice Secretary	-0.108	0.055	0.028	-0.496**	-0.241*	-0.581*
	(0.078)	(0.102)	(0.232)	(0.217)	(0.144)	(0.304)
GP Age	0.012***	0.003	0.004	0.020**	0.015**	0.044***
	(0.004)	(0.005)	(0.011)	(0.010)	(0.007)	(0.014)
Dispensing Practice	0.036	0.162	-0.434	-0.02	-0.224	0.719*
	(0.093)	(0.108)	(0.323)	(0.258)	(0.188)	(0.373)
IDTS50	-0.044	0.013	-0.081	-0.453**	0.069	-0.327
	(0.071)	(0.089)	(0.226)	(0.195)	(0.135)	(0.277)
IDTS60	-0.058	-0.135	-0.031	-0.454***	-0.03	-0.267
	(0.064)	(0.083)	(0.201)	(0.176)	(0.124)	(0.249)
Epidemic Effects						
Rural Practice	0.162*		0.277	0.266	0.155	0.908**
	(0.096)		(0.315)	(0.258)	(0.184)	(0.381)
Learning-By-Using Effects						
Portfolio Breadth	-3.151***	-5.810***	-8.098**	-10.410***	-10.206***	-5.736
	(1.120)	(1.862)	(3.550)	(3.217)	(2.193)	(4.125)
Portfolio Breadth^2	2.938	5.325	-0.659	9.202	9.886**	-0.332
	(2.365)	(3.651)	(7.706)	(6.555)	(4.632)	(8.892)
Order Effects	-1.698***	-0.277*	-6.035***	-8.487***	0.694***	-1.044***
	(0.129)	(0.153)	(0.380)	(0.793)	(0.130)	(0.297)
Stock Effects	12.374***	10.530***	15.969***	0.347	6.149***	20.635***
	(0.208)	(0.402)	(0.959)	(1.726)	(0.903)	(0.938)
N	23366	8607	8150	13628	10871	15082
Chi-squared	666.087	609.906	983.797	430.182	793.79	291.572
Log-likelihood	829.06056	294.3939	392.50908	274.69722	714.41184	7.741109
AIC	-1626.121	-558.788	-753.018	-517.394	-1396.824	16.518
BIC	-1497.18	-452.883	-640.926	-397.076	-1280.12	138.458

APPENDIX 3: TEMPLATE OF INTERVIEW SCHEDULE

Interview Schedule

Q1. Can you tell me a little about your practice?

Prompts: Age of practice
Number of people working in the practice? FT? PT?
Purpose Built
Training practice
Links to other practices/ hospitals

Q2. Does the practice operate as one legal entity or does it operate as a number of GPs working out of the same building?

Q3. Can you tell me a little about your training and prior experience?

Q4. What is the patient profile in the practice?

Prompts: Number of patients – private – public
Age
Health Status

Q5. What medical equipment do you use in your practice?

Q6. When did the practice adopt this equipment?

Q7. How did you learn about this equipment? What made you decide to adopt it?

Q8. What equipment would you consider adopting in the future?

Q9. How do you obtain information on new medical equipment?

Prompts: Suppliers
Other primary care providers
Internet

Q10. Does your practice use Information Technology? If so, for what purposes?

Prompts: Accounting purposes
Medical research purposes
On-line appointment bookings
SMS appointment reminders
Consultation records
Repeat prescriptions

Q11. What benefits do you see in using IT in your practice? What personal benefits to you see from using IT?

Prompts: Efficiency
Better service for patients

Q12. How do you obtain information on new IT applications (ways of using IT)?

Prompts: Conferences
Other primary care providers
Internet

Q13. In general, are you interested in new technology?

Prompts: New mobile phones
I-pods

Q14. Do GP practices use digital x-ray technologies?

Q15. Do you prescribe drugs new to the market to your patients?

Prompts: Regularly
On recommendation from colleagues

Q16. Can you give me some examples of drugs that have come onto the market in the last 10 years?

Prompts: Regularly prescribed drugs
Rarely prescribed drugs
No longer prescribed

Q17. From where do you obtain information on new prescription medicines?

Prompts: Suppliers/ Pharmaceutical Companies
Other primary care providers
Internet

Q18. Who makes decisions in your practice, in relation to using new equipment, IT and prescribing?

Prompts: GP
Practice Mgr
Joint decision

Q19. So far I've focused on the adoption of medical equipment, IT and new drugs. Are there any other kinds of things that are adopted in General Practices?

Q20. How often and where do you meet other primary care providers, including other GPs?

Prompts: Conferences
Email contact
Informally, socially

Q21. I will be distributing a survey to all GPs in Ireland in the coming months. Do you think I should email or post it?

Q22.With an expected outbreak of swine flu in Ireland, do you think it's a bad time to distribute a survey to GPs?

APPENDIX 4: COVER LETTER AND QUESTIONNAIRE

UCC
Coláiste na hOllscoile Corcaigh, Éire
University College Cork, Ireland

1st March, 2010

College of Business and Law
Department of Economics
www.ucc.ie/en/economics/

Dear Dr. _______,

The Departments of General Practice and Economics at University College Cork are collaborating on a research project examining the use of medical equipment and IT in General Practice throughout Ireland. This research will illustrate the extent to which GP practices invest in these technologies.

We would like to encourage your practice's participation in this study. Ideally, we would like the attached form completed by a principal in the practice. The completed form can be returned in the enclosed FreePost envelope.

Any data you provide will be treated confidentially and will be published only in aggregated form. If you have any queries about the project, please do not hesitate to contact Jane Bourke at 021-4901930.

Many thanks,

Colin P. Bradley

Jane Bourke

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Medical Equipment and IT in General Practice

Q1. Please could you tell us how many GPs currently work in your practice? (If you have part-time staff please report full time equivalents by gender).

Males	
Females	

Q2. How many GPs in your practice are in the following age categories?

Less than 30	
30-39 years	
40-49 years	
50-59 years	
60 plus	

Q3. How many Principals currently work in your practice?

Males	
Females	

Q4. Does your practice employ?

Nurse	Yes	No
Practice Manager	Yes	No
Clerical Worker	Yes	No

Q5. How would you describe the main location of your practice?

City	
Large town	
Small Town	
Village or rural	

Q6. In what year was your practice established?

Q7. Does your practice:

receive a Rural Practice Allowance?	Yes	No
act as a Training Practice? (for post-graduate GP trainees)	Yes	No
act as a Dispensing Practice?	Yes	No
participate in a 'Primary Care Team'? (as proposed by *Primary Care: A New Direction)*	Yes	No
If yes, are you co-located with the team?	Yes	No

Q8. Does your practice hold the following clinics?

Physiotherapist	Yes	No
Dietician	Yes	No
Counsellor/Psychologist	Yes	No
Other, please specify		

Q9. Does your practice have the following medical equipment? If so, approximately when did you first obtain this equipment?

	Practice Equipment	Equipment obtained in Year
ECG Machine		
24-Hr Blood Pressure Monitor		
Spirometer		
Cryotherapy		
Minor Surgery Equipment		
Dexas Scanning		
Ultra sound / doplar / foetal monitor		

Q10. Please can you tell us how the purchase of this equipment was funded?

	Funded by Practice	Funded by HSE	Funded by private company	Other, please specify
ECG Machine				
24Hr BP Monitor				
Spirometer				
Cryotherapy				
Minor Surgery				
Dexas Scanning				
Ultra sound				

Q11. How important are the following in informing your purchases of medical equipment?

	Not Important			Very Important	
Other GPs/Primary Care Workers	1	2	3	4	5
Internet	1	2	3	4	5
Flyers in the Post	1	2	3	4	5
Suppliers of Medical Equipment	1	2	3	4	5
Conferences/CME meetings	1	2	3	4	5
Other, please specify	1	2	3	4	5

Q12. For which of the following administrative functions does your practice use Information Technology?
Please tick all that apply

Accounts	
Word Processing	
Billing	
Patient registration	
Referral letters	
Appointments	
Practice Staff's Calendar	
Email	
Practice Website	

Q13. For which of the following patient care functions does the practice use Information Technology?
Please tick all that apply

Recall of items: vaccinations; immunisations; smears	
Repeat prescriptions	
Download hospital laboratory reports	
Coding of Diseases	
Consultation records	
Internet research	
Scan hospital/consultant correspondence	
Audit/Quality Assurance	

Q14. Which of the following best describes how your practice keeps consultation records?

Completely computerised consultation records	
Computerised and paper consultation records	
Completely paper consultation records	

Q15. How important are the following in informing how you use Information Technology for either administration or patient care?

	Not Important				Very Important
Other GPs/Primary Care Workers	1	2	3	4	5
Internet	1	2	3	4	5
Flyers in the Post	1	2	3	4	5
Suppliers of IT equipment	1	2	3	4	5
Conferences/CME meetings	1	2	3	4	5
ICGP/GPIT course	1	2	3	4	5
Other, please specify	1	2	3	4	5

Q16. Please could you tell us approximately how many patients are on your practice's list?

GMS patients	
Private patients	

Q17. Over the last 3 years, have you been or are you currently:

A committee member of a professional medical organisation, such as ICGP, IMO?	Yes	No
Affiliated with an academic department?	Yes	No
Actively involved in research projects?	Yes	No
Completing/completed an ICGP course, or equivalent (Examples: Certificate in Diabetes; Diploma in Women's Health)?	Yes	No

Q18. On average, approximately how many ICGP small group CME meetings do you attend each year?

None	
1 or 2	
3 to 5	
6 or more	

Q19. On average, approximately how many times a year do the following visit your practice?

	None	1 to 2	3 to 5	6 to 8	9 or more
Supplier of Medical Equipment					
Suppliers of IT equipment					
Drug Company Representatives					

Q20. Finally, how important are the following in informing your decision to prescribe a new drug for the first time?

	Not Important				Very Important
Other GPs/Primary Care Professionals	1	2	3	4	5
Internet	1	2	3	4	5
Hospital Consultants	1	2	3	4	5
Pharmaceutical Co. Reps.	1	2	3	4	5
Conferences/CME meetings	1	2	3	4	5
Journals	1	2	3	4	5
Other, please specify					

Thank you for your help in completing this form. Please return it in the FreePost Envelope provided.

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APPENDIX 5: PROBIT ESTIMATIONS OF MEDICAL EQUIPMENT USE - BASELINE MODELS

Table A5.1: Probit Estimations of Medical Equipment Use -Baseline Models

	ECG	24 Hr BPM	Spiro-meter	Cryo-therapy	Minor Surgery	Foetal Monitor
Rank Effects						
Number of GPs	-0.006	0.054***	0.027	0.009	0.019	-0.017
	(0.015)	(0.019)	(0.026)	(0.016)	(0.019)	(0.016)
Log of Patients	0.044	-0.035	0.102*	0.076**	-0.024	0.058
	(0.027)	(0.034)	(0.053)	(0.031)	(0.041)	(0.038)
Proportion of Public Patients	0.134*	0.144	0.189	0.058	-0.211*	0.074
	(0.074)	(0.090)	(0.138)	(0.077)	(0.108)	(0.098)
Nursing Support	0.081	0.289***	0.104	-0.076***	0.093	0.028
	(0.050)	(0.073)	(0.075)	(0.028)	(0.065)	(0.054)
Administrative Support	-0.012	-0.011	-0.142*	0.032	0.092	0.094
	(0.043)	(0.059)	(0.080)	(0.062)	(0.089)	(0.083)
All GPs > 40	0.029	-0.003	0	-0.004	-0.056	-0.054
	(0.029)	(0.044)	(0.067)	(0.038)	(0.057)	(0.052)
Male Dominated	0.052*	-0.013	0.108**	-0.039	0.106***	-0.045
	(0.028)	(0.034)	(0.050)	(0.029)	(0.041)	(0.036)
Order Effects						
Order	0.046*	0.023	0.149***	0.041	0.066*	-0.06
	(0.025)	(0.035)	(0.048)	(0.030)	(0.039)	(0.041)
Learning-By-Using Effects						
Portfolio	0.560***	0.442***	0.569***	0.449***	0.529***	0.379***
	(0.107)	(0.105)	(0.082)	(0.100)	(0.091)	(0.092)
Epidemic Effects						
Town	0.044	-0.069*	-0.009	0.014	0.06	0.083**
	(0.028)	(0.039)	(0.056)	(0.033)	(0.044)	(0.040)
Rural	0.004	-0.087	-0.026	0.027	0.05	0.071
	(0.040)	(0.066)	(0.078)	(0.039)	(0.054)	(0.045)
HSE Dublin North East	-0.03	-0.004	-0.131	-0.029	-0.082	-0.028
	(0.047)	(0.056)	(0.084)	(0.052)	(0.070)	(0.059)
HSE South	0.042	-0.077	-0.054	0.022	0.061	0.076*
	(0.029)	(0.050)	(0.067)	(0.037)	(0.049)	(0.043)
HSE West	0.084***	0.042	0.033	0.017	0.05	0.066
	(0.027)	(0.043)	(0.070)	(0.039)	(0.051)	(0.044)
Clinic	0.085***	0.048	0.03	-0.01	0.028	0.033
	(0.028)	(0.033)	(0.049)	(0.030)	(0.040)	(0.037)
Training Practice	0.081***	-0.001	0.137**	0.024	-0.036	-0.042
	(0.029)	(0.046)	(0.057)	(0.037)	(0.052)	(0.048)

Table A5.1 (continued): Probit Estimations of Medical Equipment Use - Baseline Models

	ECG	24 Hr BPM	Spiro-meter	Cryo-therapy	Minor Surgery	Foetal Monitor
Supplier Visits	0.014	0.002	0.001	0.031**	0.005	-0.018
	(0.010)	(0.013)	(0.017)	(0.014)	(0.015)	(0.012)
Committee Member	0.017	-0.012	-0.015	0.032	-0.049	0.041
	(0.026)	(0.034)	(0.049)	(0.029)	(0.041)	(0.035)
Academic Department	0.029	0.006	0.049	0.028	0.063	0.022
	(0.029)	(0.038)	(0.054)	(0.033)	(0.043)	(0.040)
Research Project	-0.013	0.097***	0.055	0.02	0.046	0.031
	(0.037)	(0.033)	(0.058)	(0.036)	(0.046)	(0.042)
ICGP Course	-0.008	-0.058	0.081	0.028	0.052	-0.071*
	(0.030)	(0.041)	(0.051)	(0.032)	(0.041)	(0.042)
CME Meetings	-0.005	0.016**	-0.003	0.002	0.001	-0.003
	(0.005)	(0.007)	(0.010)	(0.006)	(0.008)	(0.007)
N	522	522	522	522	522	522
Chi-Squared	190.723	171.314	152.774	118.909	122.104	76.675
P-value	0	0	0	0	0	0
BIC	410.491	482.599	663.683	472.18	574.836	574.346

APPENDIX 6: PROBIT ESTIMATIONS OF MEDICAL EQUIPMENT USE - PREFERRED MODELS

Table A6.1: Probit Estimations of Medical Equipment Use - Preferred Models

	ECG	24 Hr BPM	Spiro-meter	Cryo-therapy	Minor Surgery	Foetal Monitor
Rank Effects						
Number of GPs		0.053***	0.03	0.007	0.02	-0.016
		(0.017)	(0.023)	(0.014)	(0.019)	(0.015)
Log of Patients	0.037*	-0.04	0.095*	0.075**	-0.025	0.056
	(0.021)	(0.035)	(0.052)	(0.030)	(0.042)	(0.038)
Proportion of Public Patients	0.128*	0.162*	0.164	0.063	-0.217**	0.069
	(0.069)	(0.094)	(0.135)	(0.077)	(0.109)	(0.097)
Nursing Support	0.071	0.275***	0.109	-0.072***	0.086	0.027
	(0.046)	(0.070)	(0.073)	(0.028)	(0.064)	(0.054)
Administrative Support			-0.127	0.035	0.093	0.096
			(0.081)	(0.062)	(0.090)	(0.083)
All GPs > 40	0.033				-0.05	-0.054
	(0.026)				(0.057)	(0.051)
Male Dominated	0.058**	-0.033	0.103**	-0.039	0.106***	-0.045
	(0.027)	(0.034)	(0.047)	(0.029)	(0.041)	(0.036)
Order Effects						
Order	0.037	0.029	0.136***	0.043	0.063	-0.06
	(0.025)	(0.036)	(0.046)	(0.030)	(0.040)	(0.041)
Learning-By-Using Effects						
Portfolio	0.569***	0.527***	0.547***	0.453***	0.561***	0.379***
	(0.103)	(0.092)	(0.079)	(0.098)	(0.084)	(0.091)
Epidemic Effects						
Town	0.045*	-0.047			0.065	0.084**
	(0.025)	(0.040)			(0.044)	(0.040)
Rural		-0.08			0.052	0.073
		(0.065)			(0.055)	(0.045)
HSE Dublin North East			-0.116	-0.033	-0.066	
			(0.081)	(0.052)	(0.068)	
HSE South	0.053**	-0.062	-0.05	0.024	0.079*	0.085**
	(0.024)	(0.043)	(0.065)	(0.037)	(0.048)	(0.038)
HSE West	0.092***	0.05	0.05	0.021	0.065	0.074*
	(0.023)	(0.040)	(0.066)	(0.039)	(0.050)	(0.039)
Clinic	0.077***	0.045	0.019		0.027	0.031
	(0.026)	(0.034)	(0.047)		(0.040)	(0.037)
Training Practice	0.083***		0.114**	0.026	-0.043	-0.043
	(0.026)		(0.056)	(0.036)	(0.053)	(0.048)

Table A6.1 (continued): Probit Estimations of Medical Equipment Use - Preferred Models

	ECG	24 Hr BPM	Spiro-meter	Cryo-therapy	Minor Surgery	Foetal Monitor
Supplier Visits	0.014			0.030**		-0.018
	(0.010)			(0.014)		(0.012)
Committee		-0.03		0.032	-0.061	0.04
Member		(0.035)		(0.028)	(0.041)	(0.035)
Academic	0.029		0.044	0.026	0.063	0.021
Department	(0.027)		(0.052)	(0.033)	(0.043)	(0.040)
Research Project		0.093***	0.054	0.023	0.054	0.03
		(0.034)	(0.056)	(0.036)	(0.046)	(0.042)
ICGP Course		-0.06	0.088*	0.03	0.06	-0.072*
		(0.042)	(0.049)	(0.032)	(0.041)	(0.042)
CME	-0.005	0.019***				
Meetings	(0.005)	(0.007)				
N	530	541	531	522	531	522
Chi-Squared	190.986	184.867	149.177	118.3	130.06	76.366
P-value	0	0	0	0	0	0
BIC	372.768	463.001	641.486	441.501	571.678	562.139