Current Issues in Trade Policy

by

Terence Huw Edwards

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Abstract

The articles in this thesis reflect my work at the Centre for Study of Globalisation and Regionalisation in Warwick, centred around two EU-funded projects: one relating globalisation to social exclusion, and the second looking at the re-integration of the Central and Eastern European transition economies into the main European economy. The papers in this thesis are seen as new contributions. Chapter 1 is introductory, consisting of a brief literature survey outlining a number of important debates. This is followed by a summary of the contributions of the papers in subsequent chapters. Chapter 2, written with John Whalley, is a general equilibrium decomposition of the widening wage gap in the United Kingdom, utilising novel techniques of double calibration. The underlying question is the degree to which widening inequality reflects a change in world traded prices following liberalisation. Chapters 3 and 4 refer to regional integration. In Chapter 3 I look specifically at the likely effects of admitting several new Central and Eastern European countries to the European Single Market, using a general equilibrium model combining the new trade theory and the gravity model approach. Chapter 4 is more theoretical, examining the perceived misuse of regulatory protection in determining national product standards - in this case, in a cross-hauling duopoly. It is shown that several conclusions of the recent literature regarding the trade volume effects of regulation and the welfare effects of mutual recognition agreements, may be misleading. In Chapter 5 I delve into a new issue in trade theory: namely the implications of imperfect information, matching, search and networking. This chapter indicates a possible direction in which trade theory needs to move to better understand the growing outsourcing trade, and also draws important theoretical and policy implications. Chapter 6 draws brief conclusions.

Length: approximately 46,900 words.

0.1 Contents

0.2 Acknowledgements

I am especially grateful to Professor Carlo Perroni, my PhD supervisor, for guidance and advice during this project. Also to Professor John Whalley, now at University of Western Ontario, who was my supervisor during the early stages of the project, as well as to my two examiners, Professor David Collie and Geoff Reed. Much of the work was funded through two EU-funded research projects, and I should like to thank Dr Paul Brenton (now at the World Bank) and Dr David Barlow (University of Newcastle-upon-Tyne) for their work in organising and coordinating the two projects. I am also grateful to Dr Lisandro Abrego, now at the International Monetary Fund, for allowing me to use his data for the paper in Chapter 2, and to Liz Thompson for secretarial assistance. Others, who have given advice and helpful information during the preparation of this work, are mentioned in acknowledgements in the various chapters. A number of useful comments have been provided by participants at seminars in Warwick, Loughborough and Nottingham and in a presentation at the Royal Economic Society's annual conference. Finally, some thanks to Karligash Kenhjegalieva and Vasileis Zikos at Loughborough for help with proof-reading.

0.3 Declarations

The work in this thesis is my own, excepting Chapter 2 which was co-authored with John Whalley. The broad idea of this chapter, and some of the final drafting, were Prof Whalley's, while the modelling work and most of the text are primarily my responsibility.

The paper in Chapter 2 was presented at the Royal Economic Society conference in Warwick in April 2003, and was published as an NBER discussion paper. A revised version is currently forthcoming in the Bulletin of Economic Research. Chapters 3-5 have appeared as working papers. A revised version of chapter 3 is forthcoming in Applied Economics. Chapters 4 and 5 will shortly be submitted to journals.

This thesis has not been submitted for a degree at any other university.

0.4 Abbreviations used in this thesis

CEEC Central and Eastern European Countries

CES Constant Elasticity of Substitution

CGE Computable General Equilibrium

CU Customs Union

GDP Gross Domestic Product

GEMEE General Equilibrium Model of European Enlargement

GM Genetically Modified

GTAP Global Trade Analysis Project

H-O Heckscher-Ohlin

HOS Heckscher-Ohlin-Samuelson

IMP International Monetary Fund

NTB Non-Tariff Barrier

OECD Organisation for Economic Co-operation and Development

TBT Technical Barrier to Trade

UK United Kingdom

US United States

WTO World Trade Organisation

Other abbreviations used, for example, to denote specific data categories, are explained as they are introduced.

Chapter 1

Introduction

The world is becoming increasingly integrated economically. Between 1965 and 2001, international trade grew faster than World GDP in all but three years. Global trade's share of World GDP rose from 13 percent in 1970 to 21 percent in 1995 (World Bank, 1998).[1] Successive rounds of trade agreements have cut tariff and non-tariff barriers, while policymakers' opinions, under the influence of the Washington Consensus of the World Bank, IMF and US Treasury,[2] have generally shifted in favour of freer trade, compared to the general support for protectionism and managed trade (especially in developing countries) during the immediate postwar years.

This increased international integration can be seen as having two major aspects: both increased global integration ('globalisation') and also increased integration of business, firms and economic policy at a regional level ('regionalisation'). Both phenomena are increasingly the centre of controversy, with politicians and activists protesting against globalisation on the one hand, and with protest votes against the institutions which are associated with regional integration (such as the European Union) on the other.

[1] See Hufbauer, 1998.
[2] See Stiglitz, 2002, for a critique.

The economic arguments in this debate can be divided into a number of categories:

1.0.1 Standard arguments for greater global integration

The arguments in favour of reducing trade barriers are well-rehearsed. Not only does freer trade allow countries to make specialisation gains, as indicated by classical and neoclassical trade theory, but the advocates of newer trade theories (see, e.g. Baldwin and Venables, 1995) would argue it also produces further gains in terms of increased competition (driving down prices), increased variety of goods available to consumers and increased capital flows into regions opening themselves up to increased trade. Empirical evidence has increasingly supported the idea that more open economies tend to outperform relatively closed economies.[3] In neoclassical theory, countries as a whole would expect to make specialisation gains from liberalising their own trade, unless there is some other form of distortion present.[4] In the new trade theory, integration on a world scale also allows for increased technology flows and for countries to reap benefits of economies of scale in developing new products (see e.g. Grossman and Helpman, 1993) - consequently new trade theory approaches to estimating the gains from trade generally yield greater potential global welfare gains from trade than standard theory, although individual countries and groups within countries may lose.

[3] See e.g. Winters, 2004.

[4] At least one factor will lose from trade liberalisation. However, gains from liberalisation to owners of the abundant factors within a country are usually expected to outweigh (in monetary terms) losses to the owners of scarce factors, at least in the simpler two-country models. More complicated models of free trade areas and customs unions will have a number of opposing effects, and usually require analysis on a case-by-case basis.

1.0.2 Arguments for a deeper integration at the global or regional level

It is increasingly argued that removing formal trade barriers alone is not enough to achieve economic optimality. A major source for this view is the empirical evidence that trade between most countries - even within close trading areas such as the European Union - falls well short of that within any single country. This conclusion stems primarily from gravity analysis of trade patterns (see McCallum, 1995, Trefler, 1995), which suggests that even within a free trade area, country dummies are strong and significant and indicate powerful 'border effects' impeding trade.[5]

To a growing school of thought the logical explanation for these observed border effects is that they must reflect some form of transactions costs on businesses wishing to operate across national boundaries. However, despite attempts to explain the observed patterns (see, e.g. Obstfeld and Rogoff, 2000) the precise reason why trade between countries seems to fall short of that within countries is still far from satisfactorily explained. For example, Obstfeld and Rogoff emphasise the importance of transport costs - yet gravity models already implicitly proxy for transport costs with a distance variable, and replacement of distance with more direct estimates of average trade costs does not greatly affect the conclusions regarding border effects.[6] There is evidence that freight and insurance rates for different commodities vary, as do rates for sea as against land transport, but again it is hard to build up a conclusive case that these differences can explain the estimated border effects when these are present both for countries with land and sea borders.[7]

[5] Though McCallum's analysis has been challenged, e.g. by Hillberry (1999) or Anderson and van Wincoop (2003).

[6] In Chapter 2, below, I calibrate a variety goods model for European trade with explicit estimates of transport costs, and find results broadly in line with previous gravity simulations.

[7] It is conceivable that gravity estimations may suffer from aggregation bias, however, when one category of commodities contains a number of subcategories with very different trade costs. There is also

The alternative is to look at the effects on trade of policies other than simply tariffs and formal non-tariff trade barriers. Obstfeld and Rogoff mention currency conversion costs in this regard - and the argument that eliminating these would boost trade is frequently cited as a motivation for the European common currency. However, many forms of national policies may potentially affect international trade flows. The costs of certification and testing of goods to meet different health and safety standards, different labelling or warranty requirements in different countries can be quite significant, though varying between goods and commodities (see e.g. Harrison et al, 1996).[8]

Not only is estimation of the trade costs imposed by national policy regimes a tricky empirical task, but the interpretation of such costs is also difficult. While, on the one hand, national policies on product standards may act as impediments to trade, and may even be systematically manipulated to form 'regulatory protection', particularly when other forms of protection are ruled out (see e.g. Wallner, 1998, Baldwin, 2001),[9] on the other hand such policies may also serve important purposes of consumer protection, and so the 'regulatory protection' classification may be over-simplistic in many cases. The degree to which such an interpretation applies in practice to policy differences between countries has important implications for policy (see Chapters 3 and 4 for more detail). The belief that such differences primarily reflect protectionist motives has led to the policy conclusion that internal product regulation policies are a legitimate field of concern to international trade negotiators, and has, in particular, encouraged the development of regional agreements to reduce such barriers (notably the European Single Market). This

some possible validity in Hillberry's (1999) suggestion that estimated border effects may in fact reflect the propensity of some footloose industries to move closer to their main potential customers.

[8] Zahariadis, 2002, using figures derived from Harrison et al (1996), suggests costs on Turkish imports into the EU of 1.3 to 3.1 per cent for frictional/border costs, 1 to 2 per cent for testing/certification costs and 1 to 2.5 per cent for standardisation costs.

[9] A classic example of regulatory protection in practice was the policy of the first Mitterand government in France to divert all imported video recorders for testing at a centre in the inland town of Poitiers.

school of thought underlies much of the economic case for deeper regional integration.

In support of this view, it should be noted that advanced countries - such as those which, until recently, dominated the European Union - are likely to share a high degree of preference for reliability, safety and the like, so that mutual recognition of each other's standards (or harmonisation on a shared standard) is more likely to be beneficial in that context, though Chapter 4 shows there may still be strategic reasons why countries may distort their choice of standards in the presence of trade. Where countries greatly differ in income levels or consumer attitudes, this may not be the case - a matter which makes the extension of the European Single Market to the poorer, new members relatively more debatable.

To traditional trade theorists, regionalism - in the form of Free Trade Areas or Customs Unions - has a distinctly ambiguous nature, with offsetting trade creation and trade diversion effects. There is also a more recent literature on whether regional trade areas form a lasting barrier or a stepping stone to global trade liberalisation. The optimistic interpretation stems particularly from Kemp and Wan (1976), who showed that, on not particularly restrictive assumptions, when a country joins a Customs Union (CU), it is always possible, by adjusting tariffs (adopting the Vanek compensating tariff[10]) and, if necessary, by internal side-payments, to ensure that no country, inside or outside the CU loses. In these circumstances, a Customs Union or Free Trade Area might be expected to eventually expand to incorporate the whole World. It is not difficult to show that this result implies that members of a CU will gain if the CU sets optimum tariffs vis-a-vis the rest of the World, and nonmember states do not adjust their tariffs.[11] However, it does

[10] The Vanek compensating tariff is the tariff which maintains the level of trade with the rest of the World at pre-CU levels.

[11] Since, by definition, the optimum tariff will leave member states at least as well off as a Vanek compensating tariff.

not necessarily hold if non-member countries alter their tariffs in an optimum fashion (Richardson, 1995).

A more critical view (Krugman, 1991b) is based on an imperfectly competitive model where countries form a series of rival customs union blocs, which expand mainly in order to increase their ability to impose higher tariffs on the rest of the World. Recent studies[12] seek to investigate empirically the circumstances in which trade blocs lead to greater protectionism or greater trade.

Regardless of this debate, there is strong reason to believe the removal of regulatory barriers between member states of a regional bloc is more likely to benefit third party countries than the removal of internal tariffs within the bloc. The argument is that different regulatory standards effectively impose a real resource cost on companies trading between two nations, often modelled as an iceberg cost[13]: while removing regulatory differences between country A and country B may increase A and B's shares of each other's market at the expense of a third country C, the key difference is that if the regulatory cost is real and significant, overall incomes in both A and B will rise, and this will potentially produce an offsetting income effect on C's exports. Under these circumstances a regional agreement between A and B may well actually be of net benefit to C. Assuming this is the case, there is less conflict between regionalism and the promotion of global trade.

The two major methods by which an agreement of this sort can be implemented are, first, the application of a central harmonisation of standards and, secondly, the use of mutual recognition agreements, under which country A will accept for sale any

[12] See, e.g. Abrego et al (forthcoming).

[13] An 'iceberg cost' is a modelling device which assumes that, when a good is traded between two countries, a fixed proportion of its value is used up in the form of the transaction cost. The term 'iceberg cost' derives from a metaphor to a proportion of an iceberg melting en route.

goods from country B which meet the latter country's own regulations, as long as this is reciprocated. The latter, which effectively devolve more decision-power to individual nations, have tended to be favoured in the literature.[14] In practice, the European Single Market Initiative has used a combination of the two approaches, though mostly applying mutual recognition where possible (see Brenton et al, 2001).

Mutual recognition has a further attraction: whereas harmonisation of product standards requires a harmonising body - usually a regional body, such as the European Commission - to implement, mutual recognition agreements can be agreed between any pair of governments or trade blocs. Mutual recognition agreements are increasingly appearing on the trade agenda, forming the basis of agreements between the EU and Asia-Pacific countries, for example.

1.0.3 Distributional arguments for protection

While the case both for trade liberalisation and for the removal of other types of barriers (as discussed above) has been influential in furthering global and regional integration in recent years, there are also powerful counter-arguments. Let us start with the standard arguments on freer trade and globalisation: while trade theory generally suggests freer trade should benefit output and welfare globally, it has always been recognised that certain groups will lose out. Following Stolper and Samuelson (1941), the argument has been generally accepted that trade will tend to bring about a movement towards equalisation of factor prices worldwide.[15] For any given country, trade can serve to remedy relative factor shortages by allowing the country to import goods intensive in the factors more

[14] Again, see Wallner (1998), or Lutz (1996 (1) and (2)).

[15] The argument that it will result in full factor price equalisation requires a number of further assumptions. See chapter 2.

abundant elsewhere. Trade liberalisation between the developed world and less developed countries (LDCs) should therefore result in the richer countries, which are assumed to be more abundant in skilled relative to unskilled labour, exporting skill-intensive goods and importing less skill-intensive goods. This has the consequence (unfortunate in terms of income distribution) that unskilled labour demand in wealthy countries should fall, leading either to a fall in wages or (in more rigid labour markets) unemployment.

In this context, it is worth bearing in mind that, during the trade liberalisations of the past 2 or 3 decades, wealthy countries have indeed seen falls in unskilled labour demand (see, e.g. Slaughter, 1999 or Leamer, 1998), taking the form of rising wage differentials in the USA and UK, and of rising unemployment elsewhere. However, correlation does not necessarily imply causality, and there has been a vigorous debate among economists as to whether the observed labour demand changes really reflect trade effects, or whether the more important factor is simply technological change, for example with computers displacing unskilled workers. Most studies using aggregate data have concluded the latter, technology effect is probably the more important (see the survey in Abrego and Edwards, 2003), although some authors have argued this may reflect a failure to disaggregate sufficiently industries in which outsourcing is taking place.[16]

1.0.4 The clash between regional governance and national sovereignty

While the case for deeper regional integration, going beyond simply the removal of formal trade barriers, as outlined above, has been cited in support of the European Single Market and the Euro currency - classic cases of governance on a regional level - the economic analysis underlying this is still relatively novel and, on a theoretical level,

[16] See Anderton and Brenton, 1999.

under-developed. The currency debate - the choice between potentially trade-promoting stable exchange rates or more flexible rates to suit different national macroeconomic conditions - is well-rehearsed and beyond the scope of this thesis.

Less familiar is the parallel debate over regulatory standards. For example, in the instance of product standards, the case for regional or even global governance, either in the form of agreed harmonisation or mutual recognition, is based upon the perceived threat of 'regulatory protection'. However, there is no common economic textbook treatment of such protectionism to compare with the chapters on tariffs and quotas found in any standard trade text. Rather, work to date either consists of empirical studies characterised by sweeping assumptions, special case studies of individual industries (e.g. Gandal, 2001) or a few rather abstract theoretical pieces.[17] The claim that increased regulation hampers trade has rarely been investigated empirically, and what evidence there is (e.g. Swann et al, 1996) rather points in the opposite direction.

The problem is the dual nature of regulatory policy - whether implemented on a national or international level. Regulatory policies can be justified from the point-of-view of protecting consumer health, safety and providing insurance against substandard goods (c.f. Akerlof's 'lemons') in the presence of externalities or costs of information acquisition. Regulations of this type can be classified as 'vertical' standards regulation, in the sense that they tangibly improve some aspect of quality as experienced by consumers. Alternatively, regulations of a 'horizontal' nature (e.g. in telecommunications) can often be justified on the grounds of the need for different users to use compatible technology, which produces network externalities.[18]

[17] See Lutz, 1996 (1) and (2) or Wallner (1998).

[18] See the discussion in Maskus and Wilson (2001), particularly the chapters by Markusen and by Gandal.

The potential clash comes because on the one hand, regulation can be used potentially for protectionist reasons - hence providing a case for international intervention to avoid this - yet, on the other hand, differences in national regulations may well reflect a rational response to national differences in consumer preferences. For example, one would expect a poor country to be less willing to raise costs to consumers in order to improve, say, product safety than a rich country would be. The danger, from a policy point-of-view, is that if national regulations are weakened by harmonisation or by mutual recognition, there may be an undermining of quality, safety or reliability of goods, and this may reduce consumer utility in those countries where the preference is for higher quality or safety standards[19]. The rather bold conclusion of several studies that mutual recognition is necessarily welfare-improving are based upon rather specific assumptions about the nature of regulatory protection: studies either tend to concentrate upon the specific case of pure horizontal protection (Wallner, 1998) or to assume zero demand elasticity in response to vertical quality changes (Lutz, 1996 (1) and (2)).

In practical terms, the danger is that, unless analysis of quality regulation takes account of the vertical quality/utility effects as well as potential trade effects, there may be a tendency to over-prescribe either international harmonisation or mutual recognition, to the extent where the ability to vary national policy in response to national variations in preferences is undermined.

[19] This is essentially an adverse selection argument: consumers, arguably, lack information on different products (or the capacity to absorb such information), so that poor-quality goods drive out good ones. However, it may well be that in many circumstances, an optimal solution is international collaboration on a clear common labelling and testing system, which still allows for variation in product quality, rather than detailed harmonisation of product specifications. Such an agreement would, of course, have to rule out any deliberate attempt by one country's government to mislead consumers abroad.

1.0.5 Incomplete information, trade and national border effects

As an alternative to viewing border effects as reflective simply of protectionist barriers, a recent development in the trade literature has been to relax the assumption of perfect information. Where goods quality, or the reliability of a supplier, is important, or even more where the success of business connections depends upon a variety of factors, summarised as 'match quality' between two agents, then the quality of information one agent holds about potential partners in various parts of the globe will play a key part in determining where (s)he seeks to trade. This information, in turn, may depend upon historical and ethnic connections between countries, including cross-border migration flows, as well as geographical proximity, and such factors have been shown to be significant in gravity studies, especially in products which are qualitatively less standardised.[20] Search for such information is likely to be important,[21] as well as that of networks such as trade associations or common intermediaries in spreading information about potential match partners.[22]

It follows that trade patterns may well reflect historical, cultural and sociological factors, as well as current trade policy. The literature to date has not really taken much account of the policy implications of this (the field of informational barriers to trade is, admittedly, fairly novel). There is a distinct possibility that, in the presence of informational imperfections, while the scale of existing regulatory barriers may be exaggerated by gravity studies of border effects, the effects of relatively modest trade or regulatory barriers may be greater than estimated by standard models, and that past barriers may continue to influence trade long after they are removed. My paper in

[20] Rauch, 1999.
[21] Rauch, 1996.
[22] See Rauch and Trindade (2003) or Feenstra et al (1999).

Chapter 5 is probably one of the first serious attempts to investigate the implications of search theory for trade policy.

Going beyond the material in Chapter 5 and speculating, a model where information about trading possibilities is spread by networking and informational spillovers from one agent to another is also likely to have important welfare properties. In particular, if some of the benefits of search for trading partners are external to the agent doing the searching (i.e. there is free-riding on others' search activities),[23] then we might expect the acquisition of trade information to be suboptimal. This provides a new potential explanation for the apparent correlation between openness to trade and economic growth, as well as scope for much further investigation, not only of the links between trade policy or regulatory policy and the growth of international trade, capital and knowledge flows, but also on the significance of different models of industrial organisation and interaction between firms, trade associations, ministries and other bodies.

1.1 Organisation of this thesis and chapter summary

The thesis comprises four articles investigating a selection of topics relevant to the above debates.

1.1.1 Short- and long-run wage inequality decompositions

Chapter 2, written jointly with John Whalley, explores the issue of trade and wages in the advanced countries - in particular the question of whether trade liberalisation with LDCs can explain the relative fall in unskilled wages in the UK (and perhaps by analogy

[23] When there is networking, search information can be regarded as a type of public good.

the United States) since the 1970s. It forms part of a series of such papers[24] investigating the implications of variations in the specification of the standard Heckscher-Ohlin-Samuelson trade model for the quantitative relationship between the traded prices of unskilled-intensive versus skill-intensive goods upon relative wages. Most of these models use fairly simple assumptions (2 sectors, 2 factors both fixed in total volume within a nation, and treating the UK as a small, open economy). The justification for using a computable general equilibrium approach to decomposing observed changes is that standard econometric studies, which use a single equation, mandated wage approach, suffer from a number of flaws: specifically, the putative causal relationship between trade prices and/or technology and relative wages implied by trade theory works through changes in relative trade volumes, industry outputs and factor intensities. While it is possible to bypass any analysis of these stages, and derive and estimate a single-equation mandated wage model simply relating trade to either computerisation or prices, many such models are, in fact, inconsistent with the observed changes in industry outputs and employment. In particular, most Heckscher-Ohlin applications imply a far greater change in industrial structure than has actually occurred.

General equilibrium decompositions are, in theory, a means around this problem. The procedure adopted in various papers by Abrego and Whalley, as well as in the paper in Chapter 2 here, is decomposition by double calibration. The structure of the model and various key behavioural parameters are specified, and the model is then fitted to two years' data - one before, the other after the World price change. Estimates are then obtained for the shifts in various technology parameters, which are effectively derived as implicit residuals of the model, and a series of counterfactual model simulations is

[24]See Abrego and Edwards, 2003, for a summary.

then carried out, changing each technology parameter, or relative prices, individually. In the paper in Chapter 2 this is done by means of a series of chained steps to reduce the inevitable index number problems inherent in this type of decomposition.

The problem is that decomposition results for the United Kingdom turn out to be highly sensitive to variations in the specification of the model concerned. In our paper in Chapter 2, the specification variation under investigation is factor fixity. The Heckscher-Ohlin-Samuelson (HOS) framework generally assumes that all factors are mobile between sectors (though not between countries). In fact this has very important implications for the effects of traded prices upon wage inequality - a finding first derived with regard to the labour/capital differential in papers by Mayer and Mussa (both 1974) and Neary (1978). In the HOS framework, most of the effect of traded prices or technology upon wages comes from the magnification effect. This is the result, associated with Jones (1965), that a shift in relative traded prices causes a larger change in relative factor rewards. On certain model parameterisations,[25] a relatively modest change in goods prices can produce a large shift in relative factor demands. However, the magnification result critically assumes factors are fully mobile between sectors. Any factor immobility which hampers that structural change will reduce the effects of trade prices upon wages.

In our paper, two forms of immobility are investigated: first, a partial mobility assumption for unskilled labour. We assume that unskilled labour will only move from a declining to an expanding sector if the wage differential exceeds a certain iceberg mobility cost. The second specification is a three-factor model with capital as well as two kinds of labour, but where capital is sectorally immobile in the short-run.

[25] The scale of the magnification effect upon relative industry size and the scale of the consequent impact upon relative factor rewards depends upon a combination of relative initial factor intensities and the elasticities of substitution between factors within industries, as well as upon the degree of initial specialisation.

Numerical simulations show that even relatively modest mobility costs or modest endowments of a sectorally-immobile factor reduce the effect of trade prices upon wages, and this reduction can be large on plausible model parameterisations. In turn, this will greatly affect the residual technology parameter changes required for the model to be able to fit observed output and employment data in both start and end years. In fact, a fully factors-mobile model is shown to be quite implausible, since trade prices would produce a far larger shift in output towards skill-intensive industries than has been observed, and the model could only fit the data if there were strong sector-biased technological progress in the opposite direction (something inconsistent with Haskel and Slaughter's 1998 observations on computerisation).

In general, if we assume that factors are more mobile in the long- than in the short-run, then explaining the observed changes in wage inequality between 1979 and 1995 will depend to a large extent upon whether we consider this time-period to be more 'long-run' or 'short-run' in terms of factor mobility. If the latter, then it is likely that the full effects of trade price changes between 1979 and 1995, which favoured skilled labour, will be much less than the long-run effects implied by HOS. Consequently, it is likely that a higher proportion of the factor price changes which occurred are, in fact, attributable to technological change within the UK - while we would expect in future further increases in inequality as the longer-run effects of the trade price shift work through.

1.1.2 An economic assessment of EU single market enlargement

Chapters 3 and 4 address issues of quality standards and regional integration. In Chapter 3, which is a study commissioned by the European Commission, I investigate the implications for both existing EU members and accession states of enlargement of the

EU's Single Market to incorporate a number of Central and Eastern European Countries (CEECs). This analysis is done upon the assumption, common to previous studies by Baldwin et al (1995) and LeJour et al (2001), that different national regulations impose an iceberg cost upon firms trading across borders, while any other effects upon consumer utility are assumed to be negligible (i.e. we are talking about pure horizontal regulations). This assumption is examined more critically in Chapter 4.

The analysis in Chapter 3 utilises a 10 region, 8 commodity static general equilibrium model, where trade is based upon a 'love of variety' (Dixit-Stiglitz) formulation. The specification of the model used ('GEMEE') is laid out in detail in an appendix to the chapter. The 'love of variety' framework was chosen partly because it has properties akin to the empirical gravity model frequently used in analysing trade patterns,[26] partly because it implies (at least in the short- to medium-term) trade patterns which are not totally price-elastic (and hence has implications in terms of optimal tariff and customs union theory), and partly because it incorporates some of the scale, variety and capital stock effects which Baldwin and Venables (1995) show to be important aspects of regional trade agreements. This approach is consistent with the recent literature on trade costs, as surveyed by Anderson and van Wincoop (2004).[27]

The model is calibrated upon the assumption that, once transport costs and country size/variety affects have been corrected for, differences in shares of CEECs in the EU market in our base year (1997) compared to those attained by existing EU states in other EU markets (which we could call the implicit EU border effect) reflect extra trading costs - a combination of tariffs and NTBs (though these were almost entirely phased out even

[26] See Bergstrand (1989). However, Deardorff, 1998, has shown that on some assumptions gravity properties can also be derived from more traditional Heckscher-Ohlin-type models.

[27] The model in Chapter 3 is a novel form of what Anderson and van Wincoop (2004) term a 'theory-consistent gravity model' approach to deriving trade costs.

by 1997, except in agriculture) and the costs of regulatory differences. The residual border costs implied by this model (which correspond to EU membership dummies in more traditional gravity models) vary between 7 and 15 per cent of total cost of goods traded - which suggest they are roughly twice as large as implied by 'bottom-up' estimates such as those by Harrison et al (1996) or Zahariadis, 2002. When converted to gravity dummy equivalents, the costs are, however, broadly similar to those estimated by gravity models, such as by LeJour et al (2001).

Simulations show that accession to the Single Market is potentially much more important than reform of the existing tariff structure (this is hardly surprising, given that the Europe Agreements of the 1990s removed all bar agricultural tariffs between the EU and the accession states). The estimated welfare gains to the accession states from EU entry could be of the order of 11-20 per cent of GDP, slightly larger than the estimates by LeJour et al (2001). This perhaps reflects the difference between trade gains in a monopolistically competitive market compared to perfectly competitive national markets. Since the CEEC economies are small relative to the pre-2004 EU, their accession does not greatly affect welfare in existing EU states, but, on the assumption that Single Market enlargement consists of the removal of resource costs on trade, all member states gain, as do the states of the former Soviet Union.

1.1.3 Trade and strategic regulatory bias

In Chapter 4, I look more critically at the assumptions underlying the idea that regulatory differences between nations constitute 'regulatory protection'. In particular, I investigate one of the possible motives for quality regulation: namely the presence of monopolistic distortions, primarily using theoretical models of a monopoly and a cross-hauling duopoly.

If it costs more to produce goods of higher quality, then one would expect a monopolist (or oligopoly) to choose lower-than-optimal quality standards, for much the same reason as he will produce a smaller volume than optimal. I set up a model based on fairly simple homotheticity assumptions, where consumer utility depends on an aggregate of quantity consumed and quality (='quality adjusted output'). I assume that national regulators have power to set minimum quality standards, but not to regulate prices. Consider first a simple monopoly: if a regulator sets a minimum quality standard higher than the producer would choose, profits are lower, but consumer welfare is higher. For the socially optimal standard (assuming price regulation is infeasible), the regulator will set a standard at the point where the marginal loss of profit to the monopolist exactly offsets the marginal gains to consumers from higher quality (unless this causes profits to fall below zero[28]) . However, if the monopolistic producer is foreign, the regulator will set a higher standard than this, to the point where profits fall to zero.[29]

The approach is extended to a cross-hauling duopoly with identical consumers, producers and countries. However, in this case, the strategic game is more complicated. If national regulators do not cooperate, then in a Cournot-Nash equilibrium they will again set product standards which are higher than socially optimal, since each regulator does not take account of the effect of higher regulatory standards upon the foreign producer's profits. Consequently, there are potential welfare gains from cooperation in standard setting. However, in the absence of cooperation, trade (at least in terms of

[28] This is a feature which almost certainly depends upon the functional form selected. On the form investigated in Chapter 4, the non-negative profit constraint does not intervene in the monopoly case, so that the regulator in an importing country will always set a higher standard than that in a producing country.

[29] This result might potentially be modified if regulators were to engage in strategic games of retaliating in different sectors against a country which strategically overregulated a monopoly exporter.

quality-adjusted units) will be higher, not lower than socially optimal. The nonnegative profit constraint generally limits the degree of overregulation, but does not eliminate it. Also, if firms are identical, there is no discrimination in favour of the domestic against the foreign firm: in other words, this is an over-regulation bias, rather than regulatory protection. Against this, it is worth noting that mutual recognition also produces non-optimal results, though whether over- or under-regulation is not always clear: if each country's regulator knows that it can allow its domestic producer to cut quality and sell goods abroad at greater profit (but at a loss to foreign consumers), then there could potentially be a bias under mutual recognition to under-regulation and suboptimal trade. In other circumstances, raising regulatory standards at home may increase the firm's export share (causing a profit shift). Which effect dominates depends upon model parameterisations and the assumed setup of the regulatory game. However, in numerical simulations based upon the chosen functional form, I find that the profit-shifting motive outweighs the quality-cutting motive, so that mutual recognition consistently leads to standards above the global optimum for a wide range of parameter values. In some of these cases, the nonnegative profit constraint intervenes (so that the standards set, in practice, both with mutual recognition and with noncooperation are the zero profit standards). In these cases, mutual recognition will not alter standards or trade. In other cases, mutual recognition leads to a reduction in overregulation, which will almost certainly be welfare-improving, even if it is trade-reducing.

If the two firms differ, or if countries' tastes differ, then there may be a motivation to manipulate product standards in order to benefit the market share and profits of the domestic producer at the expense of its foreign rival. This is a profit-shifting motive for regulatory protection. However, in order for there to be such a profit-shifting motive, profits have to be significant.

A pure horizontal barrier, which raises the costs for the foreign firm, without raising the quality experienced by consumers, is unattractive when the option of tariff protection is also available. If tariffs are ruled out, there is a potential profit-shifting motive. However, to be attractive to a regulator, the profit-shift has to outweigh the loss to consumers: in the case of the Cobb-Douglas/linear functional form investigated in Chapter 4, this is not the case.

I also carry the model across to the case where it is impossible for a monopolistic producer to vary quality between one market and another, and where one country is an exporter and the other an importer of the good in question (a case in point being genetically modified foodstuffs). In these circumstances, if there is mutual recognition, the good will be produced at suboptimal quality. In this case, quality is being interpreted broadly, so that suboptimal quality may take the form of inadequate testing or labelling. By contrast, if countries set their standards separately, then if the producer is to supply both markets, we would expect it to set its quality at the standard in the importing country, which will generally be higher than those in the exporting country. However, the importing country will not be able to set standards too far above those in the exporting country, or the firm would cease to export to it. Consequently, there is a bargaining game between the two countries' regulators. The possibility that trade may be blocked completely in the short run, as countries' regulators flex their muscles (or while they wait upon a judgement from the WTO) cannot be ruled out.

1.1.4 Search and the path-dependency of trade

The paper in Chapter 5 is a contribution to a relatively new area of trade theory: namely the application of searching and matching theory to trade. The theoretical model is partly derived from Rauch and Casella's (2003) matching model of interfirm trade - however, it differs in that Rauch and Casella assume firms have only one opportunity to match with a foreign partner, and that if it is unsuccessful they can return to their previous domestic partner. By contrast, I postulate the development of trade as the outcome of a match-searching process, where firms search for information on potential partners (domestic or foreign) by undertaking a series of potential matches, until a match which exceeds their reservation match quality is achieved.

This model can be seen as rather schematic - in practice there may be plenty of ways in which firms can shorten the search process, by sharing information and the like. However, the key feature which comes across from the match-searching schema, which is perhaps overlooked in previous matching models of trade, is the importance of trade history as a determinant of the information which in turn influences current trade decisions. Consequently, trade would be expected to have strongly path-dependent properties, and perceived home bias in today's trade may be, at least in part, the legacy of a past where trade and international contact were more costly to undertake than today.

The paper draws a number of potential implications from this model. Entering into trade can be seen as a search investment (and matching information as a form of business capital) - so that greater ease of search and cheaper or better finance for trade would be expected to produce both greater trade and better eventual equilibrium match quality. Firms that have found an existing partner of greater than reservation match quality will be much less price sensitive in their choice of partner than firms who are still searching: it is an expensive and risky option to ditch a good match in the hope of finding a better one. Consequently, countries or trade blocs in a mature state, where most firms have reached at least reservation match quality, will have less price sensitive import demand than newer trade blocs. This has implications for the effects of timing and sequencing of trade decisions: an eventual free trade outcome may produce quite different trade patterns and welfare results depending upon the sequencing of the intervening trade liberalisation stages. The implications of this are investigated numerically.

Chapter 2

Short- and long-run wage inequality decompositions.

2.1 Introduction

This paper focuses on the causes of increased wage inequality in OECD countries in recent years, more specifically its decomposition into the component factors of trade surges in low wage products and technological change that has preoccupied the trade and wages literature.[1] We argue that if we assume that the observed wage inequality response to price and technology shocks reflects a short-run response in which factor allocations and output have not fully adjusted across industries, then decomposition analysis of the causes of the observed increases in inequality is substantially altered relative to a long-run world in which all factors are mobile. This finding is important because most data used in the debate are interpreted as reflective of a long-run full mobility response, when this may not be the case. Incorrect conclusions as to how trade surges and technology contribute to wage inequality can be easily drawn if the data are generated by a short-run adjustment process.

[1] See Wood (1994), Haskel and Slaughter (1998), Slaughter (1999) and Leamer (1998).

We examine two cases of factor immobility: a two-factor model where one factor is subject to mobility costs, and a Ricardo-Viner model with a third factor, immobile in the model run. In both cases, relatively small departures from the fully mobile Hecksher-Ohlin model noticeably change the decomposition results.

2.2 Long- and short-run models for trade and wages analysis

We use trade-based models to decompose the observed change in skilled-unskilled wage inequality in the UK between 1979 and 1995 to evaluate the relative importance of world prices (trade changes) and technological progress (whether sector- or factor-biased) in generating wage change. We compare results from short-run models in which some factors are either immobile or face adjustment costs moving between sectors, to those from a longer-run Heckscher-Ohlin type model where all factors are fully mobile between industries.

Models where not all factors can move easily between sectors (Mayer, Mussa, 1974, and Neary, 1978) have been used to investigate the implications of this feature for relative incomes in a two-factor model (such as whether the Stolper-Samuleson theorem still holds) and are the starting point for this paper. In these papers, the factor inputs are labour and capital, with capital immobile between sectors.

We discuss the case where the factor inputs are unskilled (U) and skilled (S) labour, with U being the factor subject to adjustment costs. In this case, if there is a fall in the world price of the U-intensive good, with S freely mobile between sectors, then since U cannot easily move towards the S-intensive sector in the short run, its wage will rise in the expanding sector and fall more steeply than the goods price in the declining sector. The wage of S will fall in the short run, though by less than the fall in the price of the U-intensive good. In the longer run, as factor U becomes free to move towards the S-intensive sector where its wage is higher, the output of this sector will expand. Given the shift towards the S-intensive sector, S's wages will rise, while U's wage will fall further in both sectors. This relative wage effect reflecting the shift over time in factors can be more marked than the initial impact effect of the price shock, and is the main factor behind the long-run Stolper-Samuelson influences on relative wages (a fall in the U-intensive good price will reduce U's wage and raise S's wage).

Although U's income will fall sharply in the U-intensive sector when the goods price falls, it will actually fall further, rather than be mitigated, once U becomes free to move to the other sector, as S's share of income gets bid up by the shift of output to the S-intensive sector. This suggests that some of the conclusions of the short-run model may differ from those predicted by the longer-run H-O model, in that much of the impact of trade on relative factor rewards (the 'magnification' effect[2]) requires factor rewards to be equated across sectors (which, in turn, will lead to changes in output): something which requires factor movement except in the polar case of Leontief production technologies. Also factor price insensitivity to endowments does not apply when not all factors are able to move, so any 'short-run' study of the causes of changing wage inequality needs to take account of changing endowments, not simply world prices and technology.

This conclusion is supported by our alternative, Ricardo-Viner case, where both types

[2] Jones (1965) identified the 'magnification' effect of product prices on factor prices, whereby if the price of a labour-intensive good (say good L) rises relative to a capital-intensive good (K), the effect upon relative factor rewards is greater than the change in relative goods prices, so that, if initial prices are 1, $w > P_L > P_K > r$. This result assumes the market equates factor rewards across sectors.

of labour are mobile, but capital is immobile. Again, the capital immobility reduces the shift in output between sectors in response to a price change, with the effects depending, among other things, on relative factor intensities. On the simulations carried out for the UK, this has a damping effect on changes in labour demand and wages, which becomes significant even with relatively small amounts of the fixed factor present. Sector output movement and changes in factor demand are noticeably reduced even when only 2% to 5% of value added comprises a fixed factor.

We consider the possibility that the changes in relative wages observed in a small open economy reflect the short-run response of the economy to a combination of world price, technological and demographic shocks. The procedures we employ are to calibrate a numerical general equilibrium model to the UK economy using data for 1979 and 1995, and then to make computations to decompose the observed change into component parts by considering the effects of changes separately. We use a Heckscher-Ohlin model, which assumes that factors can freely move between sectors, a short-term model which incorporates adjustment costs for unskilled labour and a Ricardo-Viner model.

2.2.1 A long-run trade and wages model

For our long-run model, we use a 2-factor, 2-sector Heckscher-Ohlin type formulation of a small, open economy.[3] Of the two sectors, sector E (exportables) is assumed to be intensive in the use of skilled factor S relative to sector M (importables): ie $U_E/S_E < U_M/S_M$. This holds for any pair of wage rates W_u and W_s (i.e. there are no factor intensity reversals). The factor input-output ratios for E and M, which we denote

[3]Strictly speaking, Heckscher-Ohlin trade models provide an explanation of trade patterns between countries in terms of relative factor abundance. We use the term here to refer to a mobile factors formulation of a single country.

au_E, as_E, au_M and as_M, are all functions of W_u and W_s.

We assume both labour markets are perfectly competitive. In equilibrium, these markets will clear, and factor prices and the associated input-output ratios will all adjust to clear the two factor markets. These equilibrium conditions imply that

$$\begin{aligned} au_E\{W_u, W_s\}Y_E + au_M\{W_u, W_s\}Y_M &= \overline{U}, \\ as_E\{W_u, W_s\}Y_E + as_M\{W_u, W_s\}Y_M &= \overline{S}, \end{aligned} \tag{2.1}$$

where Y_E and Y_M are outputs of the two goods and $\overline{U}$ and $\overline{S}$ are the economy-wide endowments of unskilled and skilled labour.

Competition ensures prices equal unit costs in both sectors, ie

$$\begin{aligned} au_E\{W_u, W_s\}W_U + as_E\{W_u, W_s\}W_S &= \overline{P}_E, \\ au_M\{W_u, W_s\}W_U + as_M\{W_u, W_s\}W_S &= \overline{P}_M, \end{aligned} \tag{2.2}$$

where $\overline{P}_E$ and $\overline{P}_M$ are the two goods prices set on the world market.

In order to capture the separate effects of factor- and sector-biased technical progress, we use a CES production function for each sector of the form

$$Y_i = A_i \left[\beta_i \left(\alpha_u U_i\right)^{((\sigma_i - 1)/\sigma_i)} + (1 - \beta_i)\left(\alpha_s S_i\right)^{((\sigma_i - 1)/\sigma_i)}\right]^{(\sigma_i/(\sigma_i - 1))}, \tag{2.3}$$

where A_i is a scale parameter, σ_i is the elasticity of substitution[4] between skilled and unskilled labour in production, β_i is a share parameter and α_u and α_s are factor-augmenting parameters. We can interpret an increase in A_i as representing a general increase in to-

[4] Note: we are defining the elasticity of substitution, σ_i, here as being positive.

tal factor productivity in sector i, which is purely sector-biased in its effects. Changes in α_u and α_s represent technical progress which increases the productivity of one factor across both sectors (factor-biased technological change), or, alternatively, changes in factor quality over time. Henceforth, we assume α_u and α_s are the same across sectors: the different factor shares in output between the sectors are determined by the β_i parameters.

For simplicity, we assume the elasticity of substitution between factors, σ_i, is the same in both sectors. We can therefore amend (2.3) to read:

$$Y_i = A_i \left[\beta_i \left(\alpha_u U_i\right)^{(\sigma-1)/\sigma)} + \left(1-\beta_i\right)\left(\alpha_s S_i\right)^{((\sigma-1)/\sigma)}\right]^{(\sigma/(\sigma-1))}. \tag{2.3a}$$

In the calibrations and simulations summarised below, a central case value is assumed for the elasticity of substitution, $\sigma = 1.25$, with sensitivity cases of 0.5 and 2 .

In a perfectly competitive industry, relative factor rewards will be equated to the value of marginal product. Consequently, for any level of output Y_i, W_u and W_s can be derived by differentiating (2.3a) with respect to U_i and S_i respectively, setting the marginal products of U_i and S_i equal to the respective wages divided by the product price, and then rearranging. Hence we derive

$$\begin{aligned} W_u &= P_i A_i \left(Y_i / A_i U_i\right)^{1/\sigma} \beta_i \left(\alpha_u\right)^{(\sigma-1)/\sigma}, \qquad (2.4) \\ W_s &= P_i A_i \left(Y_i / A_i S_i\right)^{1/\sigma} \left(1-\beta_i\right) \left(\alpha_s\right)^{(\sigma-1)/\sigma}. \end{aligned}$$

....

Derivation of Equation (2.4):

Rewrite (2.3a) as

$$Y_i = A_i Z_i^{(\sigma/(\sigma-1))},$$

where

$$Zi = \beta_i \left(\alpha_u U_i\right)^{(\sigma-1)/\sigma} + \left(1 - \beta_i\right) \left(\alpha_s S_i\right)^{(\sigma-1)/\sigma}.$$

Hence, by the chain rule of differentiation

$$dY_i/dU_i = \left(\sigma/\left(\sigma-1\right)\right) A_i Z_i^{(1/(\sigma-1))} (dZ_i/dU_i),$$

where

$$dZ_i/dU_i = ((\sigma-1)/\sigma)\beta_i \alpha_u^{(\sigma-1)/\sigma} U_i^{-1/\sigma},$$

and

$$Zi = (Y_i/A_i)^{(\sigma-1)/\sigma}.$$

By substitution we can write

$$\begin{aligned} dY_i/dU_i &= \left(\sigma/\left(\sigma-1\right)\right) A_i (Y_i/A_i)^{1/\sigma} ((\sigma-1)/\sigma)\beta_i \alpha_u^{(\sigma-1)/\sigma} U_i^{-1/\sigma}, \\ &= A_i (Y_i/A_i U_i)^{1/\sigma} \beta_i \alpha_u^{(\sigma-1)/\sigma}. \end{aligned}$$

We then equate this to the real product wage W_u/P_i.

The derivation for factor S can be derived analogously.

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Alternatively, we can rearrange (2.4) to derive (U_i/Y_i) and (S_i/Y_i):

$$U_i/Y_i = A_i^{\sigma-1} (W_u/(\beta_i P_i))^{-\sigma} \alpha_u^{\sigma-1}; \tag{2.4a}$$

$$S_i/Y_i = A_i^{\sigma-1}(W_s/((1-\beta_i)P_i))^{-\sigma}\alpha_s^{\sigma-1}.$$

Noting that the zero profit conditions for each sector imply $P_i = W_u(U_i/Y_i) + W_s(S_i/Y_i)$, we can substitute in for (U_i/Y_i) and (S_i/Y_i) to obtain prices for the two sectors, which are equated by competition to unit costs,

$$P_i = A_i^{-1}\{W_u^{\sigma-1}{\beta_i}^{\sigma}\alpha_u^{\sigma-1} + W_s^{1-\sigma}(1-\beta_i)^{\sigma}\alpha_s^{\sigma-1}\}^{1/(1-\sigma)}. \tag{2.5}$$

....

Derivation of Equation (2.5):

$$\begin{aligned}
P_i &= W_u(U_i/Y_i) + W_s(S_i/Y_i), \\
&= W_u(A_i^{\sigma-1}(W_u/(\beta_i P_i))^{-\sigma}\alpha_u^{\sigma-1}) + W_s(A_i^{\sigma-1}(W_s/((1-\beta_i)P_i))^{-\sigma}\alpha_s^{\sigma-1}); \\
P_i^{1-\sigma} &= A_i^{\sigma-1}[W_u^{1-\sigma}{\beta_i}^{\sigma}\alpha_u^{\sigma-1} + W_s^{1-\sigma}(1-\beta_i)^{\sigma}\alpha_s^{\sigma-1}]; \\
P_i &= A_i^{-1}[W_u^{1-\sigma}{\beta_i}^{\sigma}\alpha_u^{\sigma-1} + W_s^{1-\sigma}(1-\beta_i)^{\sigma}\alpha_s^{\sigma-1}]^{1/(1-\sigma)}.
\end{aligned}$$

....

Defining

$$\begin{aligned}
\theta_{si} &= (1-\beta_i)^{\sigma}/\alpha_s^{1-\sigma}; \\
\theta_{ui} &= {\beta_i}^{\sigma}/\alpha_u^{1-\sigma}; \\
i &= \{E, M\}; \qquad (2.6)
\end{aligned}$$

we can write

$$P_i^{1-\sigma}A_i^{1-\sigma} = \theta_{ui}W_u^{1-\sigma} + \theta_{si}W_s^{1-\sigma},$$

and cross-multiplying these equations for industries E and M gives us:

$$\begin{aligned}(P_E A_E)^{1-\sigma}(\theta_{UM} W_u^{1-\sigma} + \theta_{SM} W_s^{1-\sigma}) &= (P_M A_M)^{1-\sigma}(\theta_{UE} W_u^{1-\sigma} + \theta_{SE} W_s^{1-\sigma}); \quad (2.7)\\ W_u^{1-\sigma}[(P_E A_E)^{1-\sigma}\theta_{UM} - (P_M A_M)^{1-\sigma}\theta_{UE}] &= W_s^{1-\sigma}[(P_M A_M)^{1-\sigma}\theta_{SE} - (P_E A_E)^{1-\sigma}\theta_{SM}].\end{aligned}$$

Hence we can derive the ratio W_S/W_U.

$$\begin{aligned}(W_s/W_u)^{1-\sigma} &= [(P_E A_E)^{1-\sigma}\theta_{UM} - (P_M A_M)^{1-\sigma}\theta_{UE}]/[(P_M A_M)^{1-\sigma}\theta_{SE} - (P_E A_E)^{1-\sigma}\theta_{SM}],\\ &= [\theta_{um}\,(P_E A_E/P_M A_M)^{1-\sigma} - \theta_{uE}]/[\theta_{SE} - \theta_{SM}\,(P_E A_E/P_M A_M)^{1-\sigma}];\end{aligned}$$

$$W_s/W_u = \{[\theta_{um}\,(P_E A_E/P_M A_M)^{1-\sigma} - \theta_{uE}]/[\theta_{SE} - \theta_{SM}\,(P_E A_E/P_M A_M)^{1-\sigma}]\}^{1/1-\sigma}. \tag{2.8}$$

In this formulation, W_s/W_u is higher the larger is P_E or A_E, and the smaller is P_M or A_M. An increase in α_u/α_s will reduce W_s/W_u (this is the same result as in Davis (1997) and Haskel and Slaughter (2002)). Changes in the CES share parameters, β, however, have ambiguous effects on relative wages.

As Abrego and Whalley (2000) note, following Harry Johnson (1966), in the CES case specialization can occur for relatively small changes in goods prices (depending upon relative factor intensities and the elasticity of substitution). If specialization does occur, beyond this point traded goods prices do not affect relative wages, though changes in factor supplies will have an influence.

It is worth noting that the model equations outlined above do not contain any statement of consumer demand or utility. In this framework, prices of all goods are set on the world markets, and consumer demand at home does not affect prices or output if we assume the economy is small and open. This means that the production and consumption sides of the economy are separable; and given our focus on the determination of relative wage change we can concentrate on modelling the production side alone. The same argument applies for the short run model to which we turn next.

2.2.2 A short-run adjustment model of trade and wages

We formulate a short-run trade and wages model similar to the long-run model above, but in which labour cannot move costlessly between sectors due to adjustment costs. These may be search costs, transportation or removal costs, transactions costs in housing markets, or even psychological costs and preference for location.

In the model, we assume these transactions costs create a wedge between the wage offered in the sector where labour is currently employed and the wage needed to be offered in another sector in order for a worker to move. Wage rates in sectors which are expanding following an international price shock to the economy are thus higher than those in contracting sectors where labour shedding occurs.

We start out by looking at the theoretical properties of this model. In this model, factor U will only move from a declining sector M to an expanding sector E if wages in E exceed those in M by some proportionate amount λ_{ui}: ie if $W_{uE} - W_{uM} \geq \lambda_u W_{uM}$, and likewise for factor S if it also faces adjustment costs. This means that a sector can, in principle, fall into one of three potential categories: (i) it can be an expanding sector, where employers pay a high wage (gross of adjustment cost), (ii) it can be a declining sector, where the wage is lower, but adjustment costs are lower or (iii) it can be a static sector. In this latter case, the sector concerned will pay wages high enough that its labour force does not find it attractive to move to another sector once adjustment costs are taken into account, but not so high that it attracts labour from the other sector.

In expanding sectors (denoted sector i, a member of set e of all expanding sectors), we define the wage gross of adjustment costs as W_{ue}^{g}. The wage net of adjustment costs is then $W_{ue}^{n} = W_{ue}^{g}/(1+\lambda_U)$. In declining sectors ($i$ is a member of set d, the set of declining sectors) the wage rate W_{ud} will be the same as the wage in expanding sectors W_{ue} net of adjustment costs, which in turn equals $W_{ue}^{g}/(1+\lambda_U)$. Potentially, there may also be some sectors whose output may fetch a declining price, but where workers will take a lower wage rather than become unemployed: these will have unchanged employment if the wage lies between W_{ue}^{g} and $W_{ue}^{g}/(1+\lambda_U)$.

To capture these features we modify equation (2.4) to apply different wages to different sectors, expressing wages in all sectors in relation to the gross wage in the expanding sectors, W_{ue}^{g}. We will call this the reference wage, and label it as W_u^R. As we consider a two sector model, there are, in theory, two possible outcomes - first, one sector may be expanding and the other contracting, or alternatively both sectors may be static. In this latter case, one of the static sectors (call it the 'static, advantaged' sector) may well be paying a higher wage than the other 'static, disadvantaged' sector, but the difference in wages is not sufficient to tempt the unskilled factor to move.[5]

For each sector, we express the proportional difference between the wage received by labour in the unskilled intensive sector W_u^R, and the (gross of adjustment cost) wage paid by employers, W_u^g as lu_i. This allows us to characterise the difference in sectoral

[5] In practice, we note that a shift of factors and output between sectors is observed, which means that the second case (both sectors static) is not observed.

wage rates as follows:

$$\text{In expanding sectors } (i \subset e) : lu_i = 0; \tag{2.9a}$$

$$\text{In declining sectors } (i \subset d) : lu_i = \lambda_u; \tag{b}$$

$$\text{In static, advantaged sectors } (i \subset e) : lu_i = 0; \tag{c}$$

$$\text{In static, disadvantaged sectors } (i \subset e) : 0 < lu_i < \lambda_u. \tag{d}$$

In other words, the wage discount cannot exceed λ_u, since otherwise labour would move, reducing the discount back to this level.

We define the benchmark (pre-shock) levels of employment of U and S in each sector as $U_i^*$and S_i^*; the levels of employment if nobody leaves the sector. In a declining sector i $(i \subset d,)$ adjustment costs mean that the wage discount factor lu_j equals the maximum permitted, λ_u, and labour can move (ie the sector is 'declining').

The adjustment costs borne by those factors which move (which may be in the form of either temporary unemployment or a loss of productive efficiency) are given by:

$$\begin{aligned} \mu_u &= W_u^R \sum_i lu_i \left(U_i^* - U_i\right); \\ \mu_s &= W_s^R \sum_i ls_i \left(S_i^* - S_i\right). \end{aligned} \tag{2.10}$$

If adjustment costs are denominated in units of labour, this reduces effective economy-wide endowments

$$
\begin{aligned}
\sum_i U_i &= \overline{U} - \mu_{ui}/W_u^R; \\
\sum_i S_i &= \overline{S} - \mu_{si}/W_s^R.
\end{aligned} \tag{2.11}
$$

The effects of introducing adjustment costs into the model are thus: i) the wage of each factor will now differ between sectors by a proportion λ_u for U and λ_s for S. (ii) Factors are now less mobile in response to a price or other shock. In particular, there is a range of traded goods prices over which factors will not move, and this is wider the larger are λ_u and λ_s. (iii) Following Neary (1998), reduced mobility reduces the effects of product price changes on relative wage changes in both sectors. (iv) Because of the effects of the adjustment costs on factor movements and relative wages, the specialisation effects in a classical Heckscher-Ohlin model are less likely to occur. The modified model is easier to reconcile with observed data, where extreme changes to specialisation are not observed. (v) If we assume that in the long run λ_u and λ_s are zero, a price change will have larger effects on output, employment and wages in the long run than over the short-run. (vi) the long-run model is simply the short-run model with the parameters λ_u and λ_s set to zero.

2.2.3 A Ricardo-Viner fixed factor model of trade and wages

Our Ricardo-Viner model utilises a nested CES function to combine three factors: unskilled labour, U, skilled labour, S, and capital. Skilled and unskilled labour are mobile across sectors with a common wage, W_s or W_u respectively, while capital is sector specific, set at a level K_i. A CES nesting structure is used in which the two types of labour are used in each sector i are combined to form aggregate labour L_i using a CES aggregation. This is then combined with capital in a Cobb-Douglas function to yield total sectoral output, Y_i.

The CES aggregation function for the sectoral labour aggregate, L_i, is of the same form as equation (2.3)

$$L_i = A_i \left[\beta_i \left(\alpha_u U_i\right)^{(\sigma-1)/\sigma} + \left(1-\beta_i\right)\left(\alpha_s S_i\right)^{(\sigma-1)/\sigma}\right]^{\sigma/(\sigma-1)} \qquad ;(i=u,s). \qquad (2.12)$$

If we define an aggregate labour wage, W_i, as a CES aggregation of skilled and unskilled wages for each sector, then the first order conditions for employment of each type of labour in a competitive market can be written as $dL_i/dU_i = W_u/W_i$ and $dL_i/dS_i = W_s/W_i$. We can obtain dL_i/dU_i and dL_i/dS_i by differentiating (2.12). Consequently we can rearrange this to express the two wages W_u and W_s in terms of W_i, L_i, U_i and S_i:

$$\begin{aligned} W_u &= W_i A_i \left(L_i/A_i U_i\right)^{1/\sigma} \beta_i \alpha_u^{\sigma/(\sigma-1)}, \qquad (i=u,s), \qquad (2.13)\\ W_s &= W_i A_i \left(L_i/A_i S_i\right)^{1/\sigma} \left(1-\beta_i\right) \alpha_u^{\sigma/(\sigma-1)}, \qquad (i=u,s), \end{aligned}$$

which implies that

$$U_i/L_i = A_i^{\sigma-1}(W_u/(\beta_i W_i))^{-\sigma}\alpha_u^{\sigma-1}, \qquad (2.13a)$$

$$S_i/L_i = A_i^{\sigma-1}(W_s/((1-\beta_i)W_i))^{-\sigma_i}\alpha_s^{\sigma_i-1},$$

or

$$S_i/U_i = (W_s/W_u)^{-\sigma_i}((1-\beta_i)/\beta i)^{-\sigma_i}(\alpha_u/\alpha_s)^{(1-\sigma_i)}.$$

{Derivation of 2.13 follows that for 2.5}

The aggregate labour wage, W_i can be normalised to equal the average of skilled and unskilled wages in the sector :

$$W_i = (W_u U_i + W_s S_i) / L_i. \tag{2.14}$$

The Cobb-Douglas aggregation of L_i and K_i to form Y_i is given by: $Y_i = \Upsilon_i K_i^{\gamma_i} L_i^{1-\gamma_i}$, where $0 < \gamma_i < 1$.

γ_i is the capital share coefficient for industry I, Υ_i is a scale coefficient and from the first order conditions

$$\begin{aligned} L_i &= (1 - \gamma_i) P_i Y_i / W_i, & (2.15) \\ R_i &= \gamma_i P_i Y_i, \end{aligned}$$

where R_i is the rental return to capital.

2.3 Calibration and data

To use these models in decomposition experiments to assess the relative importance of trade surges and technological change for changes in wage inequality, we calibrate each to observed data for 1979 and 1995 for the UK. Since we compare the effects of alternatively assuming changes between those dates represent either short- or the long-run responses, we use three calibrations. In the Ricardo-Viner model we have three factors: capital, skilled and unskilled labour. In the other two versions (Heckscher-Ohlin or H-O, and partial mobility) we reallocate capital income from our database to the other two factors proportionately by sector, so the simplified model just has two factors. The H-O model differs from the partial mobility one in that λ_u and λ_s are set to zero: calibration based on this assumption means assuming a long-run equilibrium in the economy (ie the standard H-O model), whereas with λ_u set at a non-zero level we are assuming the economy is at a short-run equilibrium only. This latter treatment means that the adjustment process for the unskilled factor reflects an outcome influenced by short-run adjustment costs.

In all three models calibrated here, both goods are fully tradable and perfect substitutes for foreign goods. Consequently, if we assume the UK is a small, open economy, prices of the two goods are determined on global markets and can be taken as exogenous (although there is a downward shift in the price of the unskilled-intensive good over time, reflecting the opening up of new supply sources in Asia and elsewhere[6]). A consequence of these assumptions is that the production and factor demand side of the economy can be treated as separable from the goods demand side: we can simply treat World prices as given, with no need to model domestic goods demand, import and export volumes.

One potential problem with the above trade formulations (indeed with all neoclassical trade models) is the difficulty of reconciling the model with observed two-way trade. This is frequently used as a justification for the use of new trade theory models based upon a 'love of variety' approach (see chapter 3). However, while we acknowledge the importance of two-way trade between advanced countries in the skill-intensive sectors, arguably trade between the rich countries and the developing World is driven more by specialisation, with the rich countries as a group exporting skill-intensive goods and services and importing less skill-intensive goods. In this context, it may well be appropriate

[6]Physical and human capital accumulation in the Asian economies (see A.Young, 1995) and technological improvement in the transport sector will also play a role here.

to use more factor-driven models of trade, such as in this paper.[7] Consequently, we have used data for net imports/exports in this model.

To calibrate either the H-O or partial mobility models to the start- and end-years, we solve the model for parameter values given data for the two years, 1979 and 1995 with prices, wages, output and employment set at their observed values. We assume a value for the elasticity of substitution between factors in production σ (we assume the same elasticity for both sectors, to rule out the possibility of factor intensity reversals), and we assume values for the differential between skilled and unskilled wages in the expanding and declining sectors E and M.

Note that, for our central case we assume an elasticity of substitution between factors in production, $\sigma = 1.25$. In the Appendix, we investigate sensitivity cases where $\sigma = 0.5$ and $\sigma = 2$.The unknowns at this stage are the model parameters for each sector and each time period ($\alpha_{uit}, \alpha_{sit}, \beta_{it}$ and A_{it}).

We use the eight first-order conditions for cost-minimising behaviour (equations for 2 factors for 2 sectors for 2 years, (1979 and 1995)).

$$\begin{aligned} W_{uit} &= P_{ti} A_{it} \left(Y_{it} / A_{it} U_{it} \right)^{1/\sigma} \beta_{it} \alpha_{uit}^{(\sigma-1)/\sigma} \qquad (2.16) \\ W_{st} &= P_{it} A_{it} \left(Y_{it} / A_{it} S_{it} \right)^{1/\sigma} \left(1 - \beta_{it} \right) \alpha_{sit}^{(\sigma-1)/\sigma} \end{aligned}$$

We assume a value for the elasticity of substitution between factors in production, which we also assume to be constant across sectors (we carry out the calibration and

[7] Note that Abrego and Whalley (1999a) investigate the effects of introducing differentiated goods into general equilibrium trade-wages decompositions (a simple form of Armington model). In this paper, we prefer to investigate the effects of factor immobility separately from those of product differentiation.

simulations for a central case $\sigma = 1.25$ with sensitivity values of $\sigma = 0.5$ and $\sigma = 2.0$). Using this, it is possible to calibrate the model, i.e. to generate values of the technical coefficients (α_u, α_s, β, and A) for each sector. The other constraint we assume is that there is no decline in industry-specific technology in either sector (i.e. A_i cannot decline from period 0 to period 1), based on the assumptions that technological innovations will not be unlearnt once developed.

For the Ricardo-Viner model, we calibrate capital share coefficients γ_i from income shares. The calibrated values of the unskilled share parameters, β_i, and the labour quality coefficients, α_{ui} and α_{si}, are unchanged compared to the calibrated H-O model, while the A_i scale parameters for labour income are smaller.

Having determined parameter values in each of the models using the calibration procedures described above (which we use for the long-run model where $\lambda_u, \lambda_s = 0$ and the short-run model where $\lambda_u > 0$), we then compute counterfactual equilibria with each model. Using the 1979 UK price, technology and endowment data as inputs, we compute equilibria for the UK economy if endowments, prices and/or technological parameters are separately changed to their 1995 model values. We then compare these computed model equilibria to the actual 1995 data in which all these changes jointly appear.

Previous studies (e.g. Abrego and Whalley (2000)) have decomposed the causes of increased inequality by carrying out simulations, first altering prices, then technological parameters (or vice-versa). Due to model nonlinearities, the order of decomposition can make a difference to how much change is attributed to which cause. For this reason, we follow a method (similar to that in Kose and Riezman's (1999) study of customs unions), in which endowments, trade and technology are changed in a series of small steps (first 1/10 of the total change in endowments, then 1/10 of the total change in prices and 1/10 of the total change in technology, then repeating the cycle): the smaller the steps, the less the order matters.[8]

2.3.1 Data

We use data for the UK for 1979 and 1995 for our model analyses, similar to those used by Abrego and Whalley (1999b). They used data on skilled and unskilled employment and wages for two broad categories of industry, taken from the UK Labour Force Survey. We use an estimate of a 7.9 per cent fall in the relative price of unskilled imports between 1979 and 1995 based on an estimate derived by Abrego and Whalley (1999) from Neven and Wyplosz (1999).[9]

As two of our models have only two factors, against the three in Abrego and Whalley (1999a), we reallocate income accruing to the fixed factor in each sector between skilled and unskilled labour in the proportions used in that sector. Following Abrego and Whalley, value added is rounded to equal gross output.

The 1979 and 1995 UK data we use are shown in *Table 2.1* below. Price and wage data are in real terms. An important feature of the data used is the marked difference in skilled/unskilled labour usage between the two sectors: the ratio of skilled to unskilled workers is more than twice as great in sector E as in sector M in both years.

The rise in the average real wage of unskilled labour was approximately 23 per cent between 1979 and 1995,[10] reflecting an increase in the premium for skilled over unskilled

[8] This was confirmed by carrying out decompositions in different orders with progressively smaller steps. As the steps grow smaller, the decompositions converge.

[9] Although Neven and Wyplosz find that prices of imports from OECD countries or from developing countries do not vary much by sector skill-intensity, imports from developing countries fall relatively in price to those from OECD countries, and these weigh more heavily in total UK imports in the skill-intensive sectors.

[10] This is calibrated to UK GNP growth – see the UK national accounts 1996 Table 1.3.

wage rates from 22% in 1979 to over 59% in 1995. This occurs despite the ratio of skilled/unskilled labour inputs rising in both sectors. While there is an increase in the share of skilled intensive exportables in total production, both sectors show rising output. The change in industrial structure in the data is therefore a relatively minor factor compared with what a Heckscher-Ohlin model would usually be expected to produce in response to the assumed 7.9% fall in the relative goods prices.[11]

[11] With an elasticity of substitution of 1.25 between the two fully-mobile factors, and starting with output and employment as in our database for 1979, we show complete specialisation in good X after a price fall of just 6.3% in good M. This corresponds to a change of nearly 40% in relative skilled wages. Details of this calculation are available on request from the authors. The fact that relative factor intensities differ greatly across sectors is one reason for the speed at which specialisation is reached.

Table 2.1: 1979 and 1995 UK data used in calibrating short-run models

			1979	1995
Labour Input (bn hrs)	Good M	Unskilled	36.0	26.4
		Skilled	19.0	25.2
		Total	55.0	51.6
		S/U	0.5	1.0
	Good E	Unskilled	24.3	16.5
		Skilled	33.4	34.8
		Total	57.7	51.4
		S/U	1.4	2.1
	Total	Unskilled	60.3	42.9
		Skilled	52.4	60.1
		Total	112.7	103.0
Hourly wage pounds	Average	Unskilled	5.47	6.45
1995 prices		Skilled	6.67	10.23
Average wage ratio			1.22	1.59
Output index	Good M		100.0	134.0
	Good E		100.0	138.1
Goods prices	Good M		1	0.921
	Good E		1	1
Good M % of total value added			47.5%	44.7%

The unskilled labour mobility cost, λ_u, reflects studies which tend to indicate that unskilled labour may be less mobile between sectors than skilled. Kruse (1988) suggest unemployment periods in the US are generally longer for unskilled rather than skilled workers, which, in terms of our model, might suggest a higher threshold wage differential for the unskilled before they start to move between sectors. This is borne out by Haynes, Upward and Wright's (2000) UK study, which suggest that those with lower skills experience longer unemployment duration.

We have chosen, for simplicity, to assume that only unskilled labour, factor U, is affected by mobility costs (ie $\lambda_s = 0; \lambda_u \geq 0$) and we use a figure of 13.7 % for 1995,[12] an 'upper end' estimate of mobility costs. In later sensitivity analysis, we also evaluate models with lower values.

2.4 Model results

We use three calibrations to the 1979 and 1995 data: one involving the long-run two-factor model in which all factors are able to move freely in response to price and technology shocks; a second short-run model in which unskilled labour is only partially mobile, if intersectoral wage differentials exceed a threshold, assumed to be 13.7% of wages; and a third using a three-factor Ricardo-Viner model with sectorally fixed capital. We concentrate initially on the case where the elasticity of substitution between factors of production is 1.25 in both sectors.

Table 2.2 outlines our decomposition results for observed changes in relative wages of skilled and unskilled labour between 1979 and 1995 using these three calibrated models. The contribution of various causal factors to the observed change in the average skilled to

[12]This assumes that the 7 $\frac{3}{4}$ % difference in wages between sectors reported by Greenaway *et al.* (1999) for the UK in 1990 is explained entirely by lower unskilled wages in the declining sectors, in turn reflecting an unwillingness to move due to mobility costs. We assume the 7 $\frac{3}{4}$ % difference in average wages comprises no differential for skilled workers and a 13.7 % differential for unskilled.

unskilled wage ratio, which *Table 2.1* indicates increased from 1.22 to 1.59, is expressed by the contribution of each causal factor as a percentage of the total change.

Table 2.2: Model decomposition of wage inequality

Central case changes **Component factors:**	**Long run** **factors mobile**	**Short run** **adjustment cost**	**Ricardo-** **Viner**
World price change	152%	83%	19%
Technology:			
-sector bias	-491%	-228%	-43%
-skill bias	184%	187%	256%
-capital bias	0%	0%	-8%
-factor quality	255%	151%	67%
Endowments	0%	-92%	-191%
Total	100%	100%	100%

In the long-run Heckscher-Ohlin factors mobile model (first column of numbers), the increase in skilled and fall in unskilled factor endowments has no effect, as the factor price insensitivity result (see, e.g. Leamer and Levinsohn (1995)) suggests. However, the model shows substantial sensitivity to the change in world prices, which alone accounts for 152 % of the total observed wage change. There is also substantial factor bias in favour of the skilled factor (skill bias +184% and factor quality +255%), and rise in the skilled share of output. These results fit the observed wage and output changes due to a sizeable sector-biased technical change in the opposite direction (-491%), favouring the unskilled intensive sector M.

In the second column, the partial mobility model shows different results. The change of endowments has a large effect on relative wages narrowing the gap between skilled and unskilled wage rates (-92% of the total net observed change). The effect of world prices is reduced to around 83% of the observed total wage change, while sector bias, which still favours the unskilled-intensive good, is also smaller in this model compared to the factors mobile model (-228% of the observed change against -491%). The main factor in this model behind the increased inequality is the change in the skill share within industries (187% of the observed change), with a slightly smaller contribution from factor quality.

The final column of *Table 2.2* reports results for the Ricardo-Viner fixed factors model sectoral output and employment are less sensitive to price or sector-biased technical changes. World price changes account for just 19% of the total observed change in relative wages, 1/10 of the change in the Heckscher-Ohlin model. Sector-biased technical change has a moderate damping effect on inequality (-43%). The main picture conveyed by this model is strong factor-biased change within industries (+256% of the observed net change) in favor of skilled labour, offset partially by large effects of endowment changes (-191%).

Table 2.3a: Sensitivity of decomposition in short run models to key parameters

Per cent of total change in ratio of skilled /unskilled earnings	**Long-run model**	**Short run adj cost 5%**	**10%**	**14%**
World Price Change	152%	126%	99%	83%
Technology bias:				
-sector bias	-491%	-387%	-288%	-228%
-skill bias	184%	186%	186%	187%
-capital bias	0%	0%	0%	0%
-factor quality	255%	212%	173%	151%
Endowments change	0%	-37%	-70%	-92%
Total	100%	100%	100%	100%

Table 2.3a reports the sensitivity results for the partial mobility model to changes in the assumed mobility cost. Moving rightward the columns show adjustment costs for labour increasing from zero (Long-run model) to our maximum 13.7 %, and shows that the effect of trade upon wage changes falls markedly as the adjustment cost rises, from 152% of total observed changes in the Heckscher-Ohlin case to 83% in our maximum adjustment cost case (in other words, nearly halved). The latter is still, however, somewhat larger than estimated by most other empirical studies of the contribution of trade. The roles of factor-biased technology changes, in the opposite direction: the role of endowment changes rises rapidly as factor mobility costs are introduced.

Table 2.3b: Sensitivity of decomposition in short run models to key parameters

Per cent of total change in ratio of skilled /unskilled earnings	**Long-run**	**Ricardo-Viner Fixed fctr share 2%**	**5%**	**10%**	**20%**	**30%**
World Price Change	152%	101%	65%	41%	24%	17%
Technology bias:						
-sector bias	-491%	-324%	-201%	-119%	-60%	-36%
-skill bias	184%	204%	207%	210%	213%	214%
-capital bias	0%	0%	0%	0%	0%	0%
-factor quality	255%	188%	137%	102%	77%	66%
Endowments change	0%	-70%	-108%	-134%	-153%	-161%
Total	100%	100%	100%	100%	100%	100%

Table 2.3b summarizes the sensitivity of the Ricardo-Viner fixed factor model to different assumptions about the share of fixed factors in value added. The higher the assumed share of fixed factors in value added, the less role for trade or sector bias and the greater the role of endowment changes. However, the most revealing columns are those where we have assumed just 2% or 5% of value added consists of fixed factor payments. Introducing relatively small amounts of these fixed factors modifies the behaviour of the model quite rapidly compared to to the Heckscher-Ohlin model: the effect of traded prices, for example, is cut from 152% of observed changes to 101% with 2% of factors

fixed, and 65% with a 5% fixed factor share.[13]

The tables in the Appendix explore the sensitivity of our decomposition results in the three models to the elasticity of substitution between unskilled and skilled labour in production, which we set at 0.5 and 2 instead of our central case value of 1.25.

Comparing estimates of the contribution of various factors when the assumed elasticity of substitution between skilled and unskilled labour is changed shows that the relationship between elasticity and decomposition estimates is neither simple nor monotonic. In most cases the effects of skill bias (positive) and endowments change (negative) on relative wages are higher when the elasticity of substitution between factors is lower. Factor quality is more important in explaining relative wage changes with higher substitution elasticities. The relationship to price changes and sector bias seems to be non-monotonic.

[13] The result that the presence of a fixed factor alters the effect of trade upon factor returns is, of course, not new. However, the quantitative assessment of the degree of effect of small amounts of a fixed factor upon the response of factor returns to traded goods prices has not been shown before.

2.5 Conclusions

In this paper, we compare the use of short-run and long-run trade models to decompose changes in observed wage inequalities between skilled and unskilled labour over the period 1979-95 for the UK into trade and technology, and endowment change components. Results of these decompositions are very different depending upon whether a short-run model, with limited mobility of unskilled labour, or a long-run model is used to explain the observed changes. This emphasises that different assumed model structures applied to the same data in decomposition will substantially affect the perception of the role of trade in wage inequality change. The main contribution of this paper is to demonstrate the degree to which factor mobility assumptions are likely to affect the response of factor prices to traded goods prices in an advanced economy such as the United Kingdom. A clear conclusion is that modellers need to be explicit about the factor mobility assumptions they are making when carrying out decompositions of wage inequality changes. Since factors are generally believed to be more mobile in the long-run than the short-run, the time scale over which the decomposition is being carried out is also important.

In the long-run model, the factor-bias of technical change has no effect (except insofar as the relative quality of skilled labour has risen). As theory would suggest, factor endowments have no effect in the long run. In contrast, the effects of observed world price increases are very large: on its own this price increase would cause a larger shift in output towards the skill-intensive goods, and a larger rise in skill premia than actually observed. The long-run model can only be made consistent with the observed output and income changes if the sector-bias of technical change (the residual category of the decomposition) is in the opposite direction: for UK total factor productivity in the unskilled-intensive sector to have risen faster than in the skill-intensive sector, so damping the tendency of output to switch.

By contrast, when we use a short-run model for these decompositions, one in which unskilled labour is only partially mobile, the decomposition results are quite different. The rise in the relative supply of unskilled labour now has a sizeable damping effect on inequality. Factor-biased technical change (leading to a rise in skilled/unskilled input ratios in both sectors) despite rising skill premia will raise relative skilled wages in a short-run model. The effect of trade is less marked in the short-run model, though still quite substantial. The sector-bias in technical progress (which had been large and favoured the unskilled-intensive sector in the long-run model) is relatively minor in our short-run model.

The other short-run model specification we examine is a Ricardo-Viner model, where capital is assumed to be sector-specific. The effects of this are even more marked than in the partial mobility case - prices and sector-biased technical change have only a small effect, while factor-biased change is the main cause of insensitivity in inequality, offset by endowment changes. Sensitivity analysis shows that, even when only a small proportion of valued added is linked to fixed factors; behaviour of the model can be noticeably changed compared to the Heckscher-Ohlin formulation.

There are a number of reasons, we believe, for the short-run model decomposition to be the more plausible. First, the sign of the sector bias in our calibrated long-run model is contrary to what comparisons the effects of computerisation on wage inquality (eg by Haskel and Slaughter, 1998) would indicate. Second, the effects of labour upskilling and of factor-biased technical change in the short-term models are more consistent with what studies by labour economists would indicate (eg Borjas *et al.*, 1992; Murphy and Welch, 1991; and Katz and Murphy, 1992).

Appendix 2.1: Elasticity sensitivity of model-based decompositions

Table 2.A.1: Elasticity sensitivity of model based decompositions - substitution elasticity between skilled and unskilled set at 0.5

		Factors mobile LR	**SR adj cost**	**Ricardo-Viner**
World price change	(trade)	86%	41%	34%
Technology	Sector bias	-330%	-137%	-106%
	Skill bias	290%	315%	631%
	capital bias	0%	0%	-7%
	factor quality	54%	-6%	-83%
Endowments		0%	-113%	-369%
TOTAL		100%	100%	100%

Table 2.A.2: Elasticity sensitivity of model based decompositions - substitution elasticity between skilled and unskilled set at 1.25

		Factors mobile	**Short run**	**Ricardo-**
		Long Run	**adj cost**	**Viner**
World price change	(trade)	152%	83%	19%
Technology	Sector bias	-491%	-228%	-43%
	Skill bias	184%	187%	256%
	capital bias	0%	0%	-8%
	factor quality	255%	151%	67%
Endowments		0%	-92%	-191%
TOTAL		100%	100%	100%

Table 2.A.3: Elasticity sensitivity of model based decompositions - substitution elasticity between skilled and unskilled set at 2

		Factors mobile LR	**SR adj cost adj cost**	**Ricardo-Viner**
World price change	(trade)	155%	67%	12%
Technology	Sector bias	-400%	-132%	-22%
	Skill bias	42%	19%	64%
	capital bias	0%	0%	-5%
	factor quality	303%	221%	171%
Endowments		0%	-75%	-120%
TOTAL		100%	100%	100%

Chapter 3

An economic assessment of EU single market enlargement.

3.1 Introduction

This paper represents a study modelling the costs and benefits of the recent and likely forthcoming waves of EU enlargement to include the Central and Eastern European Countries (henceforth referred to as CEECs). In particular, I look at the effects of accession to the EU's Single Market, with its harmonisation and mutual recognition agreements, which eliminate many non-tariff barriers to trade between EU members. This is investigated using a computable general equilibrium model based upon an imperfectly competitive 'love of variety' model, using the Dixit-Stiglitz framework, which has been shown (e.g. Baldwin and Venables, 1995) to generate much more significant potential welfare gains from trade than the more traditional Armington models.

The layout of the paper is as follows. Section 2 contains a discussion of the literature to date, particularly focusing on the methodology and assumptions of major previous studies of EU accession by Baldwin *et al* (1997) and LeJour *et al* (2001). Section 3 summarises the modelling approach and data used in this paper: in particular the novel, model-consistent calibration procedure to estimate country bias effects. In section 4, I outline the results of simulations of accessions of Poland, Hungary and an Other CEEC Region into the EU, and of accessions of the rest of Central and Eastern Europe[1]. The simulations are based upon an intermediate-term Dixit-Stiglitz model, which incorporates scale and variety effects, but does not allow firm numbers to change, which would happen in a longer-term model.

The final section discusses the findings of these simulations. If we assume that trade between the EU and accession states moves into line with that between existing EU members, then the effects on the accession states, particularly Poland, could be very large, with sizeable increases in trade with the EU and income gains of up to 20 per cent. However, the assumptions upon which this conclusion is based are rather contentious: in particular our current theoretical understanding of the working of mutual recognition agreements and of the relationship between non-tariff barriers and trade volumes is rather sketchy. Some of these issues are investigated in more depth in subsequent chapters.

3.2 Background

Early studies of the economics of EU enlargement into the former Soviet bloc (e.g. Brown *et al*, 1995) concentrated on the effects of removal of tariffs and formal non-tariff barriers

[1] Due to data limitations, I am unable to carry out simulations on the precise accession list of 2004. The other CEEC region comprises the Czech Republic, Slovakia, Slovenia, Romania and Bulgaria. The latter two are not on the 2004 EU accession list, whereas the 3 Baltic States, as well as Cyprus and Malta, are.

(NTBs). Such barriers, except in agriculture, were removed in the mid 1990s by the Europe Agreements. The issue has then moved to the effects of joining the EU's Single Market, with its associated mix of regulatory harmonisation and mutual recognition agreements.

Studies (e.g. Baldwin *et al*, 1997, or LeJour *et al*, 2001) which focus on this aspect have assumed that EU membership for CEECs would have large effects upon trade with the EU. The justification comes mostly from empirical observation: it is known that trade between countries falls well short of trade within a single country[2], and that significant country bias also exists for members of trade blocs vis-à-vis non-member countries. Baldwin in particular has attributed much of this to differences in product standards, trade law and other informal barriers to trade, which supposedly constitute 'regulatory protection'[3], in many cases higher than formal trade barriers. When combined with models based upon the new trade theory, the removal of such protection can have sizeable effects, due not just to standard specialisation gains, but also to the diminution of local monopoly power, the widening of consumer choice and the achievement of scale economies in a larger market.

Estimates of the scale of non-tariff barriers are generally imputed from the empirical gravity modelling literature. It has long been believed that trade between two countries is roughly proportional, *ceteris paribus*, to the product of size of the economies, corrected for distance and formal trade barriers. However, there are residual differences, which we shall henceforth call residual country bias. Most notable is home bias: the preference

[2] McCallum (1995) found a national border effect reducing trade between Canadian provinces and neighbouring US states by a factor of 22, compared to between Canadian provinces.

[3] For the arguments on regulatory protection see, e.g., Baldwin, 2001, Maskus and Wilson, 2001 and Wallner, 1998. However, for counter-arguments, see Swann et al, 1996, Moenius, 1999 and Edwards, 2003(1). Also DTI (2005).

of consumers for produce of their own country, rather than any other, which seems empirically to be very strong, even when a country joins the single market. Beyond that is a lesser, but still significant bias towards produce of other countries within the same trade bloc.

These biases are usually picked up in gravity equations, which might typically take a form such as:

$$
\begin{aligned}
X_{i,c,cc} \quad = \quad & \alpha_g + \beta_{1i} D^{EU}_{c,cc} + \beta_{2g} d_{c,cc} + \gamma_{1s} Y_c + \gamma_{2s} y_c + \gamma_{3s} Y_{cc} + \gamma_{4s} y_{cc} + \\
& \sum_d \delta_d D_{d,i,c,cc} + \upsilon_{1s} TM_{i,c,cc} + \upsilon_{2s} TE_{i,c,cc} + \epsilon_{i,c,cc} \qquad (3.1)
\end{aligned}
$$

where all variables (except the dummies) are in logs. $X_{i,c,cc}$ is exports of industry i from country c to country cc, Y is GDP and y is GDP per capita, d is distance between capitals of the countries c and cc. D^{EU} is an EU membership dummy, set to 1 if both c and cc are EU members, otherwise set to zero. D is a set of other dummies for border effects. $TM_{g,c,cc}$ is the import tariff on imports of i from country c to country cc. $TE_{i,c,cc}$ is the export tariff levied by country c on country cc. Table 3.1 summarises LeJour *et al's* (2001) estimated of residual country bias dummies for EU membership.

Table 3.1 *EU dummies in gravity equations (LeJour et al, 2001)*		
Sector	**EU dummy**	**Trade increase%**
Agriculture	2.25*	249
Raw materials	-0.10	94
Food processing	0.66*	
Textiles & leather	0.85*	134
Non-metallic minerals	0.73*	107
Energy-intensive products	0.13	
Other manufacturing	0.08	
Metals	-0.10	
Fabricated metal products	0.44*	56
Machinery & equipment	0.31*	37
Electronic equipment	0.58*	79
Transport equipment	0.66*	94
Trade services	0.76*	113
Transport & communication	0.03	
Financial services	-0.14	
Other services	0.27*	31

The rather strong assumption made by both the LeJour *et al* and the Baldwin *et al*[4] studies is that this residual border effect of EU membership corresponds to an unspecified set of trade costs (henceforth referred to here as the 'residual border trade cost'), whose assumed removal or reduction by joining the single market is a sizeable source of potential economic benefit for the CEECs[5]. However, it must be stressed that there are plenty of alternative explanations other than iceberg-style trade costs for residual border effects in empirical models, such as differences in consumer preferences - companies producing goods suited, say, to French rather than British taste would be more likely to set up in

[4]In their earlier paper, Baldwin *et al.* (1997) assume rather arbitrarily that joining the single market would mean a reduction in trade costs (real term costs, assumed to be measured as an iceberg cost - a loss of value of all goods traded between exporting country c and country cc of fraction $\phi_{c,cc}$) of 10 per cent across the board.

[5]The economic interpretation LeJour *et al.* attach to these dummies stems from the well-known link (following Bergstrand, 1989) with a general equilibrium trade framework based upon an imperfectly competitive framework (though, in fact, LeJour *et al.* use an Armington rather than a Dixit-Stiglitz model for simulations). Though Deardorff (1998) points out that a frictionless Heckscher-Ohlin model and an Armington model (which may be the result of countries specialising on sub-categories within the measured goods categories of a H-O model) will also produce gravity relationships.

France rather than the UK - or historical search-related factors[6].

The two above studies both found significant welfare and trade gains from EU enlargement. Baldwin *et al*'s (1997) simulation results, based on an assumed 10% iceberg cost on trade between the EU and CEECs, are shown in Table 3.2 (below).

Table 3.2 *Baldwin et al. (1997) simulation results for EU enlargement*

Real income changes from EU enlargement (% change on base)

	Conservative case trade gains only	**Less conservative case with risk premium reduced**
CEEC	2.5	18.8
EU15	0.2	0.2
EFTA3	0.1	0.1
Ex-USSR	0.3	0.6

LeJour *et al* (2001) also find substantial benefits for the accession countries, particularly Poland, though not as sizeable as in Baldwin *et al* (1997). This is not surprising since LeJour *et al* use an Armington model, which assumes perfect competition within countries, and so does not provide any estimates of the potential benefits (particularly those linked to increased competition and scale economies) which a Dixit-Stiglitz model captures[7]. Both studies are agreed that enlargement involves few costs for existing EU members, though LeJour *et al* imply France may have lost slightly from the 1997 tariff changes.

[6] See, e.g., Rauch, 1997, Edwards 2003(2).
[7] See the discussion in Baldwin and Venables (1995).

Table 3.3: *LeJour et al. (2001) simulation results of EU enlargement*			
		Volume of GDP effects of removal of 1997 bilateral tariffs and adoption of Common External Tariff	Accession to the internal market
CEEC7		1.3	5.3
	Hungary	1.9	9.0
	Poland	4.3	5.8
	CEEC5	1.0	3.4
EU15		0.0	0.1
	Germany	0.0	0.1
	France	-0.2	0.1
	United Kingdom	0.0	0.0
	Netherlands	0.0	0.0
	South Europe	0.0	0.1
	Rest EU	0.0	0.1
Third Countries		0.0	0.0
	Rest OECD	0.0	0.0
	Former Soviet Union	0.0	0.0
	ROW	0.0	0.0

3.3 Methodology

Despite the doubts expressed above, this paper proceeds upon the assumption that residual border effects do indeed reflect residual border trade costs, as in the Baldwin *et al* and LeJour *et al* papers. Nevertheless, the approach here differs somewhat. First of all, in this paper I derive residual border effects by direct calibration of a theoretical Dixit-Stiglitz model, which is then used for simulation. Unlike previous studies the calibration and simulation models are fully consistent.

Secondly, I calibrate residual border effects for imports and exports between each pair of countries (though 'averages' are then constructed for inter-EU trade using model-consistent CES functions for aggregation). Since gravity studies typically use a much more parsimonious set of dummies (e.g. just a home dummy and a second dummy if both countries are EU members) they are effectively constraining many residual border effects to be equal.

The third difference from standard gravity approaches is that more specific account is taken of the importance of relative output prices. While we do not know exactly what the relative costs of production in different countries are (particularly when quality is corrected for), we can calibrate for revealed comparative costs, once a certain set of restrictive assumptions has been made about border effects. However, the assumed levels of relative production prices will directly affect the calibration of residual border effects[8], and different restrictions on border effects will consequently change the calibrated values of relative competitiveness of the CEECs in different industries. In this paper, in the absence of other data, I derive estimates of relative production prices from market shares in the 'Other OECD' region.

3.3.1 Outline of the Dixit-Stiglitz approach

Dixit and Stiglitz's (1977) model is the most widely-used formulation of the 'love of variety' approach to international trade. The presence of a number of different varieties or brands of a particular good in consumer demand is explained by the taste of each individual consumer for variety. We assume each of n_i firms within industry i produces a single, distinct variety, and that the firms compete symmetrically with one another. This is expressed by a modified CES utility function for utility gained from consuming

[8] This follows from the algebraic relationships set out in Appendix 3.1. In order to calibrate border costs to observed trade flows, if we alter our assumption about trade costs, to reduce the assumed production cost of good g in country A relative to country B, then we would have to assume higher border costs on A's exports of i to country B (and lower border costs in the opposite direction).

n_i different varieties of goods class i. This takes the form

$$U_i = (\sum_{g=1}^{n_i} a_i C_{ig}^{\rho})^{1/\rho}, \tag{3.2}$$

where U_i is utility in country i, C_{ig} is consumption of good g in country i, a_i is the share parameter for the firms in industry i and ρ is a substitution parameter. Subscript g refers to goods variety, where $g \subset \{1..n_i\}$, so that there are n_i varieties of goods within industry i. One key difference to the standard CES function is that the number of varieties, n_i, need not be fixed. As long as $0 < \rho < 1$, utility will increase with n_i. Consequently, for the model to work, we need to have a value of ρ between zero and unity.[9] Since the substitution parameter, ρ, is related to the elasticity of substitution[10], σ, by the formula

$$\sigma = 1/(1-\rho), \tag{3.3}$$

this feasible range corresponds to elasticities of substitution, σ, which are greater than unity. This makes sense in two respects: first because it implies a taste for (rather than dislike for) increased goods variety, and secondly because it reduces the chances of firms having own-price elasticities so low that profit-maximising prices tend to infinity.[11]

[9] This property, which is explained in detail in the Dixit-Stiglitz (1977) paper, can perhaps be seen most easily by examining the price of utility, which is $P_U = (n_i a_i^{1/(1-\rho)} \overline{P}^{\rho/(\rho-1)})^{(\rho-1)/\rho}$, where P_U is the unit cost of utility from consuming the produce of industry i and $\overline{P}$ is the unit price charged by each of n_i identical firms. Hence it can be seen that $dP_U/dn_i = ((\rho-1)/\rho)n_i^{-1/\rho}(a_i^{1/(1-\rho)}\overline{P}^{\rho/(\rho-1)})^{(\rho-1)/\rho}$,which will only be negative (assuming n_i, a_i and $\overline{P}$ are positive) when $0 < \rho < 1$. These are the circumstances under which increasing variety leads to an increase in utility (for a given level of expenditure).

[10] Differentiating (3.2) with respect to C_{ig}, and setting the marginal utility of consuming C_{ig} equal to P_{ig}/P_{Ui}, the ratio of price of firm g's output relative to the unit cost of utility from consuming the aggregate bundle of all varieties of good i, we obtain the equations $dU_i/dC_{ig} = a_i(U_i/C_{ig})^{1-\rho} = P_{ig}/P_{Ui}$.

Comparing this with the equivalent equation for firm h's output, and dividing dU_i/dC_{ig} by dU_i/dC_{ih}, we derive $(C_{ih}/C_{ig})^{1-\rho} = P_{ig}/P_{ih}$, which implies $(C_{ih}/C_{ig}) = (P_{ig}/P_{ih})^{1/(1-\rho)}$. Hence the elasticity of substitution, $\sigma = 1/(1-\rho)$.

[11] Firms' own-price demand elasticities are a function of the elasticity of substitution between varieties, the top-level demand elasticity for the good concerned and the demand elasticity for the aggregate good. The relationship is given by equation (3.A2.19) in Appendix 3.2. As the number of firms increases, the

The second aspect of the Dixit-Stiglitz approach is the use of Chamberlinian monopolistic competition. Under this approach, firms are assumed to be subject to increasing returns to scale (usually modelled as a fixed cost plus constant marginal cost), but firm g's size is limited by the assumption that marginal revenue declines with output. Marginal revenue is diminishing even under Bertrand competition, where the firm perceives its rivals' prices to be exogenous, so long as all firms' output is differentiated.

If new firms enter the market, each existing firm's market share, S_g, falls, which usually reduces its own-price elasticity of demand[12] (if the top-level demand for all goods within an industry is held constant, then g's own-price demand elasticity is $\sigma(1 - S_g)$). A consequence of this is that an increase in firm numbers is expected to lead to a decline in prices, benefiting consumers.[13]

In a Dixit-Stiglitz model of trade, increased openness leads to a number of benefits, as outlined by Baldwin and Venables (1995). In addition to the standard trade creation effect (offset by trade diversion where liberalisation is only between a subset of countries) there are gains from allowing consumers to spread their consumption more evenly across a variety of products from different nations. Also, there are competitive benefits from prices being forced down (rising imports generally have a similar effect on prices to an increase in the number of domestic firms) and, in versions of the model where the number of firms is endogenous, a shake-out of capacity worldwide, making it easier for firms to gain economies of scale. Agglomeration economies may take place, if production of goods which are inputs into one another's production can be concentrated more easily in one

value of the own-price elasticity will approach the elasticity of substitution.

[12] There is an exception to this, where the top-level substitution elasticity between different industries' products is high.

[13] Dixit and Stiglitz showed that, in the case of a constant elasticity of substitution between varieties, assuming no distortions were present, monopolistic competition would produce an optimum number of varieties, though this result did not hold with variable elasticities.

area, saving transport costs. Finally, there may be capital inflows into regions benefiting from increased trade openness.

Against these factors must be borne in mind the loss of tariff revenue and the effects of profit-shift effects, the sign of which is harder to determine for individual countries (though the net effect over all countries will be zero) .

3.3.2 Methodology for estimating border costs

Appendix 3.1 shows the derivation of the equations for estimating comparative costs and assumed border costs of trade in this study, and how they relate to more orthodox gravity studies. Basically, I estimate the border iceberg cost on trade in goods in sector i from country c to country cc, $\phi_{i,c,cc}$, using the equation:

$$(1-\phi_{i,c,cc})(1-\phi_{i,cc,c}) = \langle E_{i,c,cc}(1+\tau_{i,c,cc})^{1-\sigma}(1+t_{i,cc,c})^{-\sigma} \times E_{c,cc}(1+\tau_{i,cc,c})^{1-\sigma}(1+t_{i,cc,c})^{-\sigma} \mid H_{i,c}H_{i,cc}\rangle^{1/(\sigma-1)}, \quad (3.4)$$

where $E_{i,c,cc}$ is export value of i from c to cc, τ is transport cost, t is the import duty rate, $H_{i,c}$ is consumption of home-produced i in country c, $H_{i,cc}$ is consumption of home-produced i in country cc, and σ is the constant elasticity of substitution.

<For derivation of equation (3.4), see Appendix 3.1.>

Data on sales prices of each country's goods at home, P_c, may not be easy to obtain (and anyway, prices may not be directly comparable if quality varies). For that reason, it may be better to use a revealed comparative advantage approach, and actually incorporate calibration of P_c into the general calibration. This means we are calibrating the model for both prices and residual border trade costs.

3.3.3 Calibration

For calibration, I start with equation (3.4). In the absence of better data, it may well be most sensible to assume initially that average firm size within a particular industry is the same across countries. Hence turnover, $T_{i,c}$, of a typical firm in industry i in country c will satisfy $T_{i,c} = T_{i,cc} = T_i$ for all c and cc.[14]

If the only unknowns are the residual border trade costs, $\phi_{i,c,cc}$, then if we assume $\phi_{i,c,cc} = 0$ if $c = cc$ and ≥ 0 if $c \neq cc$ we need only fit for the (probable) non-zero elements of ϕ, where $c \neq cc$.

- To model the effects of the single market in terms of these border costs, I make the following definitions and assumptions about the structure of (non-tariff and non-transport) border costs: $\Psi_{i,c}$ is defined as home bias in country c. This cost is applied to import of good g in industry i, from any other country cc into c (regardless of whether or not cc and c are both members of the EU's Single Market).

- $\varphi_{i,CEEC,EU}$ is the additional cost for imports from CEEC countries to EU members (compared to imports from other EU members). This means that the total border cost for importing from a CEEC country to an EU country is: $\phi_{i,cc,c} = \Psi_{i,c} + \varphi_{i,CEEC,EU}$, where cc is a member of the CEEC region and c is a member of the EU.

- $\varphi_{i,EU,CEEC}$ is the additional cost for importing from the EU to the CEEC. The

[14] Typical firm sizes have been assumed to be larger in manufacturing sectors than in services, and smallest in agriculture.

total border cost for imports from the EU to the CEEC is therefore: $\phi_{i,c,cc} = \Psi_{i,cc} + \varphi_{i,EU,CEEC}$, where cc is a member of the CEEC region and c is a member of the EU.

- $\varphi_i, _{ROW,EU}$ reflects additional costs for imports from the rest of the World to either the CEEC or EU countries.

To calibrate, I assume $\varphi_{i,CEEC,EU} = \varphi_{i,EU,CEEC} = \varphi_i$. It is this cost on trade (which I assume to be the same in both directions) between the EU and CEEC which is removed once the CEEC country joins the Single Market.

3.3.4 The model for simulations

The model equations are summarised in detail in Appendix 3.2.

Simulations are carried out using a multi-country static computable general equilibrium (CGE) model. Goods are produced using a Cobb-Douglas aggregate of intermediate inputs and 4 primary factors: unskilled labour, skilled labour, capital and land. Land is fixed sectorally. Both types of labour are mobile between sectors, but not between countries. For capital, I investigate two variants, one where it is fixed in total within a country, and one where it is internationally mobile.

Intermediate inputs and final consumption goods are CES aggregates of home production and imports from various sources. The elasticity of substitution between different sources of a good is set at 4 in all sectors. This lies at the lower end of elasticity estimates surveyed by Anderson and Van Wincoop (2004), which vary from 4 to 5 up to around 10. However, it is relatively high compared to the elasticities traditionally used in

Armington-based[15] general equilibrium models.[16] A key factor may be time-scale (in this model I am interested in medium-run simulations, where perhaps long-run elasticities would be higher). There are also transport costs (modelled as iceberg costs[17]), iceberg unspecified trade costs (see above) and tariffs, as well as taxes/subsidies on output and use of a commodity.

Firms both at home and abroad are imperfectly competitive (competing within a Dixit-Stiglitz, symmetrical CES function), and charge profit markups dependent on their market shares. For computational reasons, the number of firms per industry and per country is however assumed to be fixed in simulations - I suggest these might be interpreted as intermediate-term simulations, assuming that the entry and expansion of new firms is a long-term process.

The top level of the utility function, where different industries' products are aggregated, uses a Cobb-Douglas structure.

3.3.5 Data

I use the GTAP[18] version 5 database. This database has harmonised trade and input-output data for regions across the world in 1997. GTAP potentially has a large number of goods and regions, so for practical purposes I aggregate data into 8 goods and 10 regions, chosen for their relevance to the issue of enlargement.

[15] It is also worth noting that it satisfies the Dixit-Stiglitz restriction that the elasticity of substitution should be greater than unity (see the discussion in 3.3.1).

[16] See Shoven and Whalley, 1992.

[17] The notion of an 'iceberg' trade cost is based upon the assumption that a good loses a constant proportion of its value when it is traded across a particular border, so that the number of units arriving in the importing country is lower than that leaving the exporting country, and the unit price correspondingly higher.

[18] Global Trade Analysis Project, an international collaborative data-sharing effort, coordinated from Purdue University.

Goods

AG:- agriculture, forestry and fishing
OP:- other primary
FP:- food processing
IS :-iron and steel
TX:- textiles
MH:- heavy manufacturing
ML:- light manufacturing
SV:- services

Regions*

PLD:- Poland
HUN:- Hungary
OCEC:- Other CEECs (Cz Rep, Slovakia, Slovenia, Romania, Bulgaria)
UK:- United Kingdom
GER:- Germany
OEUN:- Other EU Northern (Netherlands, Belgium, Luxembourg, Sweden, Finland, Denmark, Ireland)
OEUS:- Other EU Southern (Italy, Spain, Portugal, Greece)
FSU:- Former Soviet Union
ODX:- Other OECD excluding EU and CEECs
LDC:- rest of the world (mostly less developed countries)

*note GTAP version 5 has only 3 CEEC regions.

For **trade and protection,** I use 4 principal data series from GTAP for these countries and regions:[19]

GTAP data category:

- *VXMD* exports at market prices,
  VXWD exports at world prices,
  VIWS imports at world prices,
  VIMS imports at market prices (i.e. sales prices in the importing country before indirect tax).

The difference between *VXWD* and *VIWS* is taken to be the transport cost margin.

[19] In the latter case, capital rents are equated across the world at RBW. A country will then pay rent at this rate to foreigners if it imports capital. This assumption, which follows Fehr *et al.* (1995) avoids some of the problems Rodrik (1997) notes in the Baldwin *et al.* (1997) model's treatment of changing capital stocks.

VXWD - *VXMD* is a value for net export tax/subsidy, and the GTAP estimates of the tariff equivalent of some quantitative trade restrictions whose revenue accrues to the exporting country.

VIMS - *VIWS* is the value for net import tax/subsidy and the tariff equivalent of remaining NTBs.

Correction is made for some data errors in the GTAP Version 5. In particular, I have removed tariffs on trade between the EU and CEECs other than in agriculture and food processing, as these had been abolished under the Europe Agreements. Revenue has been reallocated to ensure the accounts continue to balance.

3.4 Results of the calibrations for border costs

Table 3.4 shows the formal trade barriers (tariffs and tariff equivalent of NTBs) in existence between the EU and CEECs in 1997. These are CES weighted averages over the various EU component regions (UK, GER, OEUN and OEUS). As can be seen, imports from the CEECs into the EU faced sizeable barriers in agriculture and food processing, but barriers elsewhere had been removed by 1997 under the Europe Agreements.[20]

Table 3.4	*Net formal trade barriers (tariff equivalent)*					
Industry	OCEC into EU	EU into OCEC	HUN into EU	EU into HUN	PLD into EU	EU into PLD
AG	0.178	0.107	0.166	0.177	0.308	0.253
FP	0.329	0.248	0.291	0.272	0.536	0.365

However, even when country size, transport costs and these formal trade barriers

[20] As pointed out in the previous section, adjustments had to be made to the GTAP data set to take account of this.

are taken into account, actual trade still exceeds that predicted in nearly all cases: our model attributes this home bias to an iceberg cost of trade, $\phi_{g,c,cc}$. For example, actual trade in agricultural produce between the EU and Other CEEC region (in both directions) falls short of predicted trade by around 65 per cent. These differences ((actual - predicted)/actual) are shown in Table 3.5.

Table 3.5 shows the calibrated comparative costs and country bias based on the calibration assumptions in this paper. In this case, average 'excess' EU bias against CEEC goods has been set the same as average CEEC bias against EU goods. This calibration suggests the CEECs are low-cost producers compared to the EU in almost all industries, especially services[21], agriculture, and light and heavy manufactures. Hungary is low-cost in textiles, while the OCEC region is high-cost in iron and steel.

[21] Comparative costs in services would, of course, be expected to be lower in poorer countries (see Balassa, 1962). However, it seems that, at least for Poland, the low relative costs apply to all sectors. Only for the Other CEEC region does there seem to be clear evidence supporting the Balassa-Samuelson relationship.

Table 3.5	*Calibrated relative production prices and home/country bias*			
POLAND			*Average iceberg cost*	
	Industry Relative PLD Price	Inter-EU Home Bias	EUvPLD	PLDvEU
AG	-0.412	0.683	0.076	0.076
OP	-0.210	0.500	0.201	0.201
FP	-0.351	0.681	-0.050	-0.050
TEX	-0.297	0.548	0.093	0.093
IS	-0.006	0.556	0.158	0.158
MH	-0.402	0.591	0.135	0.135
ML	-0.405	0.529	0.166	0.166
SV	-0.376	0.821	0.062	0.062
HUNGARY				
	Industry Relative HUN Price	Inter-EU Home Bias	HUNvOCEC	HUNvEU
AG	-0.350	0.683	0.098	0.098
OP	-0.495	0.500	0.334	0.334
FP	-0.406	0.681	0.051	0.051
TEX	-0.347	0.548	0.057	0.057
IS	-0.138	0.556	0.185	0.185
MH	-0.452	0.591	0.139	0.139
ML	-0.385	0.529	0.092	0.092
SV	-0.451	0.821	0.062	0.062
OTHER CEECs				
	Industry relative OCEC price	Inter-EU Home bias	EUvOCEC	OCECvEU
AG	-0.359	0.683	0.093	0.093
OP	-0.155	0.500	0.304	0.304
FP	-0.410	0.681	0.064	0.064
TEX	-0.196	0.548	0.081	0.081
IS	0.239	0.556	0.125	0.125
MH	-0.310	0.591	0.109	0.109
ML	-0.344	0.529	0.125	0.125
SV	-0.360	0.821	0.038	0.038

The average calibrated iceberg costs of trade in both directions vary from slightly negative (for Polish food processing only) to around 15% for Polish manufactures, 10-13% for other CEC manufactures and 9-14 per cent for Hungarian manufactures. For agriculture they are around 7-10%.

3.4.1 Gravity equivalent

It is also possible to convert the iceberg trade costs, $\phi_{i,c,cc}$, into equivalent gravity dummies. These can be derived from equation (3.A1.4) in *Appendix 3.1*, which shows that expenditure on goods belonging to industry i from country cc in country c has an elasticity with respect to the border cost of $(\sigma - 1)$.[22] Consequently, the coefficients on the gravity dummies will equal $-(\sigma - 1)\ln(1 - \phi_{c,cc})$. The extra dummies for imports from the EU into CEECs and from CEECs into the EU (which are both zero or negative in almost all cases) are as follows for calibration 3:

Table 3.6 *Gravity dummy equivalents of calibrated residual border effects*

INDUSTRY	OCEC into EU	EU into OCEC	HUN into EU	EU into HUN	PLD into EU	EU into PLD
AG	1.041	1.041	1.109	1.109	0.816	0.816
OP	2.807	2.807	3.305	3.305	1.540	1.540
FP	0.665	0.665	0.521	0.521	0.049	0.049
TEX	0.596	0.596	0.402	0.402	0.694	0.694
IS	0.987	0.987	1.615	1.615	1.320	1.320
MH	0.930	0.930	1.244	1.244	1.199	1.199
ML	0.923	0.923	0.650	0.650	1.304	1.304
SV	0.714	0.714	1.280	1.280	1.260	1.260

The dummies for trade between the EU and CEEC are broadly of a similar order of magnitude to those found by LeJour *et al.*'s (2001) gravity model study, which estimated

[22] Note, the volume of sales has a price-elasticity of σ, but expenditure will have an elasticity of $\sigma - 1$.

an EU trade dummy of 1.25 for much of agriculture and around 0.7 for most industrial sectors.

3.4.2 Enlargement simulations

The simulation runs are carried out on the CGE model, assuming the number of firms per sector in each country does not vary. The welfare effects are probably smaller than would be expected in a fully long-run model, where scale and variety effects of altering firm numbers were included.

Table 3.7 (below) shows the effects on consumer welfare in each region resulting from (1) customs union (the removal of the remaining tariffs on agriculture and foodstuffs between the EU and CEEC regions and harmonisation of the CEEC's external tariffs with those of the EU) and (2) assumed abolition of iceberg unspecified trading costs $\phi_{i,c,cc}$ when countries join the EU single market. These simulations are carried out for cases where capital is immobile between countries and where it is assumed to be mobile.

Customs union has only small simulated welfare effects, though these generally benefit the accession states by 0-$2\frac{1}{2}$% while having no significant effect on existing EU members. The former effect is not surprising, given the fact that most tariffs have already been abolished, while the latter reflects the small size of the CEEC economies relative to the existing EU.

Under (2), the CEEC trade shares with the EU, and the EU trade shares with the CEEC are increased to reflect the posited removal of trade costs when the CEEC countries join the single market. Since it is assumed these costs are real resource costs, it is possible in this case for all countries to gain, and this does indeed seem to be the case. The biggest beneficiaries are the CEEC countries, where welfare rises by 10-

20% compared to 1997 base. Gains to the existing EU members are small, typically around $\frac{1}{2}$%. While Germany gains most, even the poorer EU countries in the South experience gains of 0.4%, so that the benefits of expansion of trade outweigh the cheap-wage competition effects even for these countries. The Former Soviet Union and LDCs also see small welfare gains, so that trade diversion effects are outweighed for them by the effects of the overall expansion of the EU and CEEC economies.

Table 3.7	*Summary of results - change on 1997 base, calculated consumer utility*			
	1.EU-CEEC customs union		2. CEEC trade shares shift in line with intra-EU trade	
	a) National capital stocks fixed %	b) Capital mobile internationally %	a) National captal stocks fixed %	b) Capital mobile internationally %
Poland	1.87	2.44	15.27	19.39
Hungary	0.17	0.17	14.62	17.56
Other CEEC	1.03	1.21	11.46	13.25
UK	-0.01	0.00	0.16	0.14
Germany	0.01	0.00	0.64	0.71
Other EU North	0.00	0.00	0.42	0.44
Other EU South	0.01	0.00	0.37	0.36
EU total	0.01	0.00	0.42	0.44
Europe total	0.06	0.06	0.94	1.09
Former Soviet Union	0.07	0.08	0.04	0.09
Other OECD	0.00	0.00	0.00	0.00
LDCs	0.00	-0.01	0.03	0.01
Global total	0.02	0.02	0.26	0.29

Table 3.8 shows the change in trade volumes: these are typically of the order 50-100% between the EU countries and CEECs on accession.

Table 3.8	*Changes in trade volumes with trade share shifts and mobile capital assumed*		
Total trade volumes	Before	After	% change
Pld to EU	4.98	9.12	83.35
Hun to EU	2.62	4.34	65.48
OCEC to EU	6.05	9.81	61.97
EU to Pld	1.88	3.77	100.44
EU to Hun	1.45	2.20	51.03
EU to OCEC	3.56	5.50	54.52

Table 3.9, which summarises changes in output by industry shows that gains in output are spread widely across all industries in the CEEC region, though the biggest gains are to agriculture, food products and manufactures (all sectors which bear high implicit trade costs between the EU and various CEEC regions, according to Table 3.6). Within the EU there appear to be few losers, though agriculture and heavy manufactures decline marginally in the UK.

Table 3.9	*Simulated change in output by country and industry compared to 1997 base (%)*							
Industry	AG	OP	FP	TEX	IS	MH	ML	SV
PLD	17.07	-1.66	19.52	10.15	9.40	16.51	26.28	13.25
HUN	11.35	9.08	18.63	18.36	12.80	26.61	24.15	11.76
OCEC	13.72	0.85	18.54	8.54	7.75	12.49	23.10	7.33
UK	-0.03	0.35	0.07	0.45	0.67	-0.03	0.03	0.07
GER	0.95	0.68	0.72	2.03	1.41	0.90	0.86	0.47
OEUN	0.41	0.96	0.49	1.02	1.35	0.68	0.37	0.32
OEUS	0.59	0.33	0.30	0.62	0.97	0.16	-0.11	0.21
FSU	0.76	0.36	1.23	-0.22	-0.89	-0.15	-0.15	0.01
ODX	-0.07	-0.07	-0.02	0.10	-0.03	-0.13	-0.22	0.00
LDC	-0.02	-0.03	0.05	-0.15	0.15	0.03	-0.06	0.01

Table 3.10 shows that output prices in the EU generally fall as a result of the saving in costs of inputs (the unskilled wage in Germany is set to 1 in this model, to act as a numeraire). However in Poland output prices generally rise (and the same is true to a lesser degree of some sectors in other parts of the CEEC region) as prices rise towards

Western European levels.

Table 3.10 *Simulated change in output price by country and industry compared to 1997 base (%)*								
Industry Country	AG	OP	FP	TEX	IS	MH	ML	SV
PLD	5.20	3.39	6.29	1.07	3.14	4.57	5.44	3.89
HUN	-2.74	7.07	-3.07	-1.31	2.32	3.26	1.01	1.42
OCEC	2.71	1.01	3.01	-0.33	-0.25	1.28	0.99	2.22
UK	-0.79	-0.49	-0.85	-0.71	-0.69	-0.72	-0.79	-0.55
GER	-0.82	-0.40	-0.82	-0.66	-0.53	-0.91	-0.92	-0.49
OEUN	-0.78	-0.36	-0.88	-0.76	-0.75	-0.91	-0.90	-0.51
OEUS	-0.67	-0.55	-0.89	-0.77	-0.58	-0.80	-0.88	-0.51
FSU	-0.10	-0.12	-0.09	-0.31	-0.20	-0.15	-0.23	-0.18
ODX	-0.48	-0.46	-0.52	-0.57	-0.59	-0.54	-0.54	-0.47
LDC	-0.47	-0.44	-0.55	-0.51	-0.61	-0.57	-0.60	-0.46

Table 3.11, summarising changes in factor returns, indicates that relative skilled/unskilled wages do not change greatly in any country, though there are sizeable gains to both types of labour in Poland in particular. The wages quoted are all relative to the German unskilled wage: the slight wage falls in some EU countries are only relative to this (consumer goods prices fall by more). The lack of distributional changes between types of labour may partly be because of the Cobb-Douglas production function structure, and partly because the presence of a fixed factor (land) in two sectors absorbs much of the effects of changes in output prices.

Table 3.11 *Simulated changes factor returns with trade share shifts and mobile capital assumed (%)*

	Unskilled	Skilled	Capital	Land Ag	Other Prim
PLD	18.95	18.25	-0.29	23.16	1.68
HUN	14.71	14.15	-0.29	8.30	12.70
OCEC	12.36	11.08	-0.29	16.80	1.57
UK	-0.51	-0.50	-0.29	-0.82	-0.24
GER	0.00	-0.01	-0.29	0.11	0.21
OEUN	-0.23	-0.22	-0.29	-0.37	0.48
OEUS	-0.34	-0.34	-0.29	-0.09	-0.16
FSU	-0.12	-0.16	-0.29	0.66	0.25
ODX	-0.54	-0.54	-0.29	-0.55	-0.53
LDC	-0.47	-0.46	-0.29	-0.49	-0.47

(German unskilled wage kept constant).

3.5: Conclusions.

In this paper, I have extended the modelling approach of Baldwin *et al* (1997) and LeJour et al (2001), introducing a model-consistent framework of calibration and simulation to estimate the likely effects of EU enlargement to incorporate the CEECs, assuming that the 1997 residual country bias against the CEECs in EU trade (and vice-versa) reflects resource costs of regulatory differences which can be eliminated by entry to the single market. Since this observed country bias is large (EU countries trade far more with each other than with the CEECs, even correcting for size and difference), the regulatory barriers which would be needed to explain such differences would also be significant - of the order of 7 to 15 per cent on most goods. It follows that entry into the EU's Single Market would have large effects in terms of increasing trade between the EU and CEECs - in fact simulations suggest that Poland's trade with the EU could double, while Hungary and the other CEECs would also see large trade increases. Such trade increases would produce sizeable gains, not just from the elimination of the resource cost of trade and from trade more accurately reflecting comparative advantage, but also due to the effects of increased competition and scale utilisation, particularly within the CEECs. As a result, welfare in the CEECs could rise by between 11.5 and 20 per cent (Poland being the largest gainer) while the existing EU countries would not lose from enlargement. Output would rise almost across the board for all industries in the CEECs.

These calculations suggest that existing studies have, if anything, been quite cautious in their optimistic assessment of EU enlargement. However, it must be borne in mind at this point that these conclusions are highly dependent on the above assumptions. There are a number of important cautions:

-
  -
    -
      - There is considerable room for uncertainty over the comparative costs of production of different industries in different regions, and over the associated residual country biases, interpreted as iceberg trade costs $\phi_{i,c,cc}$, depending on the prior assumptions made in order to carry out the calibration (ie that $\varphi_{i,CEEC.EU} = \varphi_{i,EU,CEEC} = \varphi_i$).
    - It is probable that these prior assumptions are also important in gravity studies. Gravity modellers typically measure residual country bias with a set of trade dummies (e.g. a dummy set to 1 if both countries are members of the EU and 0 otherwise). The number of these dummies is typically much less than the number of calibrated $\phi_{i,c,cc}$ coefficients in our study, meaning that the gravity modellers are imposing far more restrictions on the relative sizes of different country bias effects.
    - Whether accession to the EU would in fact lead to the elimination of the fitted 'bias' against CEEC imports into the EU compared to the produce of other EU countries is not certain. Indeed, gravity studies of the single market (Brenton and Vancauteren 2001) cast doubt on the effects to date

of institution of the single market.

* It is possible that the use of transport costs alone may underestimate the effects of distance upon trade (a weakness of the direct calibration approach compared to standard gravity models).[23] An extra regression of estimated $\phi_{i,c,cc}$ coefficients on distance might be worthwhile, to see if there are additional distance effects at work.

* The assumption that the residual country bias represents unmeasured trade costs, $\phi_{i,c,cc}$, rather than, say, difference in tastes, perceived product quality or familiarity of products,[24] and that these costs would be reduced or removed by countries joining the EU, is a strong one. For one thing, reorientation of production and consumption is unlikely to be costless. Estimates of the savings from double-testing and frontier controls due to the Single Market are typically closer to a 5% saving[25] on the cost of traded goods, rather than the 15% typically inferred by comparing trade shares. To what extent the remainder of the 15 % actually represents other trading costs such as the effects of different product standards, labelling procedures, legal and guarantee systems etc. is hard to

[23] Both estimated transport costs (as in this study) and distances (as used by most gravity modellers) have advantages and disadvantages. Gravity models typically use arc distances between capital cities, which may be misleading where the capital cities are not centrally located, or where the countries are adjacent (so that individual regions in the two countries may abut one another, even if the capitals are some distance apart). Also, they fail to take account of the difference between land and sea borders, or of the quality of transport infrastructure on the connections, as well as of factors not directly linked to transport costs, such as the roles of ethnic or colonial ties, migrant communities or common languages. Some gravity studies incorporate extra dummy variables in an attempt to correct for these problems.

Our estimated transport costs overcome some of these difficulties, but may underestimate the role of communication other than simply the bulk transport of goods (such as the need for executives in different countries to meet and communicate). In addition, the precise derivation of the cost data by the GTAP team is not transparent.

[24] See Chapters 4 and 5 of this thesis for discussion of these points.

[25] Zahariadis, 2002, using figures derived from Harrison et al (1996), suggests costs on Turkish imports into the EU of 1.3 to 3.1 per cent for frictional/border costs, 1 to 2 per cent for testing/certification costs and 1 to 2.5 per cent for standardisation costs.

tell. Whether the harmonisation of product standards in CEEC countries to conform to the existing EU standards would benefit the accession countries, or would impose unwanted costs on producers and consumers in the accession countries merits further research.

* It is also possible, indeed likely, that over time CEEC consumers and producers may become more oriented towards trade with the EU even if the countries do not formally join the single market, so the $\phi_{i,c,cc}$ coefficients might well reduce over time anyway.
* It is also likely that in 1997 the CEEC countries were far from in equilibrium: real exchange rates and trade barriers had changed very substantially in just the preceding 4 years. For that reason, export and import volumes might well not be at an equilibrium level relative to prices and trade barriers.

Some of these points are investigated in the subsequent chapters of this thesis.

Notwithstanding the above reservations, this paper provides at least provisional grounds for optimism that the EU enlargement will provide significant benefit to the accession economies and marginally benefit the existing member states as well.

Appendix 3.1: Derivation of border and comparative production costs

It is possible, in principle, to estimate border effects directly by calibration of a general equilibrium model, rather than relying on indirect methods such as estimation of a gravity model. This is most clearly seen in the case of a Dixit-Stiglitz model, as described in section 3.3.1 in the main chapter.

The theoretical relationship between a gravity model and Dixit-Stiglitz model, with monopolistic competition between a number of differentiated varieties of products, each produced in one country only, is well-established since Bergstrand (1989). More recent work on theoretical gravity models includes Anderson and van Wincoop (2003) and Eaton and Kortum (2002).

For simplicity, consider a Dixit-Stiglitz model where goods are consumed in countries $c \in 1...C$ yielding consumer utility.[26] Consumption of good g in country cc is $Q_{g,cc}$. Total consumer utility in country cc is assumed to reflect the function:

$$U_{cc} = \left[\sum_{c} \sum_{g \in c} \beta((1 - \phi_{c,cc})Q_{g,cc})^{(\sigma-1)/\sigma} \right]^{\sigma/(\sigma-1)}, \qquad (3.A1.1)$$

where σ is the elasticity of substitution between goods varieties, and $\phi_{c,cc}$ is an iceberg cost reducing by a fixed proportion the usable value of all goods from country c consumed in cc. With a Dixit-Stiglitz framework, the assumed value for σ must exceed unity, with the corresponding substitution parameter, $\rho = (\sigma - 1)/\sigma$, lying between 0 and 1.

We differentiate (3.A1.1) and set the marginal utility of consumption of g equal to its relative price.

[26] All equations in this appendix relate to an industry i, but the subscript i has been dropped for simplicity.

$$
\begin{aligned}
dU_{cc}/dQ_{g,cc} &= (\sigma/(\sigma-1))\left[\sum_{c}\sum_{g\in c}\beta((1-\phi_{c,cc})Q_{g,cc})^{(\sigma-1)/\sigma}\right]^{1/(\sigma-1)} \\
&\quad \beta(1-\phi_{c,cc})^{(\sigma-1)/\sigma}((\sigma-1)/\sigma){Q_{g,cc}}^{-1/\sigma}, \\
&= \left[\sum_{c}\sum_{g\in c}\beta((1-\phi_{c,cc})Q_{g,cc})^{(\sigma-1)/\sigma}\right]^{1/(\sigma-1)} \quad \beta(1-\phi_{c,cc})^{(\sigma-1)/\sigma}{Q_{g,cc}}^{-1/\sigma}, \\
&= \beta(1-\phi_{c,cc})^{(\sigma-1)/\sigma}{Q_{g,cc}}^{-1/\sigma}U_{cc}^{1/\sigma}.
\end{aligned}
$$

We then set $dU_{cc}/dQ_{g,cc}$ equal to the ratio of the price of $Q_{g,cc}$, including transport costs and tariffs, $P_c(1+\tau_{c,cc})(1+t_{c,cc})$, to the aggregate price of utility in country cc, π_{cc}. Rearranging this yields

$$
Q_{g,cc} = U_{cc}\left[\beta(1-\phi_{c,cc})^{(\sigma-1)/\sigma}(\pi_{cc}/P_c(1+\tau_{c,cc})(1+t_{c,cc})\right]^{\sigma}, \tag{3.A1.2}
$$

where $\tau_{c,cc}$ is the proportionate transport cost between country c and cc, and $t_{c,cc}$ is the net contribution of import and export tariffs, subsidies and the tariff equivalents of NTBs. P_c is the selling price of goods from country c at the point of export (i.e. prior to trade costs and tariff). π_{cc} is an aggregate consumer price index for country cc.

The next step is to rewrite the equation in terms of observable variables. The nominal value of exports from c to cc, $E_{c,cc}$ is the number of goods varieties produced in country c, n_c, times the volume of sales per good, $Q_{g,cc}(g \in c)$, (upscaled by $(1+\tau_{c,cc})$ to take account of the assumed iceberg transport cost) times the export price P_c. Since U_{cc} is also not observable, I replace it with total expenditure in country cc, Y_{cc} divided by the aggregate price index π_{cc}.

$$E_{c,cc} = \beta^{\sigma}(1-\phi_{c,cc})^{(\sigma-1)} n_c (1+\tau_{c,cc}) P_c (Y_{cc}/\pi_{cc}) \\ (\pi_{cc}/P_c(1+\tau_{c,cc})(1+t_{c,cc}))^{\sigma}. \tag{3.A1.3}$$

Next we can replace n_c with the value of output in country c, X_c, divided by the size of turnover of a 'representative' firm T_c.

$$E_{c,cc} = \beta^{\sigma}(1-\phi_{c,cc})^{(\sigma-1)} X_c Y_{cc} T_c^{-1} P_c^{1-\sigma} \pi_{cc}^{\sigma-1} (1+\tau_{c,cc})^{1-\sigma} \\ (1+t_{c,cc})^{-\sigma}. \tag{3.A1.4}$$

It should be clear by taking logs that this is a very similar functional form to the equations estimated by gravity modellers, but with various parameter restrictions imposed in order to achieve consistency with the general equilibrium Dixit-Stiglitz framework. This is even clearer if we choose to model transport costs as a function of distance $d_{c,cc}$ of form:

$$\ln(1+\tau_{c,cc}) = a + b \ln d_{c,cc}. \tag{3.A1.5}$$

Substituting from (3.A1.5) into (3.A1.4), we essentially have a gravity model, but unlike the econometrically estimated gravity models the coefficients on industry output in country c and on demand in country cc are constrained to equal 1, while production prices are introduced as exogenous data (rather than being proxied by per capita income, as in many gravity studies), and it is worth noting that the tariff term is $\ln(1+t_{c,cc})$ not

$\ln(t_{c,cc})$ as in many gravity models.

$$\ln E_{c,cc} = \sigma \ln \beta + (\sigma - 1)\ln(1-\phi_{c,cc}) + \ln X_c + \ln Y_{cc} - \ln T_c + (1-\sigma)\ln(P_c/\pi_{cc})$$
$$+(1-\sigma)(a + b \ln d_{c,cc}) - \sigma \ln(1 + t_{c,cc}). \tag{3.A1.5a}$$

The number of fitted residual border cost coefficients, $\phi_{c,cc}$, is far greater than the number of dummies estimated in a gravity model. Effectively the gravity modeller is rewriting these as $\phi_{c,cc} = DUM_{c,cc} + \phi(\epsilon_{c,cc})$, where $DUM_{c,cc}$ is whatever combination of country dummies happens to apply to trade between countries c and cc, and $\epsilon_{c,cc}$ is the estimated equation residual. Because there are more coefficients to estimate in our version, there are fewer degrees of freedom, making calibration more appropriate than econometric estimation.

We are particularly interested in the fitted residual border trade cost coefficients, $\phi_{c,cc}$. To derive this, we start with equation (3.A1.4):

$$E_{c,cc} = \beta^{\sigma}(1-\phi_{c,cc})^{(\sigma-1)} X_c Y_{cc} T_c^{-1} P_c^{1-\sigma} \pi_{cc}^{\sigma-1}(1+\tau_{c,cc})^{1-\sigma}(1+t_{c,cc})^{-\sigma}$$

To eliminate the consumer price indices, the easiest way is to say that for $cc = c$ we can replace $E_{c,cc}$ with H_{cc} (home use). Also note that there are no tariffs or transport costs where $c = cc$: hence $\tau_{cc,cc} = t_{cc,cc} = 0$. This means that, dividing (3.A1.4) by the version for H_{cc} gives us:

$$E_{c,cc}/H_{cc} = (1-\phi_{c,cc})/(1-\phi_{cc,cc}))^{(\sigma-1)}(X_c/X_{cc})(T_{cc}/T_c)$$
$$(P_c/P_{cc})^{1-\sigma}(+\tau_{c,cc})^{1-\sigma}(1+t_{c,cc})^{-\sigma} \tag{3.A1.6}$$

We can rearrange this to put $(1-\phi_{c,cc})$ on the left hand side, and if we assume $\phi_{c,cc} = 0$ for $c = cc$ we can simplify somewhat:

$$\begin{aligned}(1-\phi_{c,cc}) &= \{(E_{c,cc}/H_{cc})(X_{cc}/X_c)(T_c/T_{cc})(P_{cc}/P_c)^{1-\sigma} \\ &\quad (1+\tau_{c,cc})^{\sigma-1}(1+t_{c,cc})\}^{1/(\sigma-1)}\end{aligned} \tag{3.A1.7}$$

An interesting result is found if we multiply together these expressions for trade in both directions between a pair of countries, c and cc, since a lot of terms can then be eliminated:

$$(1-\phi_{c,cc})(1-\phi_{cc,c}) = \langle\sqrt{\tilde{E}_{c,cc}\tilde{E}_{cc,c}}|\sqrt{H_c H_{cc}}\rangle^{2/(\sigma-1)} \tag{3.A1.8}$$

where the tilde represents exports adjusted for the effects of tariffs, NTBs and transport costs. Effectively, if the geometric average volume of trade between two countries, once tariffs and transport costs have been corrected for, is significantly smaller than the geometric mean of home-based consumption in the two countries, then the model implies there must be residual border trade costs present.

Once an estimated value for the elasticity of substitution, σ, has been chosen, all the other terms on the right hand side of (A1.8) are given. This means that for given observed output, consumption and trade and an assumed elasticity of substitution, the higher the value of the trade cost for imports from c to cc, $\phi_{c,cc}$, the lower will be the implicit trade cost in the other direction, $\phi_{cc,c}$. If we assume residual border trade costs are the same in each direction, then

$$\phi_{c,cc} = 1 - \langle\sqrt{\tilde{E}_{c,cc}\tilde{E}_{cc,c}}|\sqrt{H_c H_{cc}}\rangle^{1/(\sigma-1)}. \tag{3.A1.8a}$$

Appendix 3.2: General equilibrium model (GEMEE)

Notes on the structure of the model:

The model is based on an imperfectly competitive structure, using a Dixit-Stiglitz framework. In this framework, as outlined first in Dixit and Stiglitz (1977), an industry, i, contains a large number of goods produced by closely competing firms in the various regions. Each good, g, is produced in one country, c, only. Section 3.1.1 of the main chapter summarises the theory of this type of model.

In this chapter I have used the simpler version of the model, where the number of goods produced within each country and industry, $n_{c,i}$, is fixed. However, unlike many Armington models, it does allow for monopolistic markups. The full Dixit-Stiglitz variant allows the number of goods/firms to vary endogenously.

Another variant is to allow capital to flow between countries rather than be fixed within each country. The coding for this variant is also explained in this appendix.

Production of goods

The production function of each firm combines labour, land and capital using a Cobb-Douglas function to form a value added input: i.e.

$$VA_g = \theta_{c,i} {L_g}^{(1-\beta k_{c,i}-\beta d_{c,i})} K_g^{\beta k_{c,i}} Dg^{\beta d_{c,i}}, \tag{3.A2.1}$$

where VA is value added (quantity), L is labour, K is capital, D is land which is sectorally fixed, g denotes the good, i denotes industry and c denotes the country of production. θ is a scale parameter and βk and βd are share parameters. I also assume that total labour, L, is a Cobb-Douglas aggregate of unskilled labour, LU, and skilled labour, LS. This allows us to write:

$$VA_g = \theta_{c,i}(LU_g^{\beta u_{c,i}} LS_g^{\beta s_{c,i}})^{(1-\beta k_{c,i}-\beta d_{c,i})} K_g^{\beta k_{c,i}} Dg^{\beta d_{c,i}}, \tag{3.A2.2}$$

where βu and βs are share parameters for unskilled and skilled labour within total labour costs, and sum to 1 within any industry in any country.

To obtain an equation for the whole industry in country i, we assume all firms g within i in a given country, c, are identical in terms of cost, inputs, output and market share. We also choose units so that $\theta_{c,i} = 1$.

Differentiating (3.A2.2) with respect to K, LU, LS and D and setting value of marginal products equal to the wage rate and price of capital gives

$$LU_{c,i} = VA_{c,i}PV_{c,i}\beta u_{c,i}(1 - \beta k_{c,i} - \beta d_{ci})/WU_c \tag{3.A2.3a}$$

$$LS_{c,i} = VA_{c,i}PV_{c,i}\beta s_{c,i}(1 - \beta k_{c,i} - \beta d_{c,i})/WS_c \tag{3.A2.3b}$$

$$K_{c,i} = VA_{c,i}PV_{c,i}\beta k_{c,i}/R_{c,i} \tag{3.A2.3c}$$

$$D_{c,i} = VA_{c,i}PV_{c,i}\beta d_{c,i}/LDP_{c,i}, \tag{3.A2.3d}$$

where WU and WS denote the wage rates for unskilled and skilled labour, R denotes return on capital and LDP the sectoral return on land. Both types of labour are assumed to be mobile between sectors, but not between countries, so that wage rates are equal across sectors. Land is sectorally immobile, while we explore two variants in the case of capital: in the first, it is mobile between sectors but not between countries, while in the second it is internationally mobile.

Hence, in the first variant, we fix R within a country:

$$R_{c,i} = RB_c. \tag{3.A2.4}$$

The price of value added is given by

$$PV_{c,i} = (WU_c LU_{c,i} + WS_c LS_{c,i} + R_c K_{c,i} + LDP_{c,i} D_{c,i})/VA_{c,i}. \tag{3.A2.5}$$

Higher level of production function

The output of good i is produced by a combination of other goods, ii, and value added, VA. This is done again using a Cobb-Douglas production function

$$Y_{c,i} = \Omega_{c,i} VA_{c,i}^{\alpha v_{c,i}} \prod_{ii} II_{c,ii,i}^{\alpha I_{c,ii,i}}, \tag{3.A2.6}$$

where Y is output, II is the input of good ii into good i and the α coefficients are input shares which sum to 1.

Assuming cost-minimisation, this gives inputs:

$$II_{c,ii,i} = \alpha I_{c,i} Y_{c,i} PY_{c,i}/PU_{c,ii,i}, \tag{3.A2.7}$$

where PY is the output unit variable price and PU is the unit price of inputs, and

$$VA_{c,i} = \alpha v_{c,i} Y_{c,i} PY_{c,i}/PV_{c,i}. \tag{3.A2.8}$$

The marginal cost, PPY, of producing output, Y, is easily calculated from the cost of inputs per unit output:

$$PPY_{c,ii} = (VA_{c,ii}PV_{c,ii} + \sum_{i} II_{c,i,ii}PU_{c,i})/Y_{c,ii}. \tag{3.A2.9}$$

This is then adjusted for output tax and subsidies, to give a marginal per unit price including tax and subsidies:

$$PY_{c,ii} = PPY_{c,ii}(1 + OUTTAX_{c,ii}) - SUBSIDY_{c,ii}/Y_{c,ii}. \tag{3.A2.10}$$

Trade and the aggregation of goods

I assume the representative consumer in each country obtains utility by aggregating goods using a two-stage nested utility function: first, the various varieties of goods within industry i are aggregated using a Dixit-Stiglitz utility function (see section 3.3.1 in the main part of the chapter for an outline discussion). This is the lower level of aggregation. Then the aggregate goods bundles for each industry, i, are combined to provide aggregate utility using a Cobb-Douglas utility function. This is the top level of the utility function.

The total demand in country C for produce of industry i is taken to be $TU_{c,i}$. This is an aggregate bundle of all the goods, g, which belong to industry i, using a Dixit-Stiglitz demand function:

$$TU_{c,i} = \left(\sum_{g \in i} \gamma_{g,c} U_{g,c}^{\rho} \right)^{1/\rho}, \tag{3.A2.11}$$

where $U_{g,c}$ is use of good g in country c and γ is a parameter reflecting qualitative factors (e.g. compatibility of standards) and home bias in consumption. ρ is a substitution parameter, where $\rho = (\sigma - 1)/\sigma$, where σ is the elasticity of substitution between goods g in industry i (assumed to be the same in all countries and industries).

If we assume there are $n_{cc,i}$ firms in country cc making good i, and that the γ preference parameter depends only on country of origin, cc, country of use, c, and industry, i, then we can rewrite (A2.11) in order to sum, first, the various goods varieties of industry i, $g \in (cc \cap i)$, which are produced in country cc (which all carry the same γ preference parameter), and then to sum across countries:

$$TU_{c,i} = \left(\sum_{cc} \sum_{g \in (cc \cap i)} \gamma_{cc,c,i} U^{\rho}_{g,c,i} \right)^{1/\rho}. \tag{3.A2.12}$$

The assumption that all firms within an industry/country are identical in size allows us to rewrite (3.A2.12) in terms of the total purchases of goods class i by country cc from country c, $QU_{i,c,cc}$ and the total number of firms in that industry in producing country i:

$$TU_{cc,i} = \left(\sum_{c} n_{ci} \gamma_{i,c,cc} \left(QU_{i,c,cc}/n_{c,i} \right)^{\rho} \right)^{1/\rho}, \tag{3.A2.13}$$

where g is a CES share parameter, and ρ is an elasticity-related parameter, related to the elasticity of substitution σ by the formula:

$$\rho = (\sigma - 1)/\sigma. \tag{3.A2.14}$$

Total expenditure in country cc on goods in industry i (by final consumers and intermediate users) is calculated by summing final user price times volume for all goods, g, in industry i.

$$VU_{cc,i} = \sum_{c} QU_{i,c,cc} PUU_{i,c,cc}. \tag{3.A2.15}$$

This is then used to calculate the price of PU of the aggregate bundle TU:

$$PU_{cc,i} = VU_{cc,i}/TU_{cc,i}. \tag{3.A2.16}$$

Consumption (top level of the nested utility function)

Consumers' income is divided between the various industries, i, in order to maximise a Cobb-Douglas utility function

$$UT_c = \prod_i CN_{i,c}^{\beta c_{i,c}}, \tag{3.A2.17}$$

where UT is utility and CN is consumption of produce of industry i in country c by final consumers (in other words, after deducting intermediates use). The βc coefficients are expenditure shares, and sum to 1.

Consumers' expenditure on each industry, i, CN_{ic} can be calculated relatively simply from the Cobb-Douglas property that β_{ic} is the share of expenditure on i in total consumers' expenditure in country c, CE_c. Hence:

$$CN_{i,c} = \beta c_{i,c} CE_c / PU_{c,i}. \tag{3.A2.18}$$

The derivation of total consumers' expenditure is explained below.

Competition and pricing

In a Dixit-Stiglitz model, firms are imperfect competitors. In basic versions of the model, each firm produces one good, and the goods are symmetrically competitive, with a constant elasticity of substitution between all goods in an industry consumed in one country.

The own-price elasticity of demand facing a firm is derived as follows:

1) If the own price elasticity for the aggregate produce of an industry i is η_i, and if competitors do not change their prices in response to firm, g, changing its price (Bertrand-Nash equilibrium), then the own-price elasticity facing company g would be $\sigma + S_g(\eta_i - \sigma)$, where η_i is the top-level elasticity of substitution between goods g, and S_g is the value share of firm g in demand for industry i. If S_g is small (ie n is large) the own price elasticity would be approximately equal to σ.

2) Within export markets, it is assumed that a firm has a very small market share and so its own-price elasticity is σ.

3) By contrast, in the home market country c, the firm's market share S_{gc} is assumed to be significant. It is calculated as $S_{gc} = (1/n_{c,i})(1 - SM_{c,i})$, where $SM_{c,i}$ is the share of imports in consumption of i in country c. Since the top level of the consumption function (where different industries' products are aggregated) is a Cobb-Douglas function in our model, the own price elasticity for the aggregate product of industry i, $\eta_i = 1$. Consequently, the firm's own price elasticity in the home market:

$$\eta h_{c,i} = \sigma + (1/n_{c,i})(1 - SM_{c,i})(1 - \sigma), \tag{3.A2.19}$$

where, if HU denotes consumption from domestic suppliers and $PT_{i,c,cc}$ is the price at which it sells (including taxes), then

$$SM_{c,i} = 1 - HU_{c,i}PT_{i,c,c}/VU_{c,i}. \tag{3.A2.20}$$

4) The overall own price elasticity for a firm's sales is taken as a weighted average (by

sales) of its own-price elasticity in the home and export markets.

$$\eta o_{c,i} = \eta h_{c,i}(HU_{c,i}/Y_{c,i}) + \sigma(Y_{c,i} - HU_{c,i}/Y_{c,i}). \tag{3.A2.21}$$

5) In the model variant where the number of firms is fixed, we fix the value of $\eta o_{c,i}$.

Monopolistic competition markups: it is assumed that the firm marks up its production costs by a proportion $MM_{c,i}$, where

$$MM_{c,i} = 1/(1 - (1/\eta o_{c,i})) - 1. \tag{3.A2.22}$$

The price of good g including monopoly markups is therefore:

$$PM_{c,i} = PY_{c,i}(1 + MM_{c,i}). \tag{3.A2.23}$$

It is assumed that no monopoly margin is charged on import tariffs (the justification being that importers can buy the good in another country if the manufacturer starts price discrimination between markets).

Transport costs

Transport costs are assumed to be proportional to value. Consequently, the price including transport of goods class i from country c sold in country cc is

$$PTR_{i,c,cc} = PM_{c,i}(1 + Tmargin_{i,c,cc}) \tag{3.A2.24}$$

where $Tmargin$ is the proportional transport cost.

Transport costs are treated in the model as being a form of depreciation in the value of the goods transported (otherwise known as 'iceberg costs'). Hence, if $X_{i,c,cc}$ is the quantity of i leaving country c for country cc, the amount which arrives in country cc is:

$$M_{i,c,cc} = X_{i,c,cc}/(1 + Tmargin_{i,c,cc}). \tag{3.A2.25}$$

This form of treatment means that there is no need for an explicit transport industry, nor for dealing with transport specifically in the trade accounts. The costs of transport 'margin exports' in the GTAP database have been reallocated correspondingly, to maintain balance in the accounts.

Tariffs

The model allows for tariffs applied to prices including transport. Tariffs on imports of i from c into cc are expressed as a percentage rate. Consequently, the price including transport costs and tariffs is

$$PT_{i,c,cc} = PTR_{i,c,cc}(1 + tariff_{i,c,cc}/100). \tag{3.A2.26}$$

Finally, the price of produce of industry i from country c consumed in country cc, $PUU_{i,c,cc}$, also includes a proportional tax on use of i in cc, which applies to both domestically-produced and imported varieties. Hence, the price facing consumers is

$$PUU_{i,c,cc} = PT_{i,c,cc}(1 + USETAX_{cc,i}). \tag{3.A2.27}$$

Exports

We define consumption (final and intermediate) in country cc of good i produced in country c as

$$QU_{i,c,cc} = \{X_{i,c,cc}/(1 + Tmargin_{i,c,cc}) \text{ if } cc \neq c \text{ or } HU_{i,c} \text{ if } cc = c\}, \qquad (3.A2.28)$$

where $X_{i,c,cc}$ is the corresponding volume of exports, and Tmargin is the proportion which 'melts' (to use the iceberg analogy) en route between the countries.

The equation for aggregating QU within each industry, equation (3.A2.13), has already been explained.

Sales shares

We then differentiate (3.A2.13) setting price equal to marginal utility, to calculate $QU_{i,c,cc}$ as a function of total use of products of industry i in country cc, $TU_{cc,i}$ and the relative price of input of i from country cc, $PUU_{i,c,cc}$ compared to that of aggregate use of i in country cc, $PU_{cc,i}$. Hence, taking

$$TU_{cc,i} = \left(\sum_c n_{ci} \gamma_{i,c,cc} \left(QU_{i,c,cc}/n_{c,i} \right)^{\rho} \right)^{1/\rho}, \qquad (3.A2.13)$$

we differentiate with respect to QU, and set the resulting marginal product equal to PU/PUU, giving

$$\begin{aligned} dTU_{cc,i}/dQU_{i,c,cc} &= n_{ci}^{1-\rho} \gamma_{i,c,cc} QU_{i,c,cc}^{\rho-1} \left(\sum_c n_{ci} \gamma_{i,c,cc} \left(QU_{i,c,cc}/n_{c,i} \right)^{\rho} \right)^{(1-\rho)/\rho}, \\ &= n_{ci}^{1-\rho} \gamma_{i,c,cc} (TU_{cc,i}/QU_{i,c,cc})^{1-\rho} = PU_{cc,i}/PUU_{i,c,cc}. \end{aligned}$$

This is easily rearranged:

$$QU_{i,c,cc} = TU_{cc,i} n_{c,i} (\gamma_{i,c,cc} PUU_{i,c,cc} / PU_{cc,i})^{1/(1-\rho)}. \tag{3.A2.29}$$

Aggregate consumer price

The total value of expenditure on good i in country c is given by

$$VU_{cc,i} = \sum_c QU_{i,c,cc} PUU_{i,c,cc}. \tag{3.A2.30}$$

The aggregate consumer price of i in cc,

$$PU_{cc,i} = VU_{cc,i} / TU_{cc,i}. \tag{3.A2.31}$$

Factor markets

Both types of labour are immobile between countries, but mobile between industries. The wage is assumed to clear each labour market, so that total skilled and unskilled labour use by all industries equals the skilled and unskilled labour endowment of country c

$$\begin{aligned} \overline{LU}_c &= \sum_i LU_{c,i}, \\ \overline{LS}_c &= \sum_i LS_{c,i}. \end{aligned} \tag{3.A2.32}$$

We assume capital is fully mobile between industries. There are two variants - one where total capital within a country is fixed (net capital imported from abroad, $KM_c =$

0) and one where it is allowed to vary. Hence

$$\overline{K}_c + KM_c = \sum_i Ki_{c,i}. \tag{3.A2.33}$$

Where KM_c is allowed to be non-zero (so that there are international transfers of capital) the global total of KM is set to zero.

$$\sum_c KM_c = 0. \tag{3.A2.34}$$

The rate of return on capital in each industry is equated to the national rate of return, RB_c:

$$R_{c,i} = RB_c. \tag{3.A2.35}$$

Where capital is allowed to move internationally, we also set national rates of return equal to the return in the 'Other OECD' region:

$$RB_c = RB_{ODX}. \tag{3.A2.36}$$

Land is only used in two sectors: agriculture and other primary. Its rent varies according to sector. It is sectorally immobile, so

$$LD_{c,i} = \overline{LD}_{c,i}. \tag{3.A2.37}$$

Variety of goods

The model assumes all goods within an industry are produced by separate firms.

Each firm within a country is of identical size, though the average company size may vary between countries.

For sensitivity analysis, the fixed firm numbers version of the model assumes the total number of firms in each country is fixed

$$n_{c,i} = \overline{n}_{c,i}. \tag{3.A2.38}$$

National accounts

Home use of goods from industry i in country c, $HU_{c,i}$, is defined as total production in country c less exports.

$$HU_{c,i} = Y_{c,i} - \sum_{cc} X_{i,c,cc}. \tag{3.A2.39}$$

Imports of i from country cc to country c are equal to exports from cc to c deflated to take account of transport costs.

Where $c = cc$ (ie the variable $IDEN_{c,cc}$ equals 1), total use of good i in country c produced in country cc equals home use. Otherwise (when $IDEN_{c,cc}$ equals 0), total use equals imports from cc to c.

As well as tariffs, there are two types of taxes:

Use tax is assumed to be an ad valorem tax on all use of goods class i in country c. Use tax revenue is given by

$$TUY_c = \left(\sum_i HU_{c,i} PT_{i,cc} + \left(\sum_{cc} PT_{i,cc,c} EX_{i,cc,c} / (1 + tmargin_{i,cc,c}) \right) \right) (1 + usetax_{c,i}). \tag{3.A2.40}$$

Output tax, OUTTAX is a tax per unit value of output of an industry, as explained in (3.A2.10).

Total consumer expenditure in country c, CE_c, is taken as equalling value added from all industries in C +monopoly profits from all industries in country C +total tariff revenue in country C +output tax revenue +use tax revenue -total subsidies - the trade balance of country C (assumed to be constant and exogenous) - interest on net capital imports paid at the world rate. Hence,

$$\begin{aligned} CE_c \quad = \quad & \sum_i VA_{c,i}PV_{c,i} + \sum_i Y_{c,i}PY_{c,i}MM_{c,i} \\ & + \sum cc \sum_i (EX_{i,cc,c}PM_{cc,i}TR_{i,cc,c})/100) \\ & + \sum_i OT_{c,i} \left(VA_{c,i}PW_{c,i} + \sum_{ii} II_{c,ii,i}PU_{c,ii} \right) \\ & + TUY_c - TSUBY_c - BOT_c - KM_cRB_c. \end{aligned} \qquad (3.A2.41)$$

The Balance of Trade, BOT_c, (including long-term net capital payments) is assumed to be fixed.

$$BOT_c = \sum_i \sum_{cc} EX_{i,c,cc}PM_{c,i} - \sum_{cc} EX_{i,cc,c}PM_{cc,i} - KM_cRB_c. \qquad (3.A2.42)$$

The reason this includes long-term net capital payments is to cover the version of the model where capital is internationally mobile: in this case, we would expect interest to be paid at rate RB_c on net capital imported from abroad, KM_c, and one would expect this to involve country c either exporting more or importing less.

Key assumed parameter values

Demand side:

The top level utility function is Cobb-Douglas in functional form (so the elasticity of substitution between consumption of the produce of each industry, i, is unity). Share parameters for each product class are calibrated from value shares in total expenditure.

The lower level utility function has an elasticity of substitution between goods g in industry i of σ. This is assumed to equal 4 in all industries.

Supply side: production technology is assumed to be Cobb-Douglas, so elasticities of substitution between inputs are unity, and share parameters can be directly calibrated from shares in total costs (once monopoly profit has been subtracted from costs).

In the absence of other data, **firm sizes** have been set equal within each industry across countries, such that Iron and Steel and Heavy Manufacture are seen as the least competitive industries (1 and 3 firms respectively in our smallest region, Hungary), followed by Other Primary, Light Manufacturing, Textiles and Food Processing (4-6 firms per industry in Hungary). Services and (especially) agriculture have much smaller firm sizes, and so are far more competitive. Larger markets (like the EU) have more firms, and so are more competitive. The main reason for these assumptions is to simulate the pro-competitive effects of trade liberalisation in reducing monopolistic mark-ups in smaller, more sheltered economies.

Chapter 4

Trade and Strategic Regulatory Bias

4.1 Introduction

This paper examines the implications of quality regulations (e.g. on safety, reliability or public health and environmental grounds) in an open economy. The existence of trade can result in strategic distortions to regulatory policy.[1] Much of the existing literature makes a presumption not just that there will be a tendency in an open economy to excessive regulation, but that this will be of a protectionist, trade-reducing kind. By contrast, I find that regulations are generally trade-increasing, and that the need to prevent firms from leaving the market usually reduces the scope for over-regulation.

It is worth bearing in mind that most previous studies of regulatory protection assume a profit-shifting motive to benefit local producers. This suggests an oligopolistic

[1] See Brander and Spencer (1982) or Brander (1995).

trade structure[2] - yet at the same time, there is little discussion of the legitimate grounds for quality regulation which occur when an industry is monopolistic. I show that, on reasonable assumptions, monopolistic producers will tend to produce goods at suboptimal quality. It is perhaps worth noting that this quality shortfall may take many forms, such as inadequate health, safety and environmental testing, or lack of labelling. Much of this can be corrected by regulation. However, the regulation benefits consumers at the expense of producers. Where the producers are foreign, there can potentially be a bias to over-regulation, and this strategic bias can potentially continue in the case where countries are symmetrical and product quality can differ between markets. However, there is an upper limit to such regulation, since firms can exit the market if profits become negative. The higher regulatory standards actually increase trade volumes, at the expense of profits.

Mutual recognition agreements, under which a pair or group of countries agree to accept goods from other agreement signatories, so long as they meet the rules and standards of their country of origin, are also ambiguous. This is in contrast to previous studies which have claimed mutual recognition is unambiguously welfare improving. The effects depend in particular upon whether trade is balanced or in one direction: in the latter case, mutual recognition will produce under-regulation and reduce trade. When trade is balanced, the mutual recognition can produce either under- or over-regulation, though numerical simulations suggest the latter is more likely. In this case, there will often be some welfare gain compared to noncooperative standard setting, though again it will involve a reduction in trade. The precise outcome depends upon the nature of the assumed game between the regulators and firms, and upon parameters such as country size and

[2] Or, alternatively, country-specific factors.

demand elasticity.

These findings add some qualification to the common prescription of mutual recognition alone as a response to presumed regulatory bias. In many areas of current dispute, such as genetically modified foodstuffs, where the commodity involved is primarily produced in one country rather than both, removal of 'protectionist' national or regional regulations may be contrary to the interests of consumers, and, contrary to widespread assumptions, may result in falling consumer demand and reduced trade.

Section 4.2 reviews the background and existing literature on quality regulations and trade. While policymakers and economists accept regulations as potentially legitimate, the literature stresses they will often be distorted for protectionist reasons: a conclusion which this paper challenges when an industry is monopolistic.

In the subsequent sections I concentrate on the underprovision of quality by a classical cross-hauling duopoly. Next, I examine pure vertical standards: the approach is to develop a model for a simple monopoly in Section 4.3 and then, in Section 4.4, to extend it to a cross-hauling duopoly with one identical firm in each of two symmetrical countries, where consumer preferences are identical and the good concerned is a substitute for other consumer goods. In these circumstances, a vertical minimum quality standard is potentially welfare-improving, but there will be a strategic bias to overregulation in the absence of either cooperation or a mutual recognition regime.

Section 4.5 considers pure, horizontal quality standards, imposing a resource cost on foreign producers only. The previous literature suggests these may be imposed for protectionist profit-shifting, though only when tariffs are ruled out. This study suggests that, in a cross-hauling duopoly with price-elastic demand, such barriers will be unattractive. When there is also vertical regulation, the profit-shifting motive is further reduced. Where countries differ in quality of production, the higher-quality country may sometimes choose to raise minimum standards, but again the circumstances and scope for this are less than the previous literature has suggested.

In section 4.6, I consider the effects of constraining producers to supply at the same quality to both markets - in particular concentrating on the case where only one country is a producer. A mutual recognition regime under imperfect competition will result in underregulation (and reduced trade). Where there is no such recognition, the importing country will set the higher standards, but there will be a bilateral game between the two regulators in standard setting. Compared to non-cooperation, mutual recognition will unambiguously worsen welfare in the importing country.

Section 4.7 concludes.

4.2 Background and existing literature

As formal trade barriers have been reduced worldwide, there has been increasing recognition of the importance of Technical Barriers to Trade (TBTs) - barriers resulting from a whole raft of national or regional regulations and standards on labelling, product safety, labour standards, environmental quality and so on.[3] The EU Single Market initiative has largely been aimed at removing such barriers,[4] and subsequent mutual recognition agreements have been agreed between the EU and several other countries, as well as within the Asia Pacific Economic Community (see Maskus and Wilson (1), 2001). A

[3] In the case of EU members, national regulations and standards are gradually being outnumbered by EU ones. See DTI (2005).

[4] One EU report in 1996 estimated that 76% of trade between member states was subject to standards, and sectors affected by regulatory trade barriers accounted for 21% of trade and 29% of gross value added (reported in OECD, 1999).

similar awareness underlies the articles on TBTs and Sanitary and Phytosanitary Standards (SPS) in the GATT Uruguay Round, and the GATS. For example, the WTO Agreement Annex on Technical Barriers to Trade Article 2 states that:

> *'Members shall ensure that technical regulations are not prepared, adopted or applied with a view to or with the effect of creating unnecessary obstacles to international trade. For this purpose, technical regulations shall not be more trade-restrictive than necessary to fulfil a legitimate objective....'*

Nevertheless, there has been considerable concern that existing agreements do not go far enough in terms of facilitating trade, particularly from the viewpoint of developing countries.

TBTs are much more complicated to analyse than tariffs or quotas. Deciding to what extent barriers are in practice legitimate or constitute an obstacle to trade[5] is not simple. First the issue of definition: some authors have used very wide definitions of what constitutes protectionism,[6] exceeding those in the WTO Agreements.

Turning to specific cases, a few conclusions can be drawn from the literature. Even regulations which apply equally to home- and to foreign-produced goods may discriminate against firms which trade, if the regulations differ across countries. The literature often discusses pure cost-increasing protectionist regulation (e.g. Wallner, 1998): however, it seems unlikely substantial use would be made of a policy which imposes high resource costs on consumers unless tariffs, which impose a much smaller deadweight loss, were ruled out or rendered infeasible or hard to alter due to their greater visibility.

[5] Or 'regulatory protection' (see e.g. Baldwin, 2001), the terminology henceforth used in this paper.

[6] Fischer and Serra (2000) define a standard in a cross-hauling duopoly model as 'non-protectionist when it corresponds to the standard the local social planner would use if both firms were domestic'.

Regulatory differences between countries can in principle be broadly defined as either horizontal or vertical. The former impose different technologies or incompatible means of achieving a given set of results, such as plug sizes. By contrast, vertical standards are where a regulator clearly insists that goods achieve at least a certain minimum standard of safety or performance. In practice many regulations may have both horizontal and vertical aspects, such as insisting that cars achieve less than certain emissions levels, and specifying use of catalytic converters.

The most widely-recognised motive for horizontal regulation is network externalities (see, e.g. Gandal, 2001).[7] The scope for distorting such a system for protectionist purposes is also clear: if technologies are not easily compatible, the government can favour home producers.

In the case of vertical quality, the literature to date recognises three main legitimate reasons for minimum quality controls. First, unreliable or dangerous goods may impose externalities.[8] Secondly, purchasers of goods may not easily be able to distinguish the quality. In this case (see e.g. Akerlof, 1970) adverse selection may mean that bad products drive out the good, unless there is either effective central labelling or some minimum quality standard. The third motivation is where tastes are diverse and supply is oligopolistic. In this model (see Lutz, 1996(1))[9] mutual recognition benefits both countries, particularly the lower-quality producer.

However, the above papers assume a fixed number of consumers buying at most one

[7] This is the situation where there is a substantial potential gain if all consumers use a compatible technology. There may be good reason to impose one technology centrally, rather than letting different technologies fight a costly battle for supremacy.

[8] Hypothetical alternative policies (e.g. compulsory insurance) are perhaps a side issue - in practice the state usually does insist on goods meeting certain standards. The most extreme case is disease control, which is the main justification for Sanitary and Phytosanitary Standards (SPS).

[9] See also papers by Crampes and Hollander (1995) and Das and Donnenfeld (1989) for this basic model setup, which is derived from Shaked and Sutton (1982).

good each. This means they tend to ignore a key feature of the classical monopoly/oligopoly model: that producers can raise profits by restricting output. Where quality differences substitute with diminishing returns for quantity of consumption, there may be scope for producers to increase profits at consumers' expense by reducing crude quantity as well as quality. This provides another legitimate reason for minimum quality standards: to correct the underprovision of quality by monopolistic firms.

A lack of competition may reduce quality - on a broad definition - in a number of ways. These could include lack of testing and labelling or use of technological incompatibilities to tie in users to one firm's products. For example, all of these criticisms are seen in the lobbying against genetic modification of foodstuffs. The response of governments to these will, however, depend upon the geographical structure of the industry: in the case of GM technology, US firms dominate. The analysis of this paper suggests it should be no surprise that European legislators have taken a stricter line than those in North America, leading to a major trade dispute, notably over the separate labelling of GM foodstuffs - however, I would suggest it is likely, if higher labelling standards prevail, that trade will be higher than if they do not, and that this would benefit consumer welfare.[10]

More common, however, may well be industries where trade is in both directions, such as aircraft, motor vehicles, food products, clothing, petroleum products, pharmaceuticals or mobile telephones. In all of these industries, national standards are seen as extremely important, and yet the symmetries between countries are much greater than with GM crops. I argue that under these circumstances there may be a bias towards over-regulation. For example, there have long been complaints in the USA about sup-

[10] Nielsen and Anderson (2001) look at one scenario where some of the EU consumer demand is sensitive, but they do not link this to utility, which may explain their rather negative assessment of EU policy.

posed overregulation of pharmaceuticals by the Food and Drugs Administration,[11] while similar complaints can be heard from European motor vehicle manufacturers.[12] However, in this paper, I argue that these regulations may actually increase trade volumes (at least when adjusted for quality), though at a cost to manufacturers.[13] Again, the over-regulation bias is generally constrained by the need for profits to be non-negative, although, interestingly, the best-known cross-hauling duopoly case in a heavily regulated industry, the Boeing-Airbus dispute, involves subsidised firms.

The asymmetric interests cases (such as GM technology) tend to be those which crop up most in WTO disputes, while where interests are symmetric there may be fewer disagreements. While one may be tempted to talk of cases such as the GM technology as representing regulatory protectionism, this is also too simple, since it ignores the potential bias in the exporting country towards under-regulation. It is by no means clear that mutual recognition would be welfare-improving in either case - contrary to the drift of much of today's trade literature.

4.3 A model of vertical quality regulation

I examine quality regulations as a response to underprovision of quality by a monopolistic industry. Strictly speaking, 'regulations' are applied by governments, while 'standards' are voluntarily agreed by industries (Sykes, 1995).[14] I concentrate primarily on the

[11] The argument was made by Friedman (1980), but is more recently repeated, for example, by the right-wing Cato Institute: https://www.cato.org/pubs/regulation/reg15n4e.html

[12] e.g. the European Automobile Manufacturers' Association, as shown on http://www.acea.be/ACEA/20040218PressRelease.pdf

[13] In the case of pharmaceuticals, it may be more accurate to say that higher imposed testing standards would reduce the risk of consumer scares.

[14] In general, a voluntary industry standard is more likely to be operated to maximise profits of domestic firms than a government regulation. However, under the former, importers may be able to enter the market without complying.

former.

The method is to set up a series of theoretical models of a monopoly and a cross-hauling duopoly. The optimal degree of regulation is established, as are the conditions under which actual regulation differs from this, when there is total non-cooperation over regulation setting, or when there is mutual recognition.[15]

Consideration is also given to whether these regulations are in fact protectionist: for this I prefer a relatively narrow definition of protection.

DEFINITION 4.1: *A regulation is non-protectionist if it (i) does not reduce traded volumes; and (ii) does not favour local profits at the expense of foreign producers.*

This definition leaves a category of trade-related strategic distortions, notably the case where regulation causes local consumers to benefit from increased sales (at lower cost and reduced profit) by both domestic and foreign producers. In this case, there are much stronger parallels with the issue of international tax competition, rather than with tariff or quota policies.

There is actually a fair amount of evidence to suggest that standards and regulations are generally not protectionist - notably Swann et al's (1996) British study, finding that increasing numbers of quantitative standards tend to be correlated with increasing volumes of both imports and exports.[16]

In this paper I am interested in regulations which improve the minimum vertical quality experienced by consumers. In the absence of regulation, monopoly generally

[15] I label these cases 'noncooperation' and 'mutual recognition', though mutual recognition should be seen as a regime of limited noncooperation between regulators (the limit being that they can only regulate the home firm's quality).

[16] Moenius (1999) had broadly similar findings. Also note Greenaway and Milner's (1986) theoretical arguments that standards are trade-promoting, though based on rather different grounds to this paper.

reduces the quality of goods on offer, but in the presence of trade there may be strategic distortions if national regulators do not collaborate.

I start with the simplest case of a monopolist. It is assumed that consumers are identical. I consider initially a single country using a partial equilibrium approach, concentrating on just one good. Firms produce output with two features, quality, Q, and quantity, Y. I assume initially that the total cost of production, C, is a linear function of Q and Y, with a and b denoting the linear scalars,

$$C = aY + bQ. \tag{4.1}$$

Without loss of generality we can set $a = 1$, so that

$$C = Y + bQ. \tag{4.1a}$$

I assume homothetic demand for quality and output, so that we can convert quality and output to a measure of 'quality-adjusted output', X. For simplicity I assume X is a Cobb-Douglas aggregate of Y and Q,

$$X = Y^{\beta} Q^{1-\beta}, \tag{4.2}$$

where β is a scalar which lies between zero and unity, and can be seen as reflecting the relative weight consumers place on quality as against crude quantity.

We can also convert the price per unit of output, P, into a price per unit of quality-adjusted output, P_X.

Consumer utility depends upon consumption both of quality-adjusted output, X, and of a residual aggregate of other goods, $G = \bar{M} - P_X X$ (where $\bar{M}$ is an exogenously given endowment) in a quasilinear fashion — thus eliminating income effects. For simplicity, the utility from consuming the good in question is assumed to have an elasticity η with respect to consumption — implying a constant elasticity of demand, $-\epsilon = -1/(1-\eta)$. Hence

$$U = \bar{M} - P_X X + \gamma X^{\eta}, \tag{4.3}$$

where γ is a scalar, which we would expect to be related partly to country size. I assume $0 < \eta < 1$. Again, without loss of generality, we ignore $\overline{M}$, and concentrate on a measure of consumer surplus, $U = \gamma X^{\eta} - P_X X$. Setting price equal to marginal utility, we can write

$$U = \gamma(1-\eta)X^{\eta}. \tag{4.3a}$$

Since this gives $dU/dX = \gamma\eta(1-\eta)X^{\eta-1} > 0$, consumer surplus is monotonically increasing with respect to X, but the second differential shows marginal utility is decreasing.

4.3.1 Monopoly equilibrium under quality regulation.

I begin with a quality regulated monopolist, whose profit mark-up is a decreasing function of demand elasticity, ϵ. The firm will set finite prices as long as ϵ exceeds unity, which will be the case as long as $0 < \eta < 1$.

Behaviour of an unregulated monopoly

As a benchmark case, I start by considering the behaviour of an unregulated monopoly, denoted by the subscript U. For a given level of $X = X_U$, we can obtain the cost-minimising value of Q $(= Q_U)$. This satisfies

$$Q_U = ((1/b)(1-\beta)/\beta)^{\beta} X_U, \tag{4.4}$$

and hence yields a constant marginal cost of raising X,

$$MC_U = (1/\beta)((1/b)(1-\beta)/\beta)^{\beta-1}. \tag{4.5}$$

....

Derivation of Equations (4.4)-(4.5):

$$C = Y + bQ. \tag{4.1a}$$

From (4.2)

$$X = Y^{\beta} Q^{1-\beta}, \tag{4.2}$$

$$Y = X^{1/\beta} Q^{(\beta-1)/\beta},$$

so

$$C_U = X_U^{1/\beta} Q_U^{(\beta-1)/\beta} + bQ_U \ ;$$

$$dC_U/dQ_U = 0 ==> ((1-\beta)/\beta) X_U^{1/\beta} Q_U^{-1/\beta} = b;$$

$$Q_U = ((1/b)(1-\beta)/\beta)^{\beta} X_U; \tag{4.4}$$

$$C_U = X_U^{1/\beta}((1/b)(1-\beta)/\beta)^{\beta-1} X_U^{(\beta-1)/\beta} + b((1/b)(1-\beta)/\beta)^{\beta} X_U \ ,$$

$$= X_U(1/b)^{\beta-1}((1-\beta)/\beta)^{\beta-1}(1 + b(1/b)(1-\beta)/\beta);$$

$$= X_U(1/\beta)((1/b)(1-\beta)/\beta)^{\beta-1},$$

which can readily be differentiated with respect of X_U to yield marginal cost as in equation (4.5).

....

The unregulated monopoly's total revenue is

$$R_U = \gamma\eta X_U^{\eta}.$$

Hence marginal revenue is

$$MR_U = \gamma\eta^2 X_U^{\eta-1}.$$

Since a monopolist will equate this with marginal cost, which we have already found in equation (4.5), we can find unregulated output

$$X_U = \Omega^{1/(1-\eta)}((1/b)(1-\beta)/\beta)^{(1-\beta)/(1-\eta)}, \tag{4.6}$$

where $\Omega = \beta\gamma\eta^2$. Hence, we can show that

$$Q_U = \Omega^{1/(1-\eta)}((1/b)(1-\beta)/\beta)^{(1-\beta\eta)/(1-\eta)}. \tag{4.6a}$$

....

Derivation of equations (4.6) and (4.6a)

Setting marginal revenue equal to marginal cost,

$$\begin{aligned}
\gamma\eta^2 X_U^{\eta-1} &= (1/\beta)((1/b)(1-\beta)/\beta)^{\beta-1} \\
X_U &= (1/\beta\gamma\eta^2)^{1/(\eta-1)}((1/b)(1-\beta)/\beta)^{(\beta-1)/(\eta-1)}, \\
&= \Omega^{1/(1-\eta)}((1/b)(1-\beta)/\beta)^{(1-\beta)/(1-\eta)}. \qquad (4.6)
\end{aligned}$$

But

$$\begin{aligned}
Q_U &= ((1/b)(1-\beta)/\beta)^{\beta} X_U, \quad (4.4) \\
&= ((1/b)(1-\beta)/\beta)^{\beta}\Omega^{1/(1-\eta)}((1/b)(1-\beta)/\beta)^{(1-\beta)/(1-\eta)}, \\
Q_U &= \Omega^{1/(1-\eta)}((1/b)(1-\beta)/\beta)^{(1-\beta\eta)/(1-\eta)}. \qquad (4.6a)
\end{aligned}$$

....

We also note that $((1/b)(1-\beta)/\beta) = (X_U/Q_U)^{-1/\beta}$. Let us define the ratio $(X_U/Q_U) = \chi_U$. From (4.4) we can see that

$$(X_U/Q_U) = \chi_U = ((1/b)(1-\beta)/\beta)^{-\beta}. \tag{4.6b}$$

Hence we can rewrite equation (4.5) as

$$MC_U = (1/\beta)\chi_U^{(1-\beta)/\beta}. \tag{4.5a}$$

The regulated monopoly

Now introduce a regulation fixing $Q \geq Q_R$ (where the subscript R denotes a regulatory minimum quality). In practice, if $Q_R > Q_U$ then the firm will choose $Q = Q_R$. It is also assumed that the regulator only sets a minimum quality standard: there is no regulation of volume supplied or price (this may be a more realistic assumption for the oligopoly case considered later).

By contrast with the unregulated case, marginal cost is now a function of Q and X,

$$MC_R = (1/\beta)(\chi_R)^{(1-\beta)/\beta}, \tag{4.7}$$

where χ denotes the output/quality ratio X/Q.

....

Derivation of Equation (4.7):

$$C_R = X_R^{1/\beta} Q_R^{(\beta-1)/\beta} + bQ_R \ ;$$

$$dC_R/dX_R = (1/\beta)X_R^{(1-\beta)/\beta} Q_R^{(\beta-1)/\beta}.$$

....

Differentiating dC_R/dX_R with respect to Q_R, we find that

$$d(dC_R/dX_R)/dQ_R = (1/\beta)((\beta-1)/\beta)X_R^{(1-\beta)/\beta}Q_R^{-1/\beta}, \tag{4.7a}$$

which will be negative for the case where $0 < \beta < 1$,and X_R, $Q_R > 0$. Hence raising the regulatory quality lowers marginal costs. Further, by comparing (4.7) with (4.5a), we can see that if $\chi_R = \chi_U$, then $MC_R = MC_U$. Consequently, if the regulator sets the minimum standard equal to Q_U, the quality the unregulated monopolist would have chosen, then the monopolist will choose $X_R = X_U$, which would produce the same marginal cost as if he were unregulated.

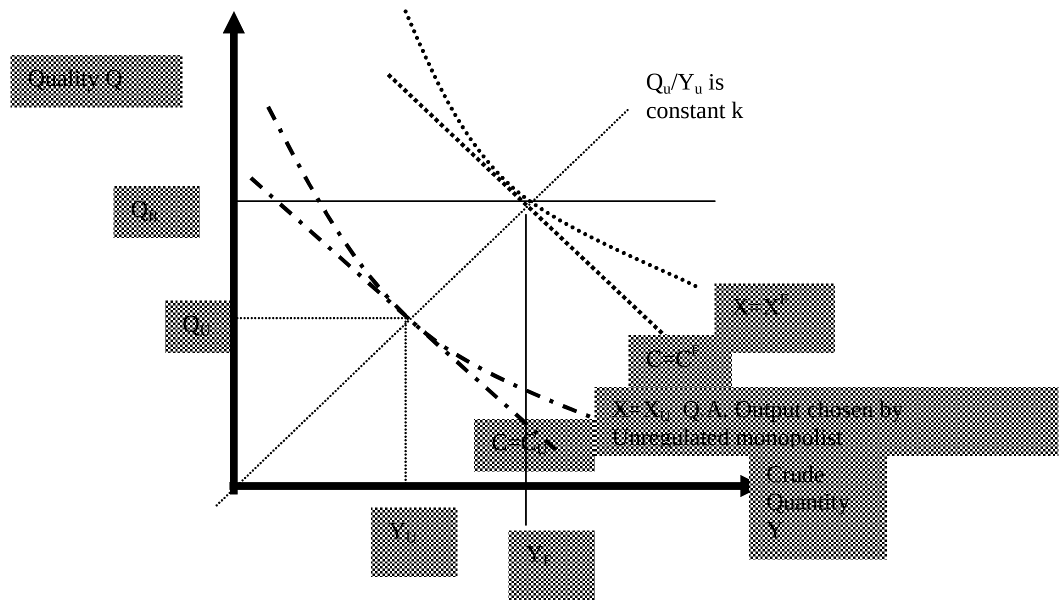
Since dMC_R/dQ_R is negative, as Q_R is increased by regulation, the marginal cost of quality-adjusted output X will fall. This leads to our first result.

LEMMA 4.1: *If a monopolist is constrained to produce to a higher standard than he would otherwise choose, the marginal cost of increasing quality-adjusted output is less than when the choice of quality is unconstrained.*

This can be shown in *Figure 4.1*, which summarises the firm's choice of crude output Y. Given free choice, the firm will choose (Q_U, Y_U) on the ray $Q_U/Y_U = k$. However, regulation prevents the firm setting $Q < Q_R$. It follows that, for quantities of quality-adjusted output up to X_F, the firm is forced to incur higher cost, C, than it would freely choose for a given level of quality-adjusted output X. Against this, as output increases the total cost line approaches the ray $Q_U/Y_U = k$. This suggests that imposing a quality standard of $Q_R > Q_U$ means the marginal cost of increasing X is less than it would be if the firm were to freely choose Q and Y, up to the point where $X = X_F$. The reason total cost is higher is because the minimum standard effectively imposes a fixed cost on the firm.[17]

[17] There are strong parallels here with regulatory policies which change the input mix of firms as a means of inducing them to change output levels - for example, insisting a firm instals more capital than it would freely choose. (Thanks to Rodney Falvey for this point).

Figure 4.1: Imposition of a minimum quality standard Q_R by a regulator.



Imposition of a minimum quality standard Q_R by a regulator.

Q_U and Y_U are the unregulated quality and quantity. Y_F corresponds to the level of demand at which the regulated standard Q_R is the same as what the monopolist would freely choose.

Assuming a constant demand elasticity, the monopolist will set a fixed proportional markup over marginal cost. Hence the introduction of Q_R will lead to lower prices (at least when quality-adjusted), and higher sales, at least as long as the standard is not set so high that the monopolist chooses to exit the market. This leads to our next result:

LEMMA 4.2: *A quality-constrained monopolist will sell more quality-adjusted output at a lower quality-adjusted price than an unregulated monopolist, and this output will rise monotonically with the quality standard as long as the firm continues to produce.*

To establish more formally the relationship between the supply of quality-adjusted output chosen by the monopolist, X_R, and the minimum quality specified by the regulator, Q_R, we note that a profit-maximising firm will set marginal cost equal to marginal revenue and solve, giving us the relationship

$$X_R = \Omega^{\beta/(1-\beta\eta)} {Q_R}^{(1-\beta)/(1-\beta\eta)} \quad . \tag{4.8}$$

This confirms that for positive γ and η, $0 < \beta < 1$ and $0 < \eta < 1$, X_R is increasing monotonically with respect to Q_R.

....

Derivation of Equation (4.8):

Marginal revenue is given by $MR = \gamma\eta^2 X^{\eta-1}$.

Setting marginal revenue equal to marginal cost

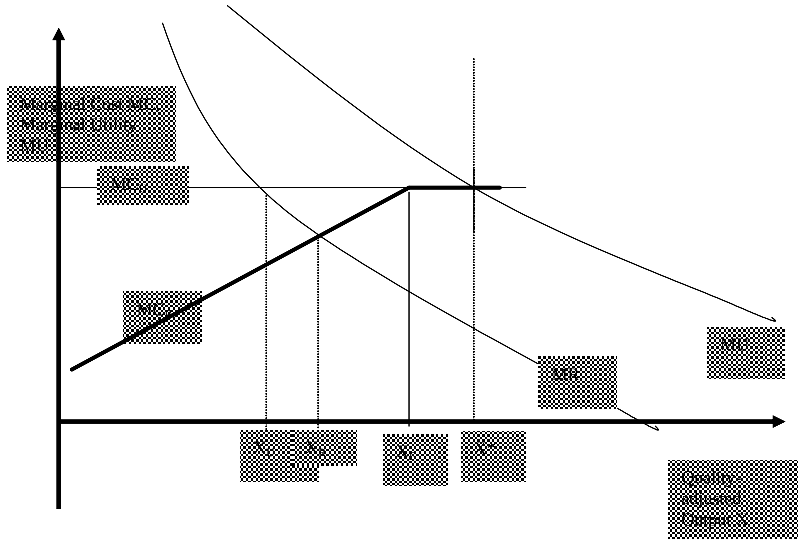
$$\gamma\eta^2 X_R^{\eta-1} = MC_R = (1/\beta)(X_R/Q_R)^{(1-\beta)/\beta},$$

$$\gamma\eta^2 (X_R)^{(\beta\eta-1)/\beta} = (1/\beta)(Q_R)^{(\beta-1)/\beta},$$

$${X_R}^{(1-\beta\eta)/\beta} = \beta\gamma\eta^2 {Q_R}^{(1-\beta)/\beta}.$$

....

Figure 4.2: Choice of quality-adjusted output under a regulatory minimum quality standard.



Choice of quality-adjusted output under a regulatory minimum quality standard.

X_U is the choice of an unconstrained monopolist. X_R is that which a quality-regulated monopolist chooses. At X_F the constrained and unconstrained outputs are the same. X* is the social optimum if the regulator could set both quality and output.

The effect on output of imposing a minimum quality standard is illustrated in *Figure 4.2*. For $X < X_F$, the new marginal cost curve, $MC_R(X)$, lies below the old one, $MC_U(X)$. Consequently the monopolist will now increase quality-adjusted output to equal X_R rather than X_U as before.

Optimal regulation according to social welfare

We now want to model the regulator's choice. In fact, given the above relationship between output and the regulatory standard, modelling welfare choices is relatively straightforward in the case of the Cobb-Douglas/linear functional form. This follows from the fact that consumer surplus, sales revenue and variable costs of production are all directly proportionate to one another. Specifically, we can relate consumer surplus, sales revenue, variable cost and quality using a series of constants. If R_R is sales revenue of a regulated monopoly, then first we note that R_R is a function of Q_R of the form

$$R_R = k_1 Q_R^{\upsilon}, \tag{4.9}$$

where

$$k_1 = \gamma\eta\Omega^{\beta\eta/(1-\beta\eta)}, \tag{4.9a}$$

and $\upsilon = (1-\beta)\eta/(1-\beta\eta)$. Note that, for $0 < \beta < 1$ and $0 < \eta < 1$, υ must also lie between zero and one. This implies that R_R, U_R and VC_R are all monotonically increasing with respect to Q_R, although at a declining marginal rate.

$$\text{consumer surplus } U_R = k_2 R_R; \tag{4.10a}$$

$$\text{variable cost } VC_R = k_3 R_R; \tag{4.10b}$$

where k_2 and k_3 are constants, whose values depend upon β and η :

$$k_2 = (1-\eta)/\eta; \tag{4.11a}$$

$$k_3 = \beta\eta. \tag{4.11b}$$

These equations imply that R_R, U_R and VC_R are all monotonically increasing with respect to Q_R, although at a declining marginal rate.

LEMMA 4.3: *Consumer surplus rises monotonically with the minimum quality, although at the marginal rise in consumer surplus is declining.*

....

Derivation of Equations:

Equations (4.9) and (4.9a)

$$R_R = Px_R X_R = \gamma\eta X_R^{\eta};$$

But

$$X_R = \Omega^{\beta/(1-\beta\eta)} {Q_R}^{(1-\beta)/(1-\beta\eta)} \quad . \tag{4.8}$$

Consequently

$$\begin{aligned} R_R &= \gamma\eta\Omega^{\beta\eta/(1-\beta\eta)} {Q_R}^{(1-\beta)\eta/(1-\beta\eta)} \quad , \\ &= \gamma\eta\Omega^{\beta\eta/(1-\beta\eta)} {Q_R}^{\upsilon} \quad . \end{aligned} \tag{4.9}$$

Derivation of Equations (4.10a) and (4.11a).

Consumer surplus is a function of quality-adjusted sales

$$\begin{aligned} U_R &= \gamma X_R^{\eta} - Px_R X_R, \\ &= \gamma(1-\eta) X_R^{\eta}, \\ &= ((1-\eta)/\eta) R_R. \end{aligned} \tag{4.10a}$$

Derivation of Equations (4.10b) and (4.11b)

Starting with cost

$$C_R = X_R^{1/\beta} Q_R^{(\beta-1)/\beta} + bQ_R,$$

we can write

$$C_R = VC_R + bQ_R,$$

where variable cost

$$VC_R = \; X_R^{1/\beta} Q_R^{(\beta-1)/\beta}.$$

Hence, substituting from (4.8)

$$\begin{aligned} VC_R &= \left(\Omega^{\beta/(1-\beta\eta)} (Q_R)^{(1-\beta)/(1-\beta\eta)}\right)^{1/\beta} Q_R^{(\beta-1)/\beta}, \\ &= \Omega^{1/(1-\beta\eta)} {Q_R}^{(1-\beta)/\beta(1-\beta\eta)} Q_R^{(1-\beta)(\beta\eta-1)/(\beta(1-\beta\eta))}, \\ &= \Omega^{1/(1-\beta\eta)} {Q_R}^{(1-\beta)\eta/(1-\beta\eta)}. \end{aligned}$$

Hence

$$\begin{aligned} VC_R/R_R &= \Omega^{1/(1-\beta\eta)}/(\gamma\eta\Omega^{\beta\eta/(1-\beta\eta)}), \\ &= \Omega/\gamma\eta, \\ &= \beta\eta. \end{aligned}$$

....

The firm's profits, π_R, will first rise and then decline as quality standards rise. This result follows from the observation that

$$\begin{aligned} \pi_R &= R_R - VC_R - bQ_R, \\ &= (1 - k_3)k_1 Q_R^{\upsilon} - bQ_R. \end{aligned} \tag{4.12}$$

Differentiating this with respect to Q_R, we can show that profits peak when

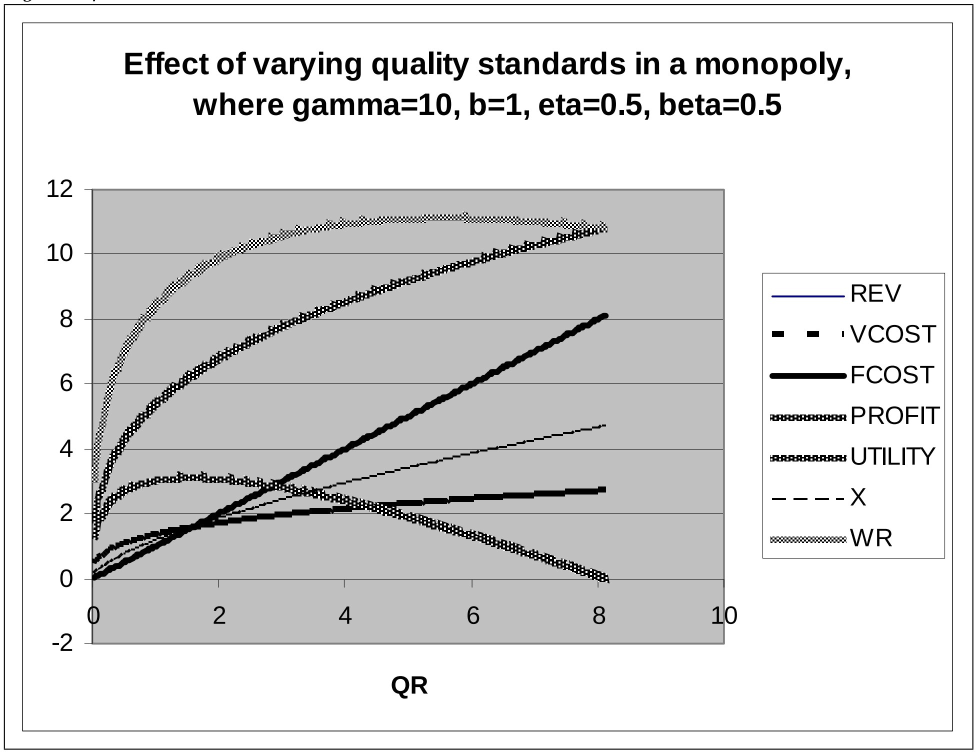
$$Q_R^{1-\upsilon} = (1 - k_3)\upsilon k_1/b, \tag{4.12a}$$

which, in fact, gives the value we have already established for Q_U.

To illustrate these relationships further, consider the case where $\gamma = 10$, $b = 1$, $\beta = 1/2$ and $\eta = 1/2$. In this case, $\upsilon = 1/3$, $\Omega = 10/8$, $k_1 = 5.387$, $k_2 = 1$, $k_3 = 1/4$. Consequently, $Q_U = 1.5625$.

The relationships between the key variables in this case are seen in *Figure 4.3*, below.

Figure 4.3



[Rev=firm's revenue; Vcost = variable cost; Fcost = fixed cost; X = firm's sales; WR = overall welfare.]

The figure shows how revenue and variable cost both increase (but at a declining rate) as quality is raised. However, due to rising fixed costs, which are a linear function of Q_R, profit starts to decline once Q_U (= 1.5625) is passed.[18] The sum of consumer surplus and profit - which equals social welfare if the firm is domestic - is maximised at a quality of around 5.6, while the firm finally exits the market at a quality standard of about 8.

[18] The graph assumes the regulator sets the quality standard. In practice, if the regulator only sets a minimum quality standard, then the firm will not implement any standard less than Q_U.

Regulation: the general case

To derive the behaviour of the regulator in a more general case, first assume the monopolist is domestic. In this case, the regulator seeks to maximise national welfare

$$\begin{aligned} W_R &= U_R + \pi_R, \\ &= (k_2 + 1 - k_3) k_1 Q_R^{\upsilon} - bQ_R. \end{aligned} \tag{4.13}$$

Differentiating this with respect to Q_R, setting the differential equal to zero and rearranging, we can find the welfare-maximising standard:

$$dW_R/dQ_R = 0 ==> Q_R^{*1-\upsilon} = (k_2 + 1 - k_3)\upsilon k_1/b. \tag{4.13a}$$

By contrast, where the monopolist is foreign, the regulator will not care about the firm's profits, and will seek simply to maximise consumer surplus. Since this is increasing monotonically with respect to the quality standard (in this case denote Q_{RF}), the only constraint is that eventually, as standards are raised, the firm's profits will reach zero and it will leave the market. We can deduce:

PROPOSITION 4.1: *If the monopolist is foreign, a regulator maximising domestic welfare will set the highest quality standard at which the firm does not exit the market.*

Normally we would assume this to be the firm's reservation level of Q_{RF} corresponding to $\pi_{RF} = 0$. In this case, the optimal standard when the monopolist is foreign is

$$\begin{aligned} (1-k_3)k_1 Q_{RF}^{\upsilon} &= bQ_{RF}; \\ Q_{RF}^{*1-\upsilon} &= (1-k_3)k_1/b. \end{aligned} \tag{4.14}$$

We next need to compare these various quality standards. Since $0 < \upsilon < 1$, we can rank the various standards quite simply. First of all, Q_{RF}^{*} is clearly greater than Q_U, since, comparing (4.14) with (4.12a), we see that

$$\begin{aligned} Q_{RF}^{*1-\upsilon}/Q_U^{1-\upsilon} &= 1/\upsilon \\ &= (1-\beta\eta)/((1-\beta)\eta) > 1. \end{aligned}$$

Next, comparing (4.13a) with (4.12a), we can show that $Q_R^{*} > Q_U$, since

$$Q_R^{*1-\upsilon}/Q_U^{1-\upsilon} = (k_2 + 1 - k_3)/(1-k_3) > 1.$$

Finally, we need to compare (4.14) with (4.13a).

$$Q_{RF}^{*1-\upsilon} - Q_R^{*1-\upsilon} = (1-k_3)k_1/b - (k_2 + 1 - k_3)\upsilon k_1/b.$$

Since k_1 and b are both positive, we can say this will exceed zero if

$$\begin{aligned} (1-k_3) &> (k_2 + 1 - k_3)\upsilon; \\ (1-\upsilon)(1-k_3) &> \upsilon k_2. \end{aligned} \tag{4.15}$$

This condition can be shown to hold at all times under the functional form and parameter restriction assumptions which we are making.

....

Proof.

Note that (4.15) is equivalent to writing

$$\begin{aligned}((1-\eta)/(1-\beta\eta))(1-\beta\eta) &> ((1-\beta)\eta)/(1-\beta\eta))(1-\eta)/\eta; \\ (1-\eta) &> ((1-\beta)/(1-\beta\eta))(1-\eta); \\ (1-\beta\eta) &> (1-\beta); \\ \eta &< 1.\end{aligned}$$

But we have already assumed $0 < \eta < 1$.

....

The above comparisons can be summed up:

PROPOSITION 4.2: *Given our Cobb-Douglas/linear functional form assumptions, the optimum regulatory standard for a foreign monopolist is higher than that for a domestic monopolist, and both are higher than the firm itself would choose.*

4.3.2 'Mutual recognition' with a monopolist[19]

If there are two countries, but a single, monopolistic producer, which can costlessly supply different national markets at different quality standards, it follows that, in the absence of a mutual recognition (or harmonisation) agreement, the importing country's regulator would always set a higher standard for a foreign firm than the firm would freely choose. By contrast, under mutual recognition, the producing country's regulator sets a common minimum standard for both countries. In doing so, it will take account of its own consumers' surplus, but not that of foreign consumers, while it will take account of the profits its own firm would set in both markets. Consequently, we would expect it to reduce the quality standard in its own country, compared with the situation under noncooperation, which leads to an even larger reduction in the (formerly excessive) standards imposed in the importing country.

Since we have already shown that reduced standards cause a fall in demand, the result of this would be a fall in volumes of trade (at least when measured in quality-adjusted units).

PROPOSITION 4.3: *The introduction of mutual recognition in the presence of a monopoly, where the firm can costlessly set separate standards for different markets, will result in a reduction in quality and quality-adjusted trade volumes compared to the noncooperative regulation case.*

[19] **'Mutual recognition' is, of course, a slightly incongruous term when only one country is producing the good. Nevertheless, looking at this case does have potential implications in the more general case where trade is largely in one direction, so it is worth considering for that reason.**

In the case where the two countries are identical in size and consumer preferences, we can quite easily model the quality standard chosen by the exporting country's regulator under mutual recognition. The exporter's regulator will seek to maximise

$$W_X = U_X - 2\pi_X = (k_2 + 2 - 2k_3)k_1 Q_X^{\upsilon} - 2bQ_X. \tag{4.16a}$$

The first order condition for maximising W_X with respect to Q_X is

$$dW_X/dQ_X = 0 ==> Q_X^{1-\upsilon} = ((k_2/2) + 1 - k_3)\upsilon k_1/b. \tag{4.16b}$$

Comparing (4.16b) with (4.13a) and (4.12a), we can see that $Q_X^{1-\upsilon}$ lies midway between $Q_U^{1-\upsilon}$ and $Q_R^{*1-\upsilon}$.

To make global welfare comparisons in this case, first we note that global welfare

$$W_G = U_G - 2\pi_G = (2k_2 + 2 - 2k_3)k_1 Q_G^{\upsilon} - 2bQ_G. \tag{4.17}$$

Maximising this would give a standard in both countries equal to Q_R^*. It follows that mutual recognition of a monopolist leads to a quality standard in both countries below the global optimum. By contrast, under noncooperative setting, the quality standard in the exporting country will be set at the global optimum, while that in the importing country will be higher than the global optimum. Since lower quality standards benefit the producer at the expense of consumers, we can summarise the situation as:

PROPOSITION 4.4: *On our model formulation, the introduction of mutual recognition in the presence of a monopoly, where the firm can costlessly set separate standards for different markets, will result in a reduction in consumer utility in both the import-*

ing and the exporting country, but with a gain to the monopolist's profits. Overall, the exporting country gains and the importing country loses.

The overall sign of the net effect on global welfare of a move to mutual recognition is not straightforward to determine.

4.3.3 Extension to alternative cost structures

The above analysis has relied upon a very simple, linear cost structure, as shown in equation (4.1). It is worth noting that the broad results carry through to more general cost structures $C = C(Y, Q)$, so long as, first, we can still write $Y = Y(X, Q)$, which implies that we can also treat C as a function of X and Q, $C = \widetilde{C}(X, Q)$ and, secondly, raising quality lowers the marginal cost of producing quality-adjusted output, i.e.

$$d(d\widetilde{C}(X, Q)/dX)/dQ < 0. \tag{4.18}$$

For example, where X is a Cobb-Douglas aggregate, but raising quality has effects on both fixed and variable costs, i.e.

$$C = Y + bQ + dQY, \tag{4.19}$$

where a, b and d are non-negative, it is relatively straightforward to show that the conditions in equation (4.18) hold so long as

$$(\beta - 1) + d(2\beta - 1)Q < 0. \tag{4.20}$$

Derivation of Equation (4.20):

$$Y = X^{1/\beta} Q^{(\beta-1)/\beta}.$$

Hence

$$\begin{aligned}
C &= X^{1/\beta} Q^{(\beta-1)/\beta} + bQ + dX^{1/\beta} Q^{(2\beta-1)/\beta}; \\
dC/dX &= (1/\beta) X^{(1-\beta)/\beta} Q^{(\beta-1)/\beta} + (d/\beta) X^{(1-\beta)/\beta} Q^{(2\beta-1)/\beta}; \\
d(dC/dX)/dQ &= ((\beta-1)/\beta^2) X^{(1-\beta)/\beta} Q^{-1/\beta} + (d(2\beta-1)/\beta^2) X^{(1-\beta)/\beta} Q^{(\beta-1)/\beta}, \\
&= (1/\beta^2) X^{(1-\beta)/\beta} Q^{-1/\beta} ((\beta-1) + d(2\beta-1)Q.
\end{aligned}$$

When this equals zero, $1 - \beta = d(2\beta - 1)Q$.

....

Clearly, for $0 < \beta < 1$ and $d = 0$ (the case in the previous section) this holds. Also when $\beta < 1/2$ it will hold. For $\beta > 1/2$ and $d > 0$, (4.20) will be satisfied if the unregulated monopolist's output,

$$Q_U < (1/d)((1-\beta)/(2\beta-1)). \tag{4.21}$$

It is possible to show that an unregulated monopolist will always choose less than this level of quality - hence quality regulation, at least at the margin, will cause the monopolist to increase output. It may be noted, however, that while the regulator will only increase Q, this will not exceed the point where (4.20) is satisfied: whether this will affect the interaction with trade depends on parameter values.

....

Proof

A monopolist will minimise costs for a given level of output (unless constrained).

Hence $dC/dQ = 0$.

But

$$\begin{aligned} dC/dQ &= ((\beta-1)/\beta)X^{1/\beta}Q^{-1/\beta} + b + d((2\beta-1)/\beta)X^{1/\beta}Q^{(\beta-1)/\beta}; \\ &= \Rightarrow (1/\beta)X^{1/\beta}Q^{-1/\beta}((\beta-1) + d(2\beta-1)Q) = -b. \end{aligned}$$

But the LH term is $\beta X(d(dC/dX)/dQ)$.

Hence for $\beta > 0$, $X > 0$ and $b > 0$, $d(dC/dX)/dQ < 0$.

....

It follows that raising Q would, at the margin, lower marginal costs, and so lead a monopolist to increase output. However, it is conceivable that there will be functional forms on which $Q_{RF} \leqslant Q_R^*$, in which case noncooperative standard setting will not result in overregulation.

Despite this qualification, for the rest of this paper, I will retain the simpler formulation, for expositional reasons.

4.4 Quality regulation in a cross-hauling, Cournot duopoly

4.4.1 Third country and reciprocal market models

Brander (1995) gives a good survey of the literature on strategic trade policy where products are identical or near-identical. Most papers to date have concentrated on the use of export and R&D subsidies, and have can be divided into those using a third market model (e.g. Brander and Spencer, 1985) or those with reciprocal markets (following Brander, 1981). None of the papers listed specifically covers the issue of quality regulation, which has generally only been tackled using the alternative, Hotelling-based heterogeneous consumers/differentiated products approach (Das and Donnenfeld, 1989, Lutz, 1996(1) and (2)).

In this chapter, I am assuming that consumers are homogeneous, and that products can be compared easily in terms of quality-adjusted output. I also follow the framework of Brander and Spencer in that the regulator within a country is seen as a first-mover, setting a standard to which the firms then respond, and that the firms compete on the basis of Cournot conjectures. Strategic games with standards are generally rather different to those involving export subsidies, in that it is difficult for exporting countries' governments to intervene in foreign markets using regulatory standards, unless a mutual recognition agreement is in force, in which case the third country would be forced to accept standards laid down by exporting countries.[20] Compared to the single monopoly exporter model which I have so far investigated, regulators' motives would would be potentially more complicated , since there are more complicated strategic motives where two exporting country regulators are both backing their domestic exporting firms (since market share, or profit-shift considerations come into play where more than one exporting country is involved).

In this chapter I prefer to follow the reciprocal markets approach to analysing strategic regulatory bias in the case where there is more than one exporter, as this brings

[20] In the absence of mutual recognition (which is, of course, a rather odd concept in the case where a country imports a good which it does not produce), the importing country regulator would simply set the highest standard at which the foreign producers do not exit the market, as established in the previous section.

out more clearly the potential conflicts between the impact of regulatory standards on domestic consumers, on foreign consumers, on supply costs and on market share/profit shift considerations. Nevertheless, it is worth bearing in mind that a global mutual recognition agreement for many products may involve elements of both reciprocal selling by exporting countries into each other's market and of third party strategic competition, and this would be a potential field for future research.

4.4.2 The model

I now assume that, instead of a monopolist, the industry contains two identical firms: $f = 1$ and 2, set in countries $c = 1$ and 2 respectively. All consumers in both countries have identical tastes, and the two firms produce goods which are perfect substitutes, with identical production functions.

As before, consumers' utility in country 1 depends on total consumption, which I now denote Z_1, where $Z_1 = X_{1,1} + X_{2,1}$, the aggregate of the quality-adjusted sales $X_{f,c}$ of the two firms to country 1.

Consumer surplus in country 1 is given by

$$U_1 = \gamma Z_1^{\eta} - P_1 Z_{1,} \tag{4.22}$$

where P_1 is the price of the quality-adjusted output in country 1, which is the same for both suppliers given their outputs are perfect substitutes. As before, we can equate marginal utility with price and insert this in (4.22) to derive

$$U_1 = \gamma(1-\eta) Z_1^{\eta}. \tag{4.22a}$$

As before, $X_{1,1}$ and $X_{2,1}$ are Cobb-Douglas aggregates of quality, $Q_{f,c}$ and crude quantity, $Y_{f,c}$. Cost, $C_{f,c}$, is a linear function of $Y_{f,c}$ and $Q_{f,c}$.[21]

We are crucially assuming that firm f chooses its quality to supply to each market separately, and that quality chosen to supply to country 1 has no effect on the costs of quality in country 2.

Since the cost side of the model is unchanged from that of the monopoly above, we can proceed by analogy. When a firm is unregulated the marginal cost of increasing quality-adjusted output $X_{f,c}$ is constant, as given by (4.5) above. Likewise, when country 1 sets a higher quality standard than the unregulated duopoly would choose, marginal costs fall as $(Q_{f,1R}/X_{f,1})$ rises, as indicated by equation (4.7).

The demand side is somewhat more complicated. Assuming consumers maximise utility, consumption is to the point where marginal utility of $X_{f,c}$ equals quality-adjusted price.

Since we are initially looking at the market in just country 1, which is assumed to be totally segregated from any other country, we can ignore subscripts for the country, and simply denote the two firms 1 and 2. Firm 1 is assumed to be domestic, while firm 2 is foreign. For maximum profit, each firm $f = \{1, 2\}$ will choose its level of output for market 1 to equate marginal cost and perceived marginal revenue. The latter is dependent upon firm f's conjecture about the behaviour of its rival g. I follow the

[21] Strictly speaking, if the values of scale parameters a and b in equation (4.1) were invariant with the number of firms, the smaller firms in a duopoly case would be producing a lower quality than the monopolist in the first case. However, a slightly modified formulation (eg where costs are a function of output and quality per plant, and the number of plants) would return the model to the classical features where a monopoly results in lower quality and quantity. Since in this paper I am only interested in cases where the number of firms is fixed, I have retained the linear formulation in (4.1) for simplicity, but it is worth bearing in mind that a and b are not invariant with the number of firms.

Cournot-Nash assumption that f chooses its quality-adjusted output, X_f, as a response to $g's$ chosen level of quality-adjusted output X_g.[22] Concentrating on firm 1, total revenue will be related to the firm's conjecture of its rival's output:

$$dU/dZ = 0 ==> P_X = \gamma\eta Z^{\eta-1},$$

$$R_1^c = \gamma\eta Z^{\eta-1} X_{1,} \tag{4.23}$$

$$R_1^c = \gamma\eta X_1 (X_1 + X_2^c)^{\eta-1}, \tag{4.23a}$$

where X_2^c is firm 1's Cournot conjecture about firm 2's output.

If we denote the firms' respective marginal costs of increasing quality-adjusted sales MC_1 and MC_2, then assuming a profit-maximising firm sets perceived marginal revenue equal to its perceived marginal cost, based upon its conjecture of the other firm's behaviour we can derive:

$$\partial R_1^c / \partial X_1 = \gamma\eta (X_1 + X_2^c)^{\eta-1} + \gamma\eta(\eta - 1) X_1 (X_1 + X_2^c)^{\eta-2} = MC_1.$$

$$(X_1 + X_2^c)^{\eta-1} + (\eta - 1) X_1 (X_1 + X_2^c)^{\eta-2} = MC_1/\gamma\eta. \tag{4.24a}$$

Likewise for firm 2

$$(X_1^c + X_2)^{\eta-1} + (\eta - 1) X_2 (X_1^c + X_2)^{\eta-2} = MC_2/\gamma\eta. \tag{4.24b}$$

[22] The alternative Bertrand-Nash duopoly will, if goods are identical, produce the uninteresting result that prices are bid down to marginal cost.

Equations (4.24a-b) define the best response functions of the two firms. These are nonlinear, though they can be solved for the Cournot-Nash equilibrium. Examples of these functions are shown graphically in *Appendix 4.2*.

The equilibrium conditions are given by

$$Z = X_1 + X_2 = [(MC_1 + MC_2)/(\gamma\eta(1+\eta))]^{1/\eta-1}, \tag{4.25}$$

and

$$\theta = (MC_1 - \eta MC_2)/(MC_2 - \eta MC_1), \tag{4.26}$$

where θ is defined as the ratio X_2/X_1, which implies that $X_1 = Z/(1+\theta)$ and $X_2 = \theta Z/(1+\theta)$.

....

Derivation of Equation (4.25)

Adding the two equations, and setting $X_1^c = X_1$ and $X_2^c = X_2$,

$$\begin{aligned}(MC_1 + MC_2)/\gamma\eta &= 2(X_1+X_2)^{\eta-1} + (\eta-1)(X_1+X_2)(X_1+X_2)^{\eta-2},\\ &= (X_1+X_2)^{\eta-1}(1+\eta).\end{aligned}$$

$$Z = [(MC_1 + MC_2)/(\gamma\eta(1+\eta))]^{1/\eta-1}. \tag{4.25}$$

Derivation of Equation (4.26)

If we denote $X_2/X_1 = \theta$, then $X_1 = Z/(1+\theta)$ and $X_2 = \theta Z/(1+\theta)$. Hence from

(4.24a),

$$\begin{aligned} Z^{\eta-1}(1+(\eta-1)/(1+\theta)) &= MC_1/\gamma\eta; \\ \gamma\eta Z^{\eta-1} &= MC_1/(1+(\eta-1)/(1+\theta)), \end{aligned}$$

and from (4.24b),

$$\begin{aligned} Z^{\eta-1}(1+(\eta-1)\theta/(1+\theta)) &= MC_2/\gamma\eta; \\ \gamma\eta Z^{\eta-1} &= MC_2/(1+(\eta-1)\theta/(1+\theta)). \end{aligned}$$

Assuming MC_1, MC_2, γ and η are non-zero, we can cross-multiply from the two equations

$$MC_2(1+(\eta-1)/(1+\theta)) = MC_1(1+(\eta-1)\theta/(1+\theta)),$$

$$\begin{aligned} (MC_2 - MC_1) &= ((\eta-1)/(1+\theta))(\theta MC_1 - MC_2), \\ (1+\theta)(MC_2 - MC_1) &= (\eta-1)(\theta MC_1 - MC_2), \\ MC_2 - MC_1 + \theta(MC_2 - MC_1) &= \theta\eta MC_1 - \theta MC_1 + (1-\eta)MC_2, \\ \eta MC_2 - MC_1 &= \theta(\eta MC_1 - MC_2), \end{aligned}$$

$$\begin{aligned}\theta &= (\eta MC_2 - MC_1)/(\eta MC_1 - MC_2), \\ &= (MC_1 - \eta MC_2)/(MC_2 - \eta MC_1). \qquad (4.26)\end{aligned}$$

....

Equation (4.26) yields non-negative values for X_1 and X_2 as long as the numerator and denominator carry the same sign. Since we are assuming $0 < \eta < 1$, the relevant cases are where numerator and denominator are both negative, which will be the case if

$$1/\eta > MC_2/MC_1 > \eta. \qquad (4.26a)$$

This implies that either MC_2 and MC_1 are close in value or that η is small.

Also note that if $M = MC_2/MC_1$, then (4.26) can be written

$$\begin{aligned}\theta &= (1 - \eta M)(M - \eta)^{-1}; \\ d\theta/dM &= -\eta(M - \eta)^{-1} - (1 - \eta M)(M - \eta)^{-2}.\end{aligned}$$

When $M = 1$,

$$d\theta/dM = -(1 + \eta)/(1 - \eta), \qquad (4.27)$$

which is negative for $0 < \eta < 1$, confirming that raising MC_2 will reduce firm 2's market share, at least at the margin.

4.4.3 Regulation of a cross-hauling duopoly

Starting with the simplest case, I consider a model where the two firms are both selling into country 1's market. The regulator in 1 sets the minimum standard. Firm 1 is domestic while 2 is foreign. I assume that both firms have identical cost functions, which do not depend upon product standards in the foreign market. In this case, marginal cost will be denoted by MC. Where there is no regulation, firms will choose a constant ratio of X_f/Q_f and marginal cost will be a constant $\overline{MC}_U$, as in the analysis of a single monopolist.

First of all, the quality standard chosen by an unregulated duopoly will be

$$Q_U = \Psi^{1/1-\eta} 2^{(2-\eta)/(\eta-1)}((1/b)(1-\beta)/\beta)^{1/1-\upsilon}, \tag{4.28}$$

where $\Psi = \beta\gamma\eta(1+\eta)$, which is positive.

....

Derivation of Equation (4.28)

The relationship between Q_U and X_U for each firm as expressed in (4.4) and (4.5) will continue to stand:

$$Q_U = ((1/b)(1-\beta)/\beta)^{\beta} X_U. \tag{4.4}$$

Total cost for firm 1 is

$$\begin{aligned} C_{1U} &= X_U^{1/\beta} Q_U^{(\beta-1)/\beta} + bQ_U; \qquad (4.5) \\ MC_{1U} &= (1/\beta)((1/b)(1-\beta)/\beta)^{\beta-1} = \overline{MC}_U. \end{aligned}$$

This implies

$$
\begin{aligned}
Z_U &= [\gamma\eta(1+\eta)/2\overline{MC}_U]^{1/1-\eta} \\
&= (\beta\gamma\eta(1+\eta)/2)^{1/1-\eta}((1/b)(1-\beta)/\beta)^{(1-\beta)/(1-\eta)}; \\
X_U &= (\beta\gamma\eta(1+\eta)/2)^{1/1-\eta}((1/b)(1-\beta)/\beta)^{(1-\beta)/(1-\eta)}/2, \text{ where the firms are identical;} \\
Q_U &= ((1/b)(1-\beta)/\beta)^{\beta}(\beta\gamma\eta(1+\eta)/2)^{1/1-\eta}((1/b)(1-\beta)/\beta)^{(1-\beta)/(1-\eta)}/2, \\
&= (\beta\gamma\eta(1+\eta)/2)^{1/1-\eta}((1/b)(1-\beta)/\beta)^{(1-\beta\eta)/(1-\eta)}/2, \\
&= \Psi^{1/1-\eta}2^{(2-\eta)/(\eta-1)}((1/b)(1-\beta)/\beta)^{1/1-\upsilon}, \qquad (4.28)
\end{aligned}
$$

where $\Psi = \beta\gamma\eta(1+\eta)$, which is positive.

....

4.4.4 The regulatory game

I assume that the regulator aims to maximise the sum of the the domestic firm's profits and domestic consumer surplus. Hence, as before, it seeks to maximise

$$W_{RC} = \pi_{1RC} + U_{RC}, \qquad (4.13b)$$

where I am using the subscripts RC to represent a regulated Cournot game. The regulator is assumed to be indifferent to the profits made by the foreign firm, or to foreigners' consumer surplus.

The setup of the game between the regulator and the two firms is also significant. In this paper, I shall assume that the regulator can accurately predict the outcome of the Cournot subgame between the two firms, and can potentially act as a first mover, committing the firms in advance to a particular quality of output.

Firm 1's total revenue is given by

$$R_{1RC} = \gamma\eta Z_{RC}^{\eta-1} X_{1RC}. \tag{4.23}$$

If we are looking at the regulator's choice of standards, then it is the regulator's conjectures of Z and X_1 which matter. I will assume that the regulator can accurately predict the outcome of the subgame between the two firms.

Firm 1's costs are derived in similar fashion to the case of a domestic monopolist. Consequently, total cost will be

$$C_{1RC} = X_{1RC}^{1/\beta} Q_{RC}^{(\beta-1)/\beta} + bQ_{RC}. \tag{4.29}$$

Crucially, if firm 1 takes the quality standard Q_{RC} as something set exogenously by the regulator, then its marginal cost will be given by

$$MC_{1RC} = (1/\beta)(X_{1RC}/Q_{RC})^{(1-\beta)/\beta}, \tag{4.30}$$

as in (4.7). Firm 2's marginal cost will be similarly determined, as the two firms are identical.

Combined sales by the two firms in this symmetrical game will be given by

$$Z_{RC} = \Psi^{\beta/(1-\beta\eta)} 2^{(1-2\beta)/(1-\beta\eta)} Q_{RC}{}^{\upsilon/\eta}. \tag{4.31}$$

....

Derivation of Equation (4.31)

The regulator can accurately predict the outcome of the Cournot subgame between the two firms, and so will assume (from 4.23)

$$\begin{aligned} Z_{RC} &= [\gamma\eta(1+\eta)/2MC_{RC}]^{1/1-\eta}, \\ MC_{RC} &= [\gamma\eta(1+\eta)/2]Z_{RC}^{\eta-1}. \end{aligned}$$

But we also know from (4.30)

$$MC_{RC} = (1/\beta)(X_{1RC}/Q_{RC})^{(1-\beta)/\beta} = (1/\beta)2^{(\beta-1)/\beta}(Z_{1RC}/Q_{RC})^{(1-\beta)/\beta}.$$

Consequently

$$\begin{aligned} [\gamma\eta(1+\eta)/2]Z_{RC}^{\eta-1} &= (1/\beta)2^{(\beta-1)/\beta}(Z_{1RC}/Q_{RC})^{(1-\beta)/\beta}, \\ Z_{RC}^{(\beta\eta-1)/\beta} &= [2/\beta\gamma\eta(1+\eta)]2^{(\beta-1)/\beta}{Q_{RC}}^{(\beta-1)/\beta}, \\ Z_{RC} &= [\beta\gamma\eta(1+\eta)/2]^{\beta/(1-\beta\eta)}2^{(\beta-1)/(\beta\eta-1)}{Q_{RC}}^{(\beta-1)/(\beta\eta-1)}, \\ &= \Psi^{\beta/(1-\beta\eta)}2^{(1-2\beta)/(1-\beta\eta)}{Q_{RC}}^{(1-\beta)/(1-\beta\eta)}, \\ &= \Psi^{\beta/(1-\beta\eta)}2^{(1-2\beta)/(1-\beta\eta)}{Q_{RC}}^{\upsilon/\eta}. \end{aligned} \tag{4.31}$$

....

Differentiating (4.28) with respect to Q_{RC}, we find that

$$dZ_{RC}/dQ_{RC} = (\upsilon/\eta)\Psi^{\beta/(1-\beta\eta)}2^{(1-2\beta)/(1-\beta\eta)}{Q_{RC}}^{(\upsilon-\eta)/\eta},$$

which is positive, given that $0 < \beta < 1$ and $0 < \eta < 1$. Consequently, we can derive

LEMMA 4.4: *If a Cournot duopoly of identical firms is regulated to produce to a higher standard than they would otherwise choose, the marginal cost of increasing quality-adjusted output is less than when the choice of quality is unconstrained.*

It is worth noting that, when the regulator sets $Q_{RC} = Q_U$, then $Z_{RC} = Z_U$ (as one would expect from the envelope theorem).

....

Proof:

$$\begin{aligned}
Z_{RC} &= \Psi^{\beta/(1-\beta\eta)} 2^{(1-2\beta)/(1-\beta\eta)} Q_U{}^{(1-\beta)/(1-\beta\eta)} \quad \text{from (4.31)}, \\
&= \Psi^{\beta/(1-\beta\eta)} 2^{(1-2\beta)/(1-\beta\eta)} \Psi^{(1-\beta)/(1-\eta)(1-\beta\eta)} 2^{(2-\eta)(1-\beta)/(\eta-1)(1-\beta\eta)} \\
&\quad ((1/b)(1-\beta)/\beta)^{(1-\beta)/(1-\eta)}, \text{from (4.28)} \\
&= \Psi^{1/(1-\eta)} 2^{1/(\eta-1)} (1/b)(1-\beta)/\beta)^{(1-\beta)/(1-\eta)} = Z_U.
\end{aligned}$$

....

Consequently, we can write

$$Z_{RC} = Z_U (Q_{RC}/Q_U)^{\upsilon/\eta}. \tag{4.31a}$$

Since $1 > \beta > 0$ and $1 > \beta\eta > 0$, we can deduce the proposition from (4.31a)

PROPOSITION 4.5: *A regulated duopoly as in lemma 4.4 will sell more quality-adjusted output at a lower quality-adjusted price than an unregulated duopoly, and this* *output rises monotonically with the quality standard as long as the firms continue to supply the market.*

Also note that, when $Q_{RC} = Q_U$,

$$MC_{RC} = [\gamma\eta(1+\eta)/2]Z_U^{\eta-1} = \overline{MC}_U. \tag{4.32}$$

Note the similarity between (4.31a) and (4.8). The elasticity of output with respect to the regulatory standard is the same for a Cournot duopoly as for a monopolist, so that for any given regulatory standard, Cournot output differs from monopoly output by a fixed proportion.

The analysis in the case of noncooperative standard setting follows the approach we used in the monopoly case. In other words, I start by deriving the relationship between firm 1's sales revenue, R_{1RC}, and the regulatory quality standard, Q_{RC}. This is of the form

$$R_{1RC} = K_1 Q_{RC}^{v}, \tag{4.33}$$

where

$$K_1 = (\gamma\eta/2)\Psi^{\beta\eta/(1-\beta\eta)}2^{(1-2\beta)\eta/(1-\beta\eta)}. \tag{4.34}$$

Next, I establish that, for the Cobb-Douglas/linear cost structure, variable costs and consumer utility are directly proportional to firm 1's sales revenue, R_{1RC}. In other words, we can write

$$U_{1RC} = K_2 R_{1RC}; \text{ and} \tag{4.35a}$$

$$VC_{1RC} = K_3 R_{1RC}; \tag{4.35b}$$

where

$$K_2 = (2(1-\eta)/\eta), \quad \text{and} \tag{4.36a}$$

$$K_3 = (\beta(1+\eta)/2). \tag{4.36b}$$

Note that K_3 is less than 1, so variable costs will always be less than the firm's revenue. K_2 is positive.

Next, I show that firm 1's total profits are given by

$$\begin{aligned} \pi_{1RC} &= R_{1RC} - C_{1RC} = R_{1RC} - VC_{1RC} - bQ_{RC,} \\ &= (1-K_3)K_1 Q_{RC}^{\upsilon} - bQ_{RC,} \end{aligned} \tag{4.37}$$

where VC_{1RC} represents variable costs, as before.

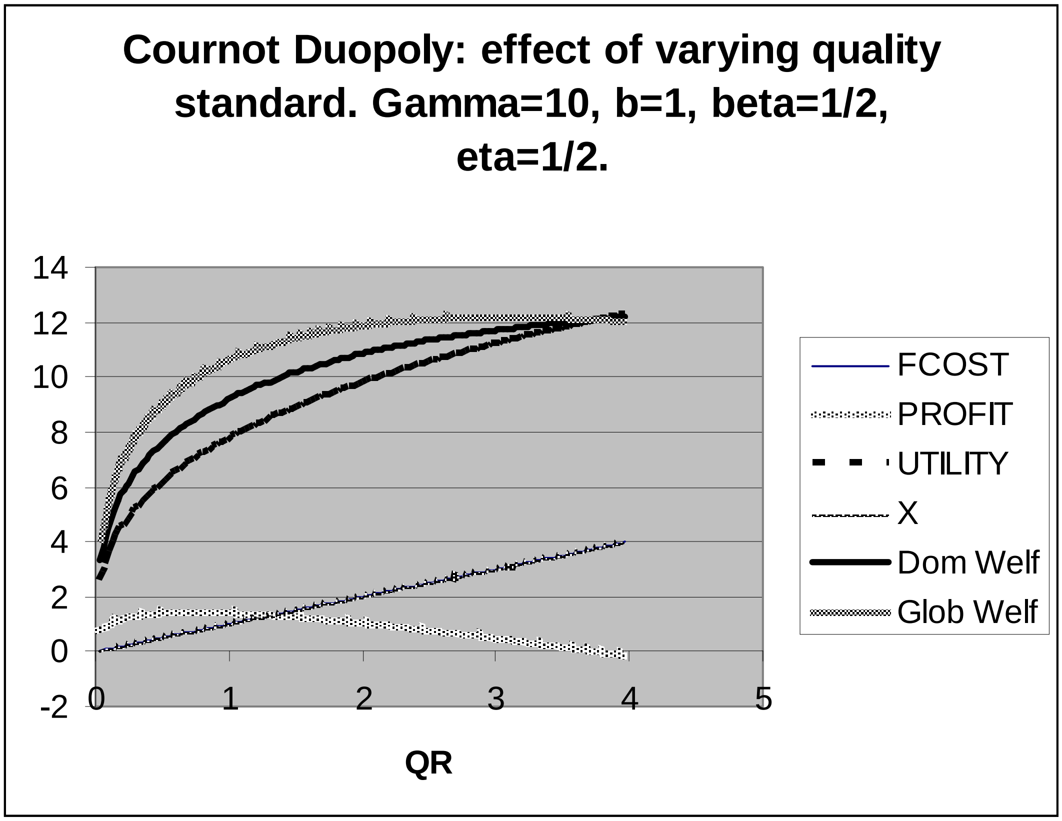
From (4.33), (4.35a) and (4.36a) we can derive

LEMMA 4.5: *Consumer surplus with a quality regulated Cournot duopoly rises monotonically with the minimum quality standard.*

This follows since sales rise monotonically with the minimum quality standard, and utility rises monotonically with sales.

Since $0 < \upsilon < 1$, it follows that both consumer surplus and the gap between revenue and variable cost increase as the quality standard is increased, but at a declining rate. By contrast, fixed cost increases linearly with the quality standard. To illustrate what this means, consider the case where $\gamma = 10$, $b = 1$, $\eta = 1/2$ and $\beta = 1/2$. In this particular case, $\Psi = \beta\gamma\eta(1+\eta) = 3.75$; $K_1 = 3.884$; $K_2 = 2$; $K3 = 3/8$. The relationship between key variables in this case is shown in *Figure 4.4*, below.

Figure 4.4:



The quality at which profit equals zero, $Q_{\#}$, is found by setting

$$\begin{aligned}(1-K_3)K_1Q_{\#}^{\upsilon} &= bQ_{\#};\ \text{from } 4.37 \\ Q_{\#}^{1-\upsilon} &= (1-K_3)K_1/b. \qquad (4.38)\end{aligned}$$

In our illustrative case,

$$Q_{\#} = [(5/8) \times 3.884]^{3/2} = 3.782.$$

....

Derivation of Equations (4.33) and (4.34)

$$
\begin{aligned}
R_{1RC} &= \gamma\eta Z_{1RC}^{\eta-1} X_{1RC} = \gamma\eta Z_{1RC}^{\eta}/2, \text{assuming identical firms,} \\
&= (\gamma\eta/2)\Psi^{\beta\eta/(1-\beta\eta)} 2^{(1-2\beta)\eta/(1-\beta\eta)} {Q_{RC}}^{(1-\beta)\eta/(1-\beta\eta)}, \\
&= (\gamma\eta/2)\Psi^{\beta\eta/(1-\beta\eta)} 2^{(1-2\beta)\eta/(1-\beta\eta)} {Q_{RC}}^{\upsilon}. \qquad (4.33) \\
R_{1RC} &= (\gamma\eta/2) Z_U^{\eta} (Q_{RC}/Q_U)^{(1-\beta)\eta/(1-\beta\eta)},
\end{aligned}
$$

Derivation of Equations (4.35a) and (4.36a)

$$
\begin{aligned}
U_{RC} &= \gamma Z_{RC}^{\eta} - Z_{RC} P_{XRC} = \gamma Z_{RC}^{\eta} - \gamma\eta Z_{RC}^{\eta}, \\
&= \gamma(1-\eta) Z_{RC}^{\eta}. \\
\text{But } \gamma\eta Z_{1RC}^{\eta}/2 &= R_{1RC}, \text{ so} \\
U_{RC} &= (\gamma(1-\eta) R_{1RC}/(\gamma\eta/2)), \\
&= (2(1-\eta)/\eta) R_{1RC}. \qquad (4.35a)
\end{aligned}
$$

Derivation of Equations (4.35b) and (4.36b)

$$
\begin{aligned}
VC_{1RC} &= X_{1RC}^{1/\beta} Q_{RC}^{(\beta-1)/\beta}, \\
&= 2^{-1/\beta} Z_{RC}^{1/\beta} Q_{RC}^{(\beta-1)/\beta}, \\
&= 2^{-1/\beta} \Psi^{1/(1-\beta\eta)} 2^{(1-2\beta)/\beta(1-\beta\eta)} Q_{RC}^{(1-\beta)\eta/(1-\beta\eta)}; \text{ (from 4.28)} \\
VC_{1RC}/R_{1RC} &= [2^{-1/\beta} \Psi^{1/(1-\beta\eta)} 2^{(1-2\beta)/\beta(1-\beta\eta)}]/[(\gamma\eta/2)\Psi^{\beta\eta/(1-\beta\eta)} 2^{(1-2\beta)\eta/(1-\beta\eta)}]; \\
VC_{1RC} &= (2^{-1/\beta}/(\gamma\eta/2))(\beta\gamma\eta(1+\eta))2^{(1-2\beta)/\beta} R_{1RC}, \\
&= (2)(\beta(1+\eta))2^{-2} R_{1RC}, \\
&= (\beta(1+\eta)/2) R_{1RC}. \qquad (4.35b)
\end{aligned}
$$

....

4.4.5 Regulatory standards and market exit

In this section, consider the effects of the assumption of a non-negative profit constraint. As in the pure monopoly case, regulatory policy can potentially raise consumer welfare by making firms supply more quality-adjusted output than they would freely choose to do. However, it is worth bearing in mind that this is usually subject to the constraint that the regulator will not force standards so high that the firms will exit the market. Before examining the effects of this constraint, however, I first analyse the standards regulators would set if firms' exit were not a problem.

No nonnegative profit constraint In a noncooperative game, W_{RC}, the regulator's objective, will be given by

$$\begin{aligned} W_{RC} &= U_{RC} + \pi_{1RC}, \\ &= [K_2 + 1 - K_3]R_{1RC} - bQ_{RC}, \\ &= [K_2 + 1 - K_3]K_1 Q_{RC}^{\upsilon} - bQ_{RC} \end{aligned} \quad (4.39)$$

We can derive the quality standard which a regulator will choose in the absence of harmonisation or mutual recognition by differentiating with respect to Q_{RC} and setting $dW_{RC}/dQ_{RC} = 0$. This will be satisfied by the condition

$$\begin{aligned} [K_2 + 1 - K_3]K_1 \upsilon Q_{RC}^{*\upsilon-1} &= b; \\ Q_{RC}^{*1-\upsilon} &= [K_2 + 1 - K_3]\upsilon K_1/b. \end{aligned} \quad (4.40)$$

Now compare this with the situation where there is a harmonised standard set by a single, global regulator. Global welfare includes utility from two (identical) countries and profit from two identical firms, each selling in both markets. Consequently

$$\begin{aligned} W_G &= 2U_{1G} + 4\pi_{1,1G}, \\ &= [2K_2 + 4 - 4K_3]K_1 Q_G^{\upsilon} - 4bQ_G. \end{aligned} \quad (4.41)$$

Again, differentiating (4.41) to obtain the global welfare-maximising quality standard, we find

$$\begin{aligned} W_G/dQ_G &= 0 ==> [2K_2 + 4 - 4K_3]K_1 \upsilon Q_G^{*\upsilon-1} = 4b; \\ Q_G^{*1-\upsilon} &= [(K_2/2) + 1 - K_3]\upsilon K_1/b. \end{aligned} \quad (4.42)$$

Note that (in this case before we take account of the nonnegative profit constraint) $Q_{RC}^{*1-\upsilon} > Q_G^{*1-\upsilon}$, the global optimum standard. This is fairly easily shown by comparing (4.40) with (4.42):

$$\begin{aligned}(Q_{RC}^{*1-\upsilon} - Q_G^{*1-\upsilon})/Q_G^{*1-\upsilon} &= [(K_2 + 1 - K_3) - ((K_2/2) + 1 - K_3)]/[(K_2/2) + 1 - K_3], \\ &= (K_2/2)/[(K_2/2) + 1 - K_3],\end{aligned}$$

which is positive given $K_2 > 0$ and $1 - K_3 > 0$.Since $0 < \upsilon < 1$, this also implies that $Q_{RC}^* > Q_G^*$, so noncooperative regulators will always set higher than the global optimum standard (unless the nonnegative profit constraint intervenes).

Lemma 4.6: *If firms will stay open regardless of whether they make a profit, then the quality standard set by noncooperative regulators will exceed that set under global harmonisation.*

With the nonnegative constraint In our illustrative case where $\gamma = 10$, $b = 1$, $\eta = 1/2$ and $\beta = 1/2$, a noncooperative regulator would wish to set $Q_{RC}^* = \{[K_2 + 1 - K_3]\upsilon K_1/b\}^{1/1-\upsilon} = 6.26$, while a single global regulator would prefer $Q_G^* = \{[(K_2/2) + 1 - K_3]\upsilon K_1/b\}^{1/1-\upsilon} = 3.06$. Since the global optimum standard in this case is 3.782, it turns out that, if subsidies are ruled out, the actions of a noncooperative regulator in raising standards above the global optimum would be limited by the standard at which the firms would exit.

More generally, $Q_{\#}$ will exceed Q^*_G if and only if

$$\begin{aligned} (1-K_3)K_1/b &> [(K_2/2)+1-K_3]\upsilon K_1/b; \\ \upsilon K_2 &< 2(1-K_3)(1-\upsilon). \end{aligned} \tag{4.43}$$

The condition in (4.43) always holds for ranges of β and η between 0 and 1.

....

Proof

(4.43) will only be satisfied if

$$\begin{aligned} ((1-\beta)\eta/(1-\beta\eta))(2(1-\eta)/\eta) &< 2(1-(\beta(1+\eta)/2))(1-((1-\beta)\eta/(1-\beta\eta))); \\ \text{Right hand side} &= (2-\beta(1+\eta))((1-\eta)/(1-\beta\eta)); \end{aligned}$$

$$\text{Left hand side } = 2(1-\eta)(1-\beta)/(1-\beta\eta).$$

Hence, since $(1-\eta)$ is positive, we can divide both sides of the equation by $(1-\eta)$ to write

$$2(1-\beta)/(1-\beta\eta) < (2-\beta(1+\eta))/(1-\beta\eta);$$

and since $(1-\beta\eta)$ is positive, we can write

$$\begin{aligned} 2(1-\beta) &< 2-\beta(1+\eta); \\ \beta(1+\eta) &> 2\beta; \\ \eta &> 1, \end{aligned}$$

which violates our assumption that $0 < \eta < 1$.

....

Comparing the conditions in (4.38) and (4.40), we can say that Q^*_{RC} will exceed $Q_\#$ if and only if

$$(1 - K_3)K_1/b < [K_2 + 1 - K_3]\upsilon K_1/b.$$

This is equivalent to the condition that

$$\beta < 2/(3 - \eta), \tag{4.44}$$

which means that $Q_\#$ will exceed Q^*_{RC} only where β is sufficiently high relative to η.

....

Derivation of (4.44)

$$\begin{aligned}
(1 - (\beta(1 + \eta)/2))((1 - \eta)/(1 - \beta\eta)) &< (2(1 - \eta)/\eta)(1 - \beta)\eta/(1 - \beta\eta);\\
1 - \beta(1 + \eta)/2 &< 2(1 - \beta);\\
2 - \beta(1 + \eta) &< 4(1 - \beta);\\
2 - \beta - \beta\eta &< 4 - 4\beta;\\
3\beta - \beta\eta &< 2;\\
\beta &< 2/(3 - \eta).
\end{aligned}$$

....

A numerical simulation (calculated assuming $\gamma = 10$ and $b = 1$, neither of which should affect the comparison), indicates the nonnegative profit constraint binds on quality standards under noncooperation for the following combinations of β and η :

	Eta	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
Beta	0.1	Y	Y	Y	Y	Y	Y	Y	Y	Y
	0.2	Y	Y	Y	Y	Y	Y	Y	Y	Y
	0.3	Y	Y	Y	Y	Y	Y	Y	Y	Y
	0.4	Y	Y	Y	Y	Y	Y	Y	Y	Y
	0.5	Y	Y	Y	Y	Y	Y	Y	Y	Y
	0.6	Y	Y	Y	Y	Y	Y	Y	Y	Y
	0.7		Y	Y	Y	Y	Y	Y	Y	Y
	0.8					Y	Y	Y	Y	Y
	0.9								Y	Y

Table 4.2: Ranges over which the nonnegative profit constraint potentially constrains quality standards under noncooperation.

PROPOSITION 4.6: *Given the functional form assumptions in this section, and assuming no subsidies are made to firms, then unless β is sufficiently high relative to η, the quality standard set in a noncooperative game will either be constrained to the highest standard at which firms do not make a loss, or the firms will have to be subsidised.*

Denoting the constrained regulatory outcomes with a hat, we can say that $\widehat{Q}_{RC} = \widehat{Q}_G = Q^{\#}$.

The analysis in this section potentially casts a new light on the best-known cross-hauling duopoly, the Boeing-Airbus case. Both firms are recipients of overt and covert subsidies, which are commonly interpreted as being a war for market-share (and hence profit-shifting, following the analysis of Brander and Krugman, 1983). However, it is worth noting that aviation is an industry where safety and environmental concerns are crucially important, and where regulation is therefore likely to be an important item in driving costs. While subsidies may well be excessive from a social viewpoint, they may well be linked, to a large degree, with excessively high regulatory quality standards, which occur not for profit shifting but to benefit consumers in a cross-hauling duopoly at the expense of the foreign firm.

4.4.6 Mutual recognition and harmonisation

I now examine a mutual recognition agreement, under which each country will set its own quality standard for production, but will accept any goods produced abroad which are acceptable to the producing country's regulator. This is a somewhat more complex case, since we need to consider the interaction between the two regulators' policies. I will assume there is a Cournot subgame between the two firms in each country's market, and that there is an overall regulatory game between the two regulators. This means that, with mutual recognition, the regulator in country 1 assumes firm 1 will sell goods at quality Q_{1M} in both markets, but at the same time, it assumes the regulator in country 2 will not change the standards it is setting for firm 2. I will also assume that the legal arrangement is such that each firm has to sell goods at the quality specified by its home country regulator.[23]

Under mutual recognition, country 1's regulator will seek to maximise

$$W_M = \pi_{1,1M} + \pi_{1,2M} + U_{1M}, \tag{4.45}$$

where $\pi_{1,2M}$, for example, denotes the profits made by firm 1 in country 2. U_{1M} denotes

[23] If this rule were not the case, then an alternative possible outcome would be kinked reaction functions, as firm 2 could match cuts in Q_{R1} for its sales to country 1, but would not match increases in Q_{R1}.

consumer surplus in country 1.

Looking in particular at the decision process for regulator 1 (regulator 2 faces an identical problem), I assume regulator 1 sets Q_1 as a response to Q_2^c, its Cournot conjecture of the standard regulator 2 will set. Comparing noncooperative quality setting under mutual recognition with full global optimum, there are two omitted effects - the omission of the benefits of raising Q_1 for consumers in country 2 and the omission of losses to firm 2. These latter reflect a profit shift effect, which follows from equation (4.26):

$$\theta = X_2/X_1 = (MC_1 - \eta MC_2)/(MC_2 - \eta MC_1), \tag{4.26}$$

which applies in both markets. If regulator 1 obliges firm 1 to raise its standards above what it would freely desire, this lowers MC_1 (but imposes a higher fixed cost on firm 1). This raises firm 1's share of both markets and lowers firm 2's share, hence shifting profits towards firm 1.[24]

The effects of omitting foreigners' utility and omitting the effect on the foreign firm's profits carry opposite signs, so it is not easy to say a priori whether the equilibrium outcome under mutual recognition will be for higher- or lower-than-optimal standards. Profits do, of course, fall to zero as product standards are raised - however, profit shift applies to the markup over marginal (variable) cost, which remains positive, though falling. Marginal consumer utility also falls as quality standards are raised (though it remains positive).

[24] It is worth recalling in this context that, in our assumed game setup, firm 1 makes Cournot assumptions about firm 2's behaviour. By contrast, the regulators predict accurately the outcome of the subgame between the two firms: this means regulator 1 will be more optimistic about the marginal effect of raising standards on firm 1's profits than will firm 1 itself.

4.4.7 Mutual recognition

The two country regulators are assumed to play a standard-setting game, taking into account the anticipated result of changes in their national standard upon the outcome of the subgames between the firms in both national markets. Mutual recognition changes this game, in that each national regulator is now assumed to be able to set the standard for its own firm in both markets, but cannot directly influence the standard the foreign firm sets. I assume that each regulator will act on the conjecture that the other regulator's strategy (and hence, the foreign firm's standard) is exogenous: an equilibrium is where actual standards equal conjectured ones for both countries. An equilibrium can also be seen (as in the case of the subgame between the two firms analysed above) as the point of intersection of the two regulators' reaction functions. For some functional forms, these will intersect just once, at a symmetric equilibrium where $Q_1 = Q_2$. Where the reaction functions are monotonically-sloping, there will be only one point of intersection.

Let us start by considering the equations governing the reaction functions of the two regulators. I will concentrate on regulator 1, since regulator 2 is essentially a mirror-image of it. Regulator 1 will assume regulator 2 will maintain a constant standard, so $Q_2^c = \overline{Q}_2^c$. Regulator 1 will then choose a new standard Q_{1M} in order to maximise his conjecture of welfare in country 1. We can rewrite (4.45) in more detail, taking advantage of the assumed symmetry of the two countries, so firm 1 earns the same profits in both markets.

$$W_M = U_{1M} + 2\pi_{1,1M};$$

$$W_M = U_{1M} + 2R'_{1M} - 2VC'_{1M} - 2bQ_{1M}, \tag{4.45a}$$

where the prime denotes firm 1's revenue or costs in any one market, and subscript M denotes the mutual recognition case. Differentiating this implies the first order condition

$$dW_M/dQ_{1M} = dU_{1M}/dQ_{1M} + 2dR'_{1M}/dQ_{1M} - 2dVC'_{1M}/dQ_{1M} - 2b = 0. \quad (4.45b)$$

The solution to (4.45b) will potentially depend upon $\overline{Q}_2^c$.

To examine the solution(s) for (4.45b), we need to consider each element in more detail. Consumer surplus is $U_{1M} = \gamma(1-\eta)Z_{1M}^{\eta}$, as before. I also denote firm 1's market share by S_{1M}, where $S_{1M} = 1/(1+\theta)$ and allow regulator 1 to alter its quality standard (while assuming regulator 2 continues to impose $\overline{Q}_2^c$). R'_{1M} is sales revenue in any one market by the firm 1 and VC'_{1M} is the associated variable cost, such that

$$R'_{1M} = \gamma\eta S_{1M} Z_{1M}^{\eta}; \quad (4.46a)$$

$$VC'_{1M} = S_{1M}^{1/\beta} Z_M^{1/\beta} Q_{1M}^{(\beta-1)/\beta}. \quad (4.46b)$$

S_{1M} and Z_M are functions of both Q_{1M} and Q_{2M}.

We can differentiate (4.46a) and (4.46b) by parts, to give us expressions for the marginal effects on revenue and variable cost of increasing Q_{1M}, while keeping Q_2 constant.

These are

$$dR'_{1M}/dQ_{1M} = \gamma\eta^2 Z_{1M}^{\eta-1}[S_{1M}(dZ_{1M}/dQ_{1M}) + (Z_{1M}/\eta)(dS_{1M}/dQ_{1M})]; \tag{4.47a}$$

$$dVC'_{1M}/dQ_{1M} = (1/\beta)S_{1M}^{1/\beta}Z_M^{(1-\beta)/\beta}Q_{1M}^{(\beta-1)/\beta} [(dZ_{1M}/dQ_{1M}) + Z_{1M}S_{1M}^{-1}(dS_{1M}/dQ_{1M}) + (\beta-1)Z_{1M}/Q_{1M}]. \tag{4.47b}$$

....

Derivation of (4.47a-b)

Differentiating (4.46a) and (4.46b) with respect to Q_{1M}, given $Q_2^c = \overline{Q}_2^c$, we can write

$$R'_{1M} = \gamma\eta S_{1M}Z_{1M}^{\eta}; \text{ so} \tag{4.46a}$$

$$dR'_{1M}/dQ_{1M} = \gamma\eta^2 Z_{1M}^{\eta-1}[S_{1M}(dZ_{1M}/dQ_{1M}) + (Z_{1M}/\eta)(dS_{1M}/dQ_{1M})]. \tag{4.47a}$$

$$VC'_{1M} = S_{1M}^{1/\beta}Z_M^{1/\beta}Q_{1M}^{(\beta-1)/\beta}; \tag{4.46b}$$

$$dVC'_{1M}/dQ_{1M} = (1/\beta)S_{1M}^{1/\beta}Z_M^{(1-\beta)/\beta}Q_{1M}^{(\beta-1)/\beta} [(dZ_{1M}/dQ_{1M}) + Z_{1M}S_{1M}^{-1}(dS_{1M}/dQ_{1M}) + (\beta-1)Z_{1M}/Q_{1M}]; \tag{4.47b}$$

....

Next, consider the effects on total consumer surplus in country 1, U_{1M}, of altering Q_{1M}. Consumer surplus $U_{1M} = \gamma(1-\eta)Z_{1M}^{\eta}$, so

$$dU_{1M}/dQ_{1M} = \gamma\eta(1-\eta)Z_{1M}^{\eta-1}(dZ_{1M}/dQ_{1M}), \tag{4.48}$$

As a consequence, we can rewrite (4.45b) as

$$dW_M/dQ_{1M} = dU_{1M}/dQ_{1M} + 2dR'_{1M}/dQ_{1M} - 2dVC'_{1M}/dQ_{1M} - 2b = 0. \tag{4.45b}$$

$$\begin{aligned}
&\gamma\eta(1-\eta)Z_{1M}^{\eta-1}(dZ_{1M}/dQ_{1M}) + 2\gamma\eta^2 Z_{1M}^{\eta-1}[S_{1M}(dZ_{1M}/dQ_{1M}) \\
&+(Z_{1M}/\eta)(dS_{1M}/dQ_{1M})] - 2(1/\beta)S_{1M}^{1/\beta}Z_M^{(1-\beta)/\beta}Q_{1M}^{(\beta-1)/\beta} \\
&[(dZ_{1M}/dQ_{1M}) + Z_{1M}S_{1M}^{-1}(dS_{1M}/dQ_{1M}) + (\beta-1)Z_{1M}/Q_{1M}] \\
= \quad & 2b.
\end{aligned}$$

This leaves us with

$$\begin{aligned}
&[\gamma\eta(1-\eta)Z_{1M}^{\eta-1} + 2\gamma\eta^2 Z_{1M}^{\eta-1}S_{1M} \\
&-2(1/\beta)S_{1M}^{1/\beta}(Z_M/Q_{1M})^{(1-\beta)/\beta}](dZ_{1M}/dQ_{1M}) \\
&+[(Z_{1M}/\eta) + 2(1/\beta)S_{1M}^{(1-\beta)/\beta}Z_M^{1/\beta}Q_{1M}^{(\beta-1)/\beta}](dS_{1M}/dQ_{1M}) \\
&-2((\beta-1)/\beta)S_{1M}^{1/\beta}(Z_M/Q_{1M})^{1/\beta} \\
= \quad & 2b.
\end{aligned} \tag{4.45c}$$

There remains to be sorted out the issue of how the outputs of the two firms change when Q_{1M} and $\overline{Q}_2^c$ alter.

First, consider how firm 1's market share (S_{1M}, which is the same in both markets) will alter with respect to its quality (keeping $\overline{Q}_2^c$ constant). If the ratio of marginal costs, MC_2/MC_1, is denoted M,[25] then we can derive that

$$S_{1M} = (M - \eta)/((1 + M)(1 - \eta)), \tag{4.49}$$

and

$$dS_1/dM = S_{1M}^2(1 - \eta^2)/(M - \eta)^2. \tag{4.50}$$

Noting that $\eta < 1$, dS_1/dM is positive as long as M is greater than η, and decreases as M rises.

....

Derivation of equation (4.49) and (4.50)

To find dS_1/dQ_{1M}, I start with the ratio $\theta = (1 - S_1)/S_1$. From (4.26)

$$\begin{aligned} \theta &= (MC_1 - \eta MC_2)/(MC_2 - \eta MC_1), \\ &= (1 - \eta M)/(M - \eta), \end{aligned}$$

where $M = MC_2/MC_1$. Differentiating this with respect to M, we find

$$\begin{aligned} d\theta/dM &= [-\eta(M - \eta) - (1 - \eta M)]/(M - \eta)^2, \\ &= (\eta^2 - 1)/(M - \eta)^2. \end{aligned}$$

[25] Ruling out the case $MC_1 = 0$.

If

$$\begin{aligned} S_1 &= (1+\theta)^{-1}; \\ &= (M-\eta)/((M-\eta)+(1-\eta M)), \\ &= (M-\eta)/((1+M)(1-\eta)); \quad (4.49) \\ dS_1/d\theta &= -(1+\theta)^{-2} = -S_1^2; \\ dS_1/dM &= S_1^2(1-\eta^2)/(M-\eta)^2. \quad (4.50) \end{aligned}$$

....

Also, where

$$M = (Q_{1M}(1-S_{1M})/\overline{Q}_2^c S_{1M})^{(1-\beta)/\beta} \quad (4.51)$$

$$dM/dQ_{1M} = ((1-\beta)(M-\eta)(1-\eta M))/[(1-\eta M)(1-\beta\eta M^{-1})+\eta((1-\beta)(M-\eta))]Q_{1M}. \quad (4.52)$$

Finally, from the chain rule

$$dS_1/dQ_{1M} = (dS_1/dM)(dM/dQ_{1M}) \quad (4.52a)$$

....

Derivation of equations (4.51) and (4.52)

To relate the marginal cost ratio, M, to Q, note that

$$\begin{aligned} MC_{1M} &= (1/\beta)(X_{1M}/Q_{1M})^{(1-\beta)/\beta}; \\ MC_{2M} &= (1/\beta)(X_{2M}/Q_{2M})^{(1-\beta)/\beta}; \end{aligned}$$

$$
\begin{aligned}
M &= MC_{2M}/MC_{1M}=(Q_{1M}X_2/Q_{2M}X_1)^{(1-\beta)/\beta}, \\
M &= (Q_{1M}(1-S_{1M})/Q_{2M}S_{1M})^{(1-\beta)/\beta}, \qquad (4.51)\\
&= (\theta Q_{1M}/Q_{2M})^{(1-\beta)/\beta}, \\
&= ((Q_{1M}/Q_{2M})(1-\eta M)/(M-\eta))^{(1-\beta)/\beta}, \\
M(M-\eta)^{(1-\beta)/\beta} &= (Q_{1M}/Q_{2M})^{(1-\beta)/\beta}(1-\eta M)^{(1-\beta)/\beta}; \\
M^{\beta/(1-\beta)}(M-\eta) &= (Q_{1M}/Q_{2M})(1-\eta M); \\
M^{1/(1-\beta)} - \eta M^{\beta/(1-\beta)} &= (Q_{1M}/Q_{2M})(1-\eta M)
\end{aligned}
$$

Totally differentiating this

$$
\begin{aligned}
(1/(1-\beta))M^{\beta/(1-\beta)}dM - (\beta/(1-\beta))\eta M^{(2\beta-1)/(1-\beta)}dM &= ((1-\eta M)/Q_{2M})dQ_{1M} \\
&\quad -((1-\eta M)Q_{1M}/Q_{2M}^2)dQ_{2M} \\
&\quad -\eta(Q_{1M}/Q_{2M})dM.
\end{aligned}
$$

Rearranging this, holding the perceived value of Q_{2M} (denoted $\overline{Q}_2^c$) constant (so its differential is zero)

$$
\begin{aligned}
&[(1/(1-\beta))M^{\beta/(1-\beta)} - (\beta/(1-\beta))\eta M^{(2\beta-1)/(1-\beta)} + \eta(Q_{1M}/\overline{Q}_2^c)]dM \\
= \quad &((1-\eta M)/\overline{Q}_2^c)dQ_{1M}.
\end{aligned}
$$

$$
\begin{aligned}
&[(1/(1-\beta))M^{\beta/(1-\beta)}(1-\beta\eta M^{-1})+\eta(Q_{1M}/\overline{Q}_2^c)]dM \\
= \quad &((1-\eta M)/\overline{Q}_2^c)dQ_{1M}.
\end{aligned}
$$

But $M^{\beta/(1-\beta)} = (Q_{1M}/\overline{Q}_2^c)(1-\eta M)/(M-\eta)$, so

$$
\begin{aligned}
&[(1/(1-\beta)(Q_{1M}/\overline{Q}_2^c)((1-\eta M)/(M-\eta))(1-\beta\eta M^{-1})+\eta(Q_{1M}/\overline{Q}_2^c)]dM \\
= \quad &((1-\eta M)/\overline{Q}_2^c)dQ_{1M}.
\end{aligned}
$$

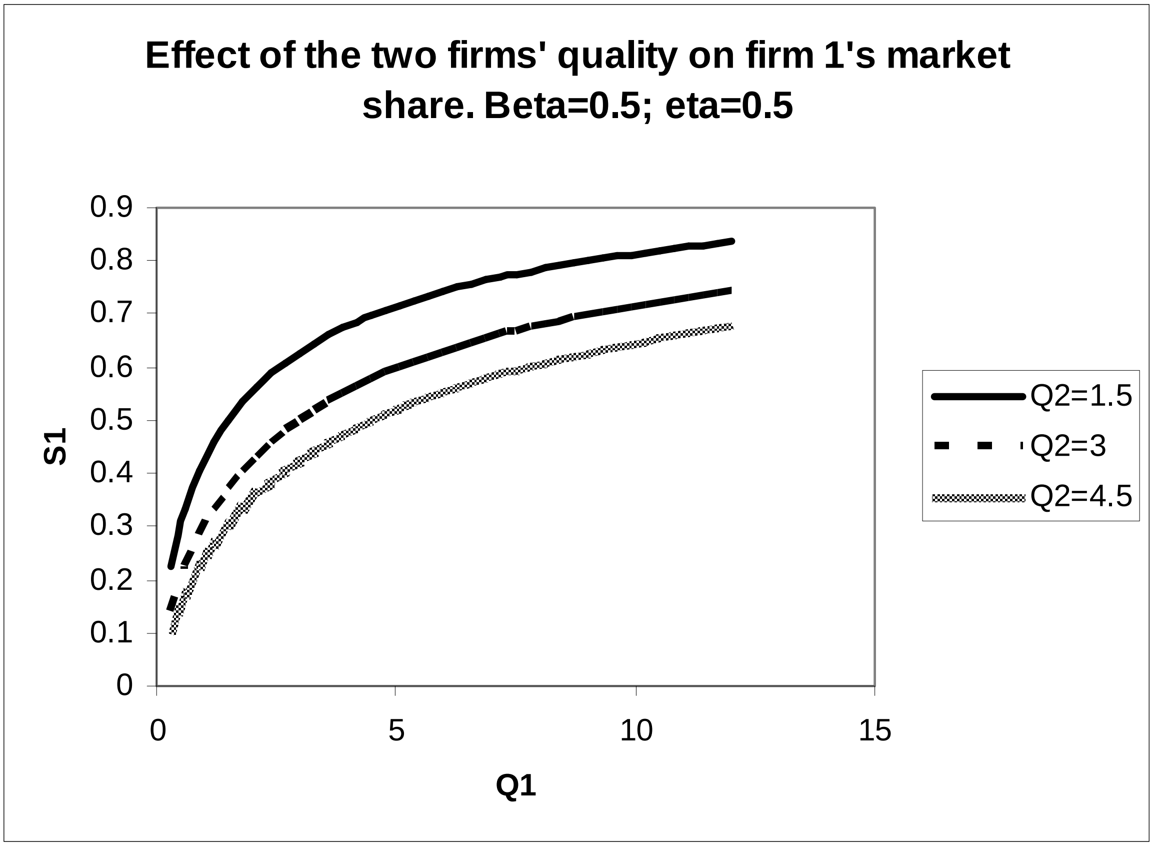
$$
\begin{aligned}
&[(1/((1-\beta)(M-\eta))(1-\beta\eta M^{-1})+\eta/(1-\eta M)]Q_{1M}dM \\
= \quad &dQ_{1M}.
\end{aligned}
$$

Multiplying through by $((1-\beta)(M-\eta)(1-\eta M))$:

$$
\begin{aligned}
&[(1-\eta M)(1-\beta\eta M^{-1})+\eta((1-\beta)(M-\eta))]Q_{1M}dM \\
= \quad &((1-\beta)(M-\eta)(1-\eta M))dQ_{1M}.
\end{aligned}
$$

This implies that

$$
dM/dQ_{1M} = ((1-\beta)(M-\eta)(1-\eta M))/[((1-\eta M)(1-\beta\eta M^{-1})+\eta((1-\beta)(M-\eta)))Q_{1M}]. \tag{4.52}
$$



==

(4.49)-(4.52a) represent a system of simultaneous equations relating S_{1M}, M, Q_{1M} and $\overline{Q}_2^c$. Unfortunately, they do not easily reduce into a simple reduced form. However, plotting the solution for various parameter values indicates a monotonically upward-sloping function, curving off as S_{1M} approaches 1. The graph below, for the case $\beta = \eta = 0.5$, is typical.

Total sales in country 1 (which will be mirrored by sales in country 2) are given by

$$Z_{1M} = [((S_{1M}Z_{1M}/Q_{1M})^{(1-\beta)/\beta} + ((1-S_1)Z_{1M}/\overline{Q}_2^c)^{(1-\beta)/\beta})/(\beta\gamma\eta(1+\eta))]^{1/\eta-1}, \quad (4.53)$$

while the differential of Z_{1M} with respect to Q_{1M} depends upon both the share of firm 1 and upon the sensitivity of that share to changes in the quality standard imposed upon it:

$$
\begin{aligned}
dZ_{1M}/dQ_{1M} &= ((1-\beta)/\Psi(\beta\eta-1))[S_{1M}{}^{(1-2\beta)/\beta}Q_{1M}{}^{(\beta-1)/\beta} \\
&\quad -(1-S_{1M})^{(1-2\beta)/\beta}\overline{Q}_2^{c(\beta-1)/\beta}](Z_{1M}/Z_{1M}^{(\beta\eta-1)/\beta})dS_{1M}/dQ_{1M} \\
&\quad +((1-\beta)/\Psi(1-\beta\eta))S_{1M}{}^{(1-\beta)/\beta}Q_{1M}{}^{-1/\beta}(Z_{1M}/Z_{1M}^{(\beta\eta-1)/\beta})dQ_{1M};
\end{aligned}
\quad (4.54)
$$

....

Derivation of equations (4.53) and (4.54)

I start with equations (4.25) and (4.30):

$$Z_{1RC} = (X_{1RC} + X_{2RC}) = [(MC_{1RC} + MC_{2RC})/(\gamma\eta(1+\eta))]^{1/\eta-1}, \quad (4.25)$$

$$MC_{1RC} = (1/\beta)(X_{1RC}/Q_{RC})^{(1-\beta)/\beta}, \quad (4.30)$$

and likewise for MC_{2RC}.

Substituting into this for $X_{1M} = S_{1M}Z_{1M}$ and $X_{2M} = (1-S_{1M})Z_{1M}$, we get

$$Z_{1M} = [((S_{1M}Z_{1M}/Q_{1M})^{(1-\beta)/\beta} + ((1-S_1)Z_{1M}/\overline{Q}_2^c)^{(1-\beta)/\beta})/(\beta\gamma\eta(1+\eta))]^{1/\eta-1}; \quad (4.53)$$

$$\begin{aligned}
\Psi Z_{1M}^{\eta-1} &= (S_{1M}Z_{1M}/Q_{1M})^{(1-\beta)/\beta}+((1-S_{1M})Z_{1M}/\overline{Q}_2^c)^{(1-\beta)/\beta}; \\
\Psi Z_{1M}^{(\beta\eta-1)/\beta} &= S_{1M}{}^{(1-\beta)/\beta}Q_{1M}{}^{(\beta-1)/\beta}+(1-S_{1M})^{(1-\beta)/\beta}\overline{Q}_2^{c\,(\beta-1)/\beta},
\end{aligned}$$

remembering that $\Psi = \beta\gamma\eta(1+\eta)$.Totally differentiating

$$\begin{aligned}
(\beta\eta-1)\Psi Z_{1M}^{(\beta\eta-1)/\beta}Z_{1M}^{-1}dZ_{1M} &= ((1-\beta)/\beta)S_{1M}{}^{(1-2\beta)/\beta}Q_{1M}{}^{(\beta-1)/\beta}dS_{1M} \\
&\quad -((1-\beta)/\beta)(1-S_{1M})^{(1-2\beta)/\beta}\overline{Q}_2^{c\,(\beta-1)/\beta}dS_{1M} \\
&\quad +((\beta-1)/\beta)S_{1M}{}^{(1-\beta)/\beta}Q_{1M}{}^{-1/\beta}dQ_{1M};
\end{aligned}$$

$$\begin{aligned}
(\beta\eta-1)\Psi Z_{1M}^{(\beta\eta-1)/\beta}Z_{1M}^{-1}dZ_{1M} &= ((1-\beta)/\beta)[S_{1M}{}^{(1-2\beta)/\beta}Q_{1M}{}^{(\beta-1)/\beta} \\
&\quad -(1-S_{1M})^{(1-2\beta)/\beta}\overline{Q}_2^{c\,(\beta-1)/\beta}]dS_{1M} \\
&\quad +((\beta-1)/\beta)S_{1M}{}^{(1-\beta)/\beta}Q_{1M}{}^{-1/\beta}dQ_{1M};
\end{aligned}$$

$$\begin{aligned}
(\beta\eta-1)\Psi Z_{1M}^{(\beta\eta-1)/\beta}Z_{1M}^{-1}dZ_{1M} &= (1-\beta)[S_{1M}{}^{(1-2\beta)/\beta}Q_{1M}{}^{(\beta-1)/\beta} \\
&\quad -(1-S_{1M})^{(1-2\beta)/\beta}\overline{Q}_2^{c\,(\beta-1)/\beta}]dS_{1M} \\
&\quad +(\beta-1)S_{1M}{}^{(1-\beta)/\beta}Q_{1M}{}^{-1/\beta}dQ_{1M};
\end{aligned}$$

$$
\begin{aligned}
dZ_{1M}/dQ_{1M} \quad = \quad & ((1-\beta)/\Psi(\beta\eta-1))[S_{1M}{}^{(1-2\beta)/\beta}Q_{1M}{}^{(\beta-1)/\beta} \\
& -(1-S_{1M})^{(1-2\beta)/\beta}\overline{Q}_2^{c\,(\beta-1)/\beta}](Z_{1M}/Z_{1M}^{(\beta\eta-1)/\beta})dS_{1M}/dQ_{1M} \\
& +((1-\beta)/\Psi(1-\beta\eta))S_{1M}{}^{(1-\beta)/\beta}Q_{1M}{}^{-1/\beta}(Z_{1M}/Z_{1M}^{(\beta\eta-1)/\beta})dQ_{1M};
\end{aligned} \tag{4.54}
$$

....

While, in principle, it is possible to derive reaction curves and equilibrium values from the above equations, they do not easily reduce to a comprehensible reduced form. For this reason, I proceed by numerical means, estimating equilibrium values for a wide range of combinations of parameter values. In addition, given the complexity of some of the differentials, I concentrate on deriving symmetric equilibria, which are somewhat easier to derive than asymmetric equilibria. I will consider later the issue of possible asymmetric equilibria, or other multiple equilibria.

Derivation of symmetric equilibrium values A symmetric, pure strategy equilibrium is one where $Q_1 = Q_1^c = Q_2 = Q_2^c$. Because it is symmetric, we can solve it just looking at country 1's decision as a response to country 2's standard setting. Consequently, I start by examining the locus of symmetric quality regulations, where $Q_1 = \overline{Q}_2^c$. A symmetric Nash equilibrium is a point on this locus where neither regulator will wish to adjust quality (assuming the other regulator's standard is constant). To be practicable, such an equilibrium must also lie above the standard the firms would independently set, and below the level at which they exit the market. Concentrating on regulator 1's decision: he will assume regulator 2 will maintain the initial standard, $\overline{Q}_2^c$. Regulator 1 will then choose a new standard Q_{1M} in order to maximise his conjecture of welfare in country 1.

In this equilibrium, both national markets will be split equally between the two firms, so $S_{1M} = (1 - S_{1M}) = 1/2$.

Going through the various equations defining the equilibrium, by simple substitution (4.47a) and (4.47b) become:

$$\begin{aligned} dR'_{1M}/dQ_{1M} &= (\gamma\eta^2 Z_{1M}^{\eta-1}/2)[(dZ_{1M}/dQ_{1M}) \\ &\quad +2(Z_{1M}/\eta)(dS_{1M}/dQ_{1M})]; \\ dVC'_{1M}/dQ_{1M} &= (1/\beta)2^{-1/\beta}(Z_{1M}/\overline{Q}_2^c)^{(1-\beta)/\beta}[(dZ_{1M}/dQ_{1M}) \\ &\quad +2Z_{1M}(dS_{1M}/dQ_{1M}) + (\beta-1)Z_{1M}/\overline{Q}_2^c]; \end{aligned} \quad \text{(A), (B)}$$

(4.48) and (4.45b) are unchanged:

$$dU_M/dQ_{1M} = \gamma\eta(1-\eta)Z_{1M}^{\eta-1}(dZ_{1M}/dQ_{1M}), \quad \text{(C)}$$

$$dW_M/dQ_{1M} = dU_{1M}/dQ_{1M} + 2dR'_{1M}/dQ_{1M} - 2dVC'_{1M}/dQ_{1M} - 2b = 0. \quad \text{(D)}$$

From (4.50) and (4.51) we are able to derive a simpler reduced form for the marginal effect of altering Q_{1M} on S_1, when starting from $Q_{1M} = \overline{Q}_2^c$:

$$dS_1/dQ_{1M} = ((1+\eta)(1-\beta)/4\overline{Q}_2^c(1+\eta-2\beta\eta). \quad \text{(E)}$$

....

Derivation of equation (E)

$$dM/dQ_{1M} = ((1-\beta)(M-\eta)(1-\eta M))/[((1-\eta M)(1-\beta\eta M^{-1})+\eta((1-\beta)(M-\eta)))Q_{1M}]. \tag{4.52}$$

In the symmetric case, $M = 1$, so

$$\begin{aligned} dM/dQ_{1M} &= ((1-\beta)(1-\eta)(1-\eta))/[((1-\eta)(1-\beta\eta)+\eta((1-\beta)(1-\eta)))\overline{Q}_2^c], \\ &= ((1-\beta)(1-\eta))/[((1-\beta\eta)+\eta(1-\beta))\overline{Q}_2^c], \\ &= ((1-\eta)(1-\beta))/[(1+\eta-2\beta\eta)\overline{Q}_2^c]. \end{aligned}$$

Also, from (4.50)

$$\begin{aligned} dS_1/dM &= S_1^2(1-\eta^2)/(M-\eta)^2, \\ &= (1/4)(1-\eta)(1+\eta)/(1-\eta)^2, \\ &= (1+\eta)/4(1-\eta). \end{aligned}$$

So

$$\begin{aligned} dS_1/dQ_{1M} &= (dS_1/dM)(dM/dQ_{1M}) = \{(1+\eta)/4(1-\eta)\} \\ &\quad \{((1-\eta)(1-\beta))/[(1+\eta-2\beta\eta)\overline{Q}_2^c]\}, \\ &= ((1+\eta)(1-\beta))/(4\overline{Q}_2^c(1+\eta-2\beta\eta)). \qquad \text{(E)} \end{aligned}$$

....

Total sales along the symmetric locus can be expressed as an increasing function of quality, where both firms' quality is increased simultaneously. The function for this has already been examined:

$$Z_{1RC} = (\eta/\upsilon)K'\overline{Q}_2^{c\,\upsilon/\eta}, \qquad \text{(F)}$$

where

$$K' = (\upsilon/\eta)\Psi^{\beta/(1-\beta\eta)}2^{(1-2\beta)/(1-\beta\eta)}. \qquad \text{(G)}$$

....

Derivation of equations (F) and (G)

These derive from equation (4.31), which derives Z_{1RC}, the combined sales if both firms sell goods of the same standard.

$$Z_{RC} = \Psi^{\beta/(1-\beta\eta)}2^{(1-2\beta)/(1-\beta\eta)}Q_{RC}{}^{\upsilon/\eta}. \qquad (4.31)$$

....

The marginal effect on total sales of increasing Q_{1M} is half that of increasing both countries' standards simultaneously:

$$dZ_{1M}/dQ_{1M} = (1/2)dZ_{1RC}/dQ_{RC}, \tag{H}$$

where

$$dZ_{1RC}/dQ_{RC} = K' Q_{RC}^{(\upsilon-\eta)/\eta}. \tag{I}$$

....

Derivation of equations (H) and (I)

For (H), note that

$$\begin{aligned}
Z_{1M} &= [((S_{1M}Z_{1M}/Q_{1M})^{(1-\beta)/\beta} + ((1-S_1)Z_{1M}/\overline{Q}_2^c)^{(1-\beta)/\beta})/(\beta\gamma\eta(1+\eta))]^{1/\eta-1}, \\
\Psi Z_{1M}^{\eta-1} &= ((S_{1M}Z_{1M}/Q_{1M})^{(1-\beta)/\beta} + ((1-S_1)Z_{1M}/\overline{Q}_2^c)^{(1-\beta)/\beta}), \\
\Psi Z_{1M}^{(\beta\eta-1)/\beta} &= (S_{1M}/Q_{1M})^{(1-\beta)/\beta} + ((1-S_1)/\overline{Q}_2^c)^{(1-\beta)/\beta};
\end{aligned}$$

so that, totally differentiating (but keeping $\overline{Q}_2^c$ constant)

$$\begin{aligned}
(\Psi((\beta\eta-1)/\beta)Z_{1M}^{(\beta\eta-1)/\beta}/Z_{1M})dZ_{1M} &= ((1-\beta)/\beta)S_{1M}^{(1-2\beta)/\beta}{Q_{1M}}^{(\beta-1)/\beta}dS_{1M} \\
&\quad +((\beta-1)/\beta)S_{1M}^{(1-\beta)/\beta}{Q_{1M}^{-1/\beta}}dQ_{1M} \\
&\quad -((1-\beta)/\beta)(1-S_{1M})^{(1-2\beta)/\beta}{\overline{Q}_2^c}^{(\beta-1)/\beta}dS_{1M};
\end{aligned}$$

On the symmetric locus

$$(\Psi((\beta\eta-1)/\beta)Z_{1M}^{(\beta\eta-1)/\beta}/Z_{1M})dZ_{1M} = ((\beta-1)/\beta)S_{1M}^{(1-\beta)/\beta}{Q_{1M}^{-1/\beta}}dQ_{1M};$$

$$dZ_{1M}/dQ_{1M} = ((\beta-1)/\beta)2^{(\beta-1)/\beta}\overline{Q}_2^{c\,-1/\beta}Z_{1M}/((\Psi(\beta\eta-1)/\beta)Z_{1M}^{(\beta\eta-1)/\beta}).$$

By contrast, when $Q_{1M} = \overline{Q}_2^c = Q_{RC}$, and both standards are changed simultaneously

$$\begin{aligned}\Psi Z_{1RC}^{(\beta\eta-1)/\beta} &= (1/2Q_{RC})^{(1-\beta)/\beta}+(1/2Q_{RC})^{(1-\beta)/\beta},\\ &= 2^{(2\beta-1)/\beta}Q_{RC}{}^{(\beta-1)/\beta};\\ \Psi((\beta\eta-1)/\beta)Z_{1RC}^{(\beta\eta-1)/\beta}/Z_{1RC})dZ_{1RC} &= ((\beta-1)/\beta)2^{(2\beta-1)/\beta}Q_{RC}{}^{-1/\beta}dQ_{RC};\end{aligned}$$

$$dZ_{1RC}/dQ_{RC} = ((\beta-1)/\beta)2^{(2\beta-1)/\beta}Q_{RC}{}^{-1/\beta}Z_{1RC}/(\Psi((\beta\eta-1)/\beta)Z_{1RC}^{(\beta\eta-1)/\beta})).$$

Consequently,

$$\begin{aligned}(dZ_{1M}/dQ_{1M})/(dZ_{1RC}/dQ_{RC}) &= 2^{-1}; \qquad \text{(H)}\\ dZ_{1M}/dQ_{1M} &= (1/2)dZ_{1RC}/dQ_{RC}.\end{aligned}$$

(I) follows from differentiating (F) with respect to Q.

....

Equations (A) to (I) define a pure-strategy symmetric equilibrium for quality, $\widehat{Q}$, in the mutual recognition case. While it is possible to derive a reduced form from these equations and solve it for the equilibrium value of $Q_{1M} = \overline{Q}_2^c = \widehat{Q}$, it is not particularly informative in this case, which is why I prefer to derive a solution by numerical means. Nevertheless, it is worth exploring the implications of writing out more fully the first order condition for an equilibrium in (4.45c). Imposition of symmetry allows us to write

$$\begin{aligned} & [\gamma\eta(1-\eta)Z_{1M}^{\eta-1} + \gamma\eta^2 Z_{1M}^{\eta-1}{}_{1M} \\ & -2^{(\beta-1)/\beta}(1/\beta)(Z_M/\overline{Q}_2^c)^{(1-\beta)/\beta}](dZ_{1M}/dQ_{1M}) \\ & +[(Z_{1M}/\eta) + 2(1/\beta)Z_M^{1/\beta}(2\overline{Q}_2^c)^{(\beta-1)/\beta}](dS_{1M}/dQ_{1M}) \\ & -2((\beta-1)/\beta)(Z_M/2\overline{Q}_2^c)^{1/\beta} \\ = \;& 2b. \end{aligned} \tag{4.55}$$

This same result can also be found by substituting into (D) from (A)-(C).

....

Derivation of equation (4.55)

Start with

$$\begin{aligned} & [\gamma\eta(1-\eta)Z_{1M}^{\eta-1} + 2\gamma\eta^2 Z_{1M}^{\eta-1} S_{1M} \\ & -2(1/\beta)S_{1M}^{1/\beta}(Z_M/Q_{1M})^{(1-\beta)/\beta}](dZ_{1M}/dQ_{1M}) \\ & +[(Z_{1M}/\eta) + 2(1/\beta)S_{1M}^{(1-\beta)/\beta} Z_M^{1/\beta} Q_{1M}^{(\beta-1)/\beta}](dS_{1M}/dQ_{1M}) \\ & -2((\beta-1)/\beta)S_{1M}^{1/\beta}(Z_M/Q_{1M})^{1/\beta} \\ = \;& 2b. \end{aligned} \tag{4.45c}$$

$$
\begin{aligned}
& [\gamma\eta(1-\eta)Z_{1M}^{\eta-1} + \gamma\eta^2 Z_{1M}^{\eta-1}{}_{1M} \qquad (4.55) \\
& -2^{(\beta-1/\beta)}(1/\beta)(Z_M/\overline{Q}_2^c)^{(1-\beta)/\beta}](dZ_{1M}/dQ_{1M}) \\
& +[(Z_{1M}/\eta) + 2(1/\beta)Z_M^{1/\beta}(2\overline{Q}_2^c)^{(\beta-1)/\beta}](dS_{1M}/dQ_{1M}) \\
& -2((\beta-1)/\beta)(Z_M/2\overline{Q}_2^c)^{1/\beta} \\
= \;& 2b.
\end{aligned}
$$

....

(4.55) can also be written in a more intuitive form as:

$$
\begin{aligned}
& (dZ_M/dQ_{1M})[dU_M/dZ_M + 2dR_{1M}/dZ_M - 2(dVC_{1M}/dZ_M)] \\
& +2(dS_{1M}/dQ_{1M})[2R_{1M} - 2TVC_1] \\
& -2((\beta-1)^2/\beta)(TVC_1/Q_1) + (4/\beta)TVC_1(dS_{1M}/dQ_{1M}) \\
= \;& 2b. \qquad (4.55a)
\end{aligned}
$$

where TVC_{1M} refers to total variable cost for each market incurred by firm 1. Intuitively, the first line in (4.55a) represents the marginal effect of rising output on consumer surplus, firm 1's revenue and firm 1's variable costs, ignoring the change in firm 1's market share. The second line is a profit shift effect. The third line reflects more complex effects upon the overall cost mix. The right hand side is the extra fixed cost to firm 1 in each market of raising quality.

Compare this now to the first order conditions for the global optimum standard, Q_G.

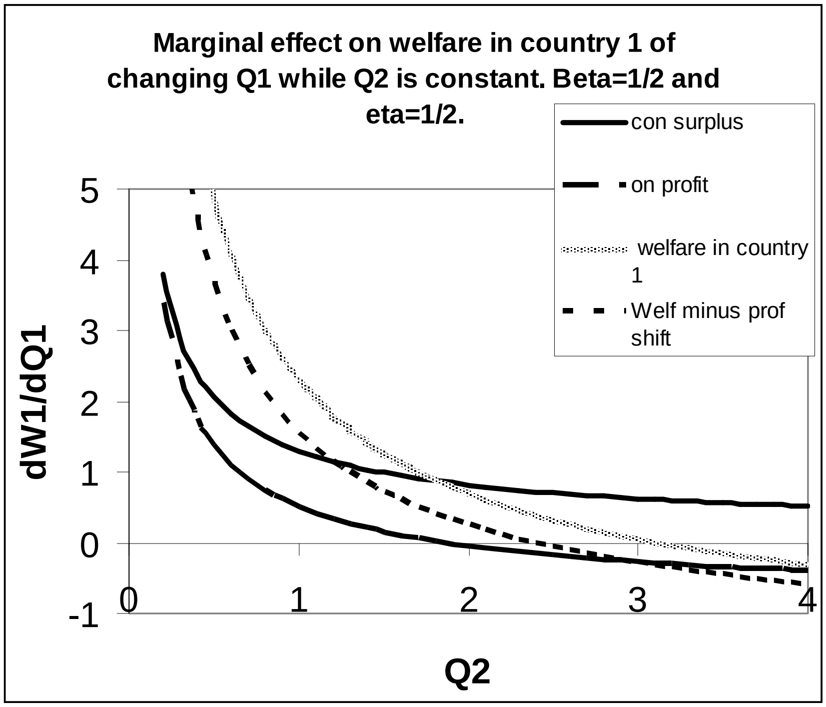
$$WG = 2U_{1G} + 4(R_{1G} - VC_{1G} - bQ_G);$$

$dW_G/dQ_G = 0 ==>$

$$(dZ_{1G}/dQ_G)[dU_{1G}/dZ_{1G} + 2dR_{1G}/dZ_{1G} - 2dVC_{1G}/dZ_{1G}] = 2b. \qquad (4.56)$$

The similarity between the left hand side of (4.56) and the first line of (4.55a) is readily apparent. However, note that the first line of (4.55a) is written in terms of (dZ_{1M}/dQ_{1M}) (i.e.assuming only firm 1's quality is changed), and is smaller than (dZ_{1G}/dQ_G) by a factor of (1/2). Since (dZ_{1M}/dQ) is declining with respect to Q, we would expect (4.55a) to give a quality standard less than Q_G, if the effects in the second and third lines were zero. However, the profit shift and cost mix effects are not zero, and will reduce the equilibrium value of Q, so that it is not easy to determine whether quality standards under mutual recognition will exceed, or fall short of the global optimum.

Numerical analysis In order to illustrate the relative effects at work, I start by examining the effects at various levels of $\overline{Q}_2^c$, the standard set by regulator 2, of altering Q_{1M}, country 1's standard, while holding $\overline{Q}_2^c$ constant, in the case where $\beta = 1/2$ and $\eta = 1/2$. Marginal effects of changing Q_{1M} are calculated for different levels of $\overline{Q}_2^c$, at intervals of 0.1. This indicates that raising Q_{1M} always benefits consumers, although beyond a point $\overline{Q} = \hat{Q}$ the fall in profits outweighs the marginal gain to consumers. The point at which this occurs is at $\widehat{Q} = 3.14$, which exceeds Q_G (calculated in this case to equal 3.05). However, but for the profit shift effect (the effect in line 3 of (4.55a)), the net welfare effect of raising Q_{1M} would become negative at a lower level of around



$\overline{Q} = 2.4$. Recalling the outcomes already calculated, a ranking of the outcomes of the various regulatory scenarios on these parameter values would therefore be:

$Q_{RC} = 6.27$; unconstrained noncooperative solution;

$Q_{\#} = 3.78$; firms leave the market;

$\widehat{Q} = 3.14$; mutual recognition equilibrium;

$Q_G = 3.05$; globally optimum regulated equilibrium;

$\widehat{Q}$ excluding profit shift $= 2.4$;

$Q_U = 1.76$; unregulated equilibrium.

Appendix 4.3 summarises the results of numerical simulations over a wider range of values of β and η. For scaling purposes, the outcomes of the various regulatory games are expressed in each case as a ratio relative to the quality chosen by an unregulated duopoly, Q_U. A summary of the conclusions of the simulations carried out is as follows:

1. Varying the market scale parameter, γ, and the relative cost parameter for quality,

b, has no effect on any of the regulatory outcomes (when they are expressed as proportions of Q_U). Consequently, without loss of generality, we can concentrate on the case where $\gamma = 10$ and $b = 1$.

2. The simulations confirm the conclusions of the theoretical analysis that, in all cases, $Q_{RC} > Q_G > Q_U$.

3. In all cases examined, the zero profit quality, $Q_{\#}$ exceeds the global optimum, Q_G. This is again consistent with the theoretical findings above.

4. As *Table 4.2* has already shown, $Q_{\#}$ will constrain the local regulator in the noncooperative scenario, except for cases where β is relatively high and η relatively low.

5. In all the cases examined, the unconstrained equilibrium quality under mutual recognition, $\widehat{Q}$, is lower than the unconstrained noncooperative equilibrium, Q_{RC}, but higher than the global optimum, Q_G. This indicates that the profit shift effect outweighs any gain to profits from cutting quality sold to foreigners. However, this difference is marginal, and in practice the difference between Q_{RC} and Q_G is very small in all cases.

6. The nonnegative profit constraint, $Q_{\#}$, does not constrain the quality set under mutual recognition in any of the cases examined.

7. In all cases examined, mutual recognition would lower the standard compared to noncooperation. As this is a move towards the global optimum ($\widehat{Q}$ is still greater than Q_G), we would expect this to be welfare-improving.

Tables 4.3 and 4.4 summarise the degree to which the constrained quality under noncooperation exceeds that under mutual recognition, and the degree to which the mutual recognition quality exceeds the global optimum in these simulations.

$(\widetilde{Q}_{RC} - \widetilde{Q}_{MR})/Q_U$	$\eta =$	0.3	0.4	0.5	0.6	0.7	0.8
$\beta =$	0.3	0.24	0.20	0.16	0.12	0.09	0.06
	0.4	0.38	0.31	0.24	0.19	0.14	0.10
	0.5	0.57	0.46	0.37	0.28	0.20	0.14
	0.6	1.85	0.69	0.55	0.42	0.30	0.20
	0.7	1.32	1.07	0.85	0.64	0.46	0.30
	0.8	1.57	1.49	1.44	1.10	0.79	0.51

Table 4.3: difference between standards under noncooperative standard-setting and under mutual recognition, taking account of the nonnegative profit constraint.

$(\widetilde{Q}_{MR} - Q_G)/Q_U$	$\eta =$	0.3	0.4	0.5	0.6	0.7	0.8
$\beta =$	0.3	0.02	0.03	0.03	0.02	0.02	0.01
	0.4	0.03	0.04	0.04	0.03	0.03	0.01
	0.5	0.05	0.05	0.05	0.05	0.04	0.02
	0.6	0.06	0.06	0.07	0.06	0.06	0.03
	0.7	0.07	0.08	0.08	0.08	0.07	0.06
	0.8	0.08	0.10	0.10	0.11	0.10	0.09

Table 4.4: Difference between the standard set under mutual recognition (taking account of the nonnegative profit constraint) and the global optimum standard.

As with any numerical simulations, a word of caution is needed: it is not possible to confirm that the results carry over to parameter values other than those investigated. Due to the nonlinearity of the model, values of β or η less than 0.3 or greater than 0.8 could not be investigated. Also, some different functional forms might give qualitatively different results.

Alternative equilibria In theory, with a complex model structure such as that under investigation in this section, it is not possible to rule out the existence of multiple equilibria - either multiple symmetric equilibria or asymmetric equilibria. These could potentially happen where the gradient of national welfare with respect to the national standard changes sign more than once (for a given foreign standard), so causing reaction functions to double back on themselves. However, even when a model consists of a number of simultaneous nonlinear equations, as in this case, where no simple reduced form equation can be derived, this does not necessarily mean the reaction functions will be highly nonlinear, and even if they are, there is no necessity that they cross in more than one place, at least within the range of feasible solutions (which is limited by the assumed inability of regulators to make firms set standards less than Q_U, or higher than $Q_{\#}$).

Numerical simulation can be of assistance in this case, as it can be used to show whether national welfare is 'well' or 'badly-behaved' with respect to domestic and foreign regulatory standards, over a range of parameter values (β and η). As an illustration, I show below a plot of welfare in country 1, calculated over a grid of values for Q_1 and Q_2, in the case where $\beta = \eta = 0.5$.

Looking down each column, taking Q_2 as given, W_1 first improves and then declines with respect to Q_1. In each column, the cell where W_1 is maximised is shaded. These form almost a horizontal row (and the mirror-image points, which, by symmetry, would maximise W_2 with Q_1 given, are almost vertical). The point where these two reaction curves meet is a single, symmetric equilibrium with a value of Q_1 and $Q2$ between 3 and 3.3 (confirming the model, which indicates a solution of 3.14).

This exercise has been repeated for all combinations of $\beta = 0.3$, 0.5 and.7 and $\eta = 0.3$,

WELFARE IN COUNTRY 1 AS A FUNCTION OF BOTH FIRMS QUALITY
Rho=0.5; Beta=0.5

Firm 1's quality	Firm 2's quality: 1.5	1.8	2.1	2.4	2.7	3	3.3	3.6	3.9
1.5	11.45	11.44	11.45	11.47	11.50	11.53	11.57	11.62	11.67
1.8	11.78	11.76	11.75	11.75	11.76	11.79	11.81	11.84	11.88
2.1	12.03	11.99	11.96	11.96	11.96	11.97	11.98	12.00	12.03
2.4	12.20	12.15	12.12	12.10	12.09	12.09	12.10	12.11	12.13
2.7	12.32	12.26	12.22	12.19	12.18	12.17	12.17	12.17	12.18
3	12.40	12.33	12.28	12.25	12.22	12.21	12.20	12.20	12.20
3.3	12.43	12.36	12.30	12.26	12.23	12.21	12.19	12.19	12.18
3.6	12.43	12.35	12.29	12.24	12.21	12.18	12.16	12.15	12.14
3.9	12.39	12.31	12.25	12.20	12.16	12.12	12.10	12.08	12.07

(yellow) *Points where Q1 is optimised subject to Q2 being given*
(cyan) *Points where Q2 is optimised subject to Q1 being given*

0.5 and.7. In all cases, the reaction functions were relatively straight and monotonic and intersecting at a single symmetric equilibrium.

It should be borne in mind that numerical search techniques cannot rule out the existence of multiple equilibria for parameter values which have not been specifically investigated: in particular, for extreme values where β or η is close to 0 or 1.

4.5 Horizontal quality regulation

The discussion above has concentrated on vertical regulations, which raise some measure of quality experienced by consumers for all goods within an industry. By contrast, much of the literature on TBTs focuses on pure, horizontal regulations, which discriminate between suppliers in one country against another, or between those using one technique rather than another, and which do not directly affect consumer utility.

A horizontal TBT involves imposing a resource cost on imports. Any changes in import share could equally be achieved by an equivalent tariff, which would, by contrast, raise revenue for the importing country. It follows that pure, horizontal TBTs are only likely to appeal where tariffs are ruled out (e.g. by trade agreements), or where TBTs are regarded as less visible, and hence less likely to provoke retaliation. Again, it is worth bearing in mind that in a perfectly competitive model, horizontal TBTs just lower national welfare, since they impose a resource cost which worsens both the importing and the exporting countries' terms of trade.

Horizontal TBTs may, however, appeal to regulators in four circumstances, where the alternative of tariffs is ruled out: (i) given monopolistic profit, there may be a profit-shifting incentive to raise domestic suppliers' market share, to raise their profits, even when this involves imposing a cost on consumers; (ii) agglomeration economies may mean that a country which raises output by imposing TBTs can either lower production costs or raise local factor rents; (iii) there may be agency capture so that the regulator represents local producers rather than the importing country as a whole; (iv) horizontal legislation may to some extent be inevitable where there are network externalities.

In this paper I consider the first of these motives only.

4.5.1 Pure, horizontal technical barriers to trade

Consider first a pure, horizontal TBT in the non-cooperative Cournot duopoly model where there is no vertical regulation. I assume the horizontal TBT adds a cost of T per quality-adjusted unit of the good imported into country c_1, while having no effect on the vertical quality experienced by consumers.[26] By contrast, it does not affect the costs to

[26] One could, of course, consider an alternative specification where the pure horizontal barrier adds a fixed cost to firm 2, but this would not affect behaviour unless it were so high as to induce market exit.

domestic suppliers. It is assumed that tariffs are ruled out by agreement.

From (4.5), where there is no vertical regulation, marginal costs of producing X are constant at MC_U. However, since we have introduced the horizontal TBT, marginal costs for firm 2 selling to country 1 are now

$$MC_{2H}= MC_{2U}+T, \tag{4.57}$$

where the subscript $_H$ denotes the case with horizontal barriers.

Firm 1 will set its output in market 1 as determined by (4.24a). However, the corresponding equation for firm 2, (4.24b), requires modification

$$(X^c_{1H} + X_{2H})^{\eta-1} + (\eta - 1)X_{2H}(X^c_{1H} + X_{2H})^{\eta-2} = (MC_{2U} + T)/\gamma\eta. \tag{4.58}$$

Equations (4.24a) and (4.58) define the reaction functions of the two firms.

Adding the two equations, and setting $X^c_{1H} = X_{1H}$ and $X^c_{2H} = X_{2H}$, we can derive Z_H:

$$Z_H = (X_{1H} + X_{2H}) = [(MC_{1H} + MC_{2H} + T)/(\gamma\eta(1 + \eta))]^{1/\eta-1}. \tag{4.59}$$

....

Derivation of equation 4.59

$$
\begin{aligned}
(MC_{1H} + MC_{2H} + T)/\gamma\eta &= 2(X_{1H} + X_{2H})^{\eta-1} \\
&\quad +(\eta - 1)(X_{1H} + X_{2H})(X_{1H} + X_{2H})^{\eta-2}, \\
&= (X_{1H} + X_{2H})^{\eta-1}(1 + \eta).
\end{aligned}
$$

$$
Z_H = (X_{1H} + X_{2H}) = [(MC_{1H} + MC_{2H} + T)/(\gamma\eta(1 + \eta))]^{1/\eta-1}. \tag{4.59}
$$

....

We can note that, since consumers will equate price to marginal utility, the quality-adjusted price in this case, $P_{XH} = \gamma\eta Z_H^{\eta-1}$, so we can easily derive the price from (4.59):

$$
P_{XH} = \gamma\eta Z_H^{\eta-1} = (MC_{1H} + MC_{2H} + T)/(1 + \eta). \tag{4.59a}
$$

As before, I denote $X_{2H}/X_{1H} = \theta$, then $X_{1H} = Z_H/(1+\theta)$ and $X_{2H} = \theta Z_H/(1+\theta)$. This allows us to deduce

$$
\theta = (MC_1 - \eta(MC_2 + T))/((MC_2 + T) - \eta MC_1). \tag{4.60}
$$

....

Derivation of equation 4.60

The derivation is essentially the same as (4.26), but replacing firm 2's marginal cost with $MC_2 + T$.

....

(4.60) yields non-negative values for X_{1H} and X_{2H} so long as

$$1/\eta > (MC_2 + T)/MC_1 > \eta. \tag{4.61}$$

In practice (4.61) sets an upper limit on the horizontal TBT a regulator can set, unless he is prepared to let the foreign firm exit the market.

I shall start by assuming that the regulator does not wish to drive the foreign firm out of the market completely (on the grounds that this would presumably reduce consumer welfare). Focusing on the case where there is no vertical regulation (only horizontal regulation), then marginal production costs (before the cost of the barrier is added) will be constant and equal for both firms. Hence $MC_{1H} = MC_{2H} = \overline{MC}$, so the limit to T implied by (4.61) will be

$$T_{\#} = MC(1-\eta)/\eta. \tag{4.52a}$$

I will rewrite T in terms of this constant marginal cost, so that $T = t\overline{MC}$. Note that (4.57) implies

$$Z_H = [\gamma\eta(1+\eta)/(2\overline{MC} + T)]^{1/1-\eta} = [\gamma\eta(1+\eta)/((2+t)\overline{MC})]^{1/1-\eta}.$$

Consumer surplus is

$$U_H = \gamma(1-\eta)Z_H^{\eta}.$$

Price

$$P_{XH} = \gamma\eta Z_H^{\eta-1} = (2+t)\overline{MC}/(1+\eta),$$

which confirms that an increase in t will have a more marked effect on prices, the lower is η.[27]

Revenue by firm 1 is

$$R_1 = (1/(1+\theta))\gamma\eta Z_H^{\eta},$$

which implies profits to the home firm,

$$\pi_{1H} = (1/(1+\theta))(\gamma\eta Z_H^{\eta} - \overline{MC}Z_H).$$

If the regulator acts to maximise

$$\begin{aligned} W_H &= U_H + \pi_{1H}, \\ &= \gamma(1-\eta)Z_H^{\eta} + (1/(1+\theta))(\gamma\eta Z_H^{\eta} - \overline{MC}Z_H), \end{aligned}$$

and can only alter the pure, horizontal TBT, T, then the problem can be solved by the first order condition $dW_H/dT = 0 ==> dW_H/dt = 0$;

$$\gamma\eta(1-\eta)Z_H^{\eta-1}dZ/dt + (1/(1+\theta))(\gamma\eta^2 Z_H^{\eta-1} - \overline{MC})dZ/dt$$

$$-(1/(1+\theta))^2 Z_H(\gamma\eta Z_H^{\eta-1} - \overline{MC})d\theta/dt = 0. \tag{4.62}$$

These terms can be interpreted as follows:

1. $\gamma\eta(1-\eta)Z_H^{\eta-1}dZ/dt$ is the marginal change in consumer surplus from imposing the TBT. Since the TBT raises prices and reduces consumption, this will be negative.

2. $(1/(1+\theta))(\gamma\eta^2 Z_H^{\eta-1} - \overline{MC})dZ/dt$ is the marginal effect of changing total consumer

[27] Since the price elasticity of demand $\varepsilon = 1/(1-\eta)$, it follows that when $\eta = 0$, $\varepsilon = 1$ and the price will equal $(2+t)\overline{MC}$. When $\eta = 1$, $\varepsilon = \infty$ and the price is $(1+(t/2))\overline{MC}$. Hence, the more price-elastic demand is, the lower prices will be and the less the cost of a pure horizontal barrier will be passed on to consumers.

demand on firm 1's profits, based on its initial market share. Raising T causes sales volume to fall, but if this reduction is towards the collaborative level, it may cause a rise in producer surplus.

3. $-(1/(1+\theta))^2 Z_H(\gamma\eta Z_H^{\eta-1} - \overline{MC})d\theta/dt$ is the marginal shift of profits towards firm 1 caused by a discriminatory barrier, T, shifting market demand towards firm 1. This is positive, but clearly its size depends, inter alia, upon the size of initial profits $\gamma\eta Z_H^{\eta} - \overline{MC}Z_H$.

If we look at the three components of dW_H/dt, the conflicting signs of these effects indicate that there may in principle be plenty of circumstances where, even at the point where there is no initial TBT, the marginal gain to domestic welfare from a TBT will be negative, even when there are no tariffs and no other regulatory interference in profits, since initial profits may be insufficient to provide enough profit-shift incentive to outweigh the net effect of the other two effects. This is investigated more formally below.

For Z_H, note that

$$Z_H = [(2+t)\overline{MC}/\gamma\eta(1+\eta)]^{1/\eta-1}.$$

Also

$$dZ_H/dt = (-Z_H/(1-\eta)(2+t)). \tag{4.63}$$

....

Derivation of equation 4.61

For dZ_H/dt, note that

$$\begin{aligned}
Z_H &= [(2+t)\overline{MC}/\gamma\eta(1+\eta)]^{1/\eta-1}; \\
dZ_H/dt &= (1/(\eta-1))[(2+t)\overline{MC}/\gamma\eta(1+\eta)]^{(2-\eta)/(\eta-1)}(\overline{MC}/\gamma\eta(1+\eta)), \\
&= (1/(\eta-1)(2+t))[(2+t)\overline{MC}/\gamma\eta(1+\eta)]^{1/(\eta-1)}, \\
&= (-Z_H/(1-\eta)(2+t)).
\end{aligned}$$

....

When $t = 0$, (4.63) will become

$$dZ_H/dt = -Z_H/2(1-\eta). \qquad (4.63a)$$

Also note that

$$\theta = (1-\eta(1+t))/((1+t)-\eta),$$

and

$$d\theta/dt = -(\theta+\eta)/((1+t)-\eta), \qquad (4.64)$$

which is negative.

....

Derivation of equation 4.64

When both firms face identical marginal costs, (4.62) can be rewritten:

$$\begin{aligned}
\theta &= (1-\eta(1+t))/((1+t)-\eta), \\
&= (1-\eta(1+t))((1+t)-\eta)^{-1}; \\
d\theta/dt &= -((1+t)-\eta)^{-2}(1-\eta(1+t))-\eta((1+t)-\eta)^{-1}, \\
&= -(\theta+\eta)/((1+t)-\eta). \qquad (4.64)
\end{aligned}$$

When $t = 0$ and $\theta = 1$, this is

$$d\theta/dt = -(1+\eta)/(1-\eta). \qquad (4.64a)$$

We should also note that

$$\gamma\eta Z_H^{\eta-1} - \overline{MC} = (\gamma\eta(1+t-\eta)/(2+t))Z_H^{\eta-1}, \qquad (4.65)$$

and

$$\gamma\eta^2 Z_H^{\eta-1} - \overline{MC} = (\gamma\eta((1+t)\eta-1))/(2+t)Z_H^{\eta-1}. \qquad (4.66)$$

Derivation of equations 4.65 and 4.66

Note that

$$\begin{aligned}
\gamma\eta Z_H^{\eta-1} &= (2+t)\overline{MC}/(1+\eta); \\
\gamma\eta Z_H^{\eta-1} - \overline{MC} &= (1+t-\eta)\overline{MC}/(1+\eta); \\
&= (\gamma\eta(1+t-\eta)/(2+t))Z_H^{\eta-1}, \qquad (4.65)
\end{aligned}$$

since

$$\overline{MC} = (\gamma\eta(1+\eta)/(2+t))Z_H^{\eta-1}.$$

It follows that

$$\begin{aligned}
\gamma\eta^2 Z_H^{\eta-1} - \overline{MC} &= ((2+t)\eta - (1+\eta))\overline{MC}/(1+\eta), \\
&= ((1+t)\eta - 1))\overline{MC}/(1+\eta), \\
&= (\gamma\eta((1+t)\eta - 1))/(2+t))Z_H^{\eta-1}. \qquad (4.66)
\end{aligned}$$

....

Looking in turn at the three terms in (4.66),

$$\begin{aligned}
\gamma\eta(1-\eta)Z_H^{\eta-1}dZ/dt &= \gamma\eta(1-\eta)Z_H^{\eta-1}(-Z_H/(1-\eta)(2+t)), \\
&= -\gamma\eta Z_H^{\eta}/(2+t), \text{ from (4.61)} \qquad (4.67)
\end{aligned}$$

$$
\begin{aligned}
(1/(1+\theta))(\gamma\eta^2 Z_H^{\eta-1} - \overline{MC})dZ/dt &= (1/(1+\theta))(\gamma\eta((1+t)\eta-1))/(2+t))Z_H^{\eta-1} \\
&\quad ((-Z_H/(1-\eta)(2+t))), \qquad (4.67a) \\
&= -(1/(1+\theta))(\gamma\eta((1+t)\eta-1))Z_H^{\eta}/((1-\eta)(2+t)^2).
\end{aligned}
$$

$$
\begin{aligned}
-(1/(1+\theta))^2 Z_H(\gamma\eta Z_H^{\eta-1} - \overline{MC})d\theta/dt &= -(1/(1+\theta))^2 Z_H(\gamma\eta(1+t-\eta)/(2+t))Z_H^{\eta-1} \\
&\quad (-(\theta+\eta)/((1+t)-\eta)), \qquad (4.68) \\
&= (1/(1+\theta))^2\gamma\eta(\theta+\eta)Z_H^{\eta}/(2+t).
\end{aligned}
$$

Hence (4.66) can be written

$$
\begin{aligned}
dW_H/dt &= -\gamma\eta Z_H^{\eta}/(2+t) - (1/(1+\theta))(\gamma\eta((1+t)\eta-1))Z_H^{\eta}/((1-\eta)(2+t)^2) \\
&\quad +(1/(1+\theta))^2\gamma\eta(\theta+\eta)Z_H^{\eta}/(2+t). \qquad (4.69)
\end{aligned}
$$

To understand the properties of (4.69), first consider the differential when $t = 0$ and

$\theta = 1:$

$$\begin{aligned} dW_H/dt &= -\gamma\eta Z_H^\eta/2 - (1/2)(\gamma\eta(\eta-1))Z_H^\eta/((1-\eta)4) + (1/4)\gamma\eta(1+\eta)Z_H^\eta/2, \\ &= -\gamma\eta Z_H^\eta/2 + (1/8)\gamma\eta Z_H^\eta + (1/8)\gamma\eta(1+\eta)Z_H^\eta, \\ &= (1/8)\gamma\eta Z_H^\eta(-4+1+(1+\eta)), \\ &= (1/8)\gamma\eta Z_H^\eta(\eta-2). \end{aligned} \tag{4.69a}$$

Note for values of η between 0 and 2 this means that, at the margin, raising a TBT will reduce welfare. In fact, we have assumed (and in the monopoly case at least, non-negative pricing requires) $0 < \eta < 1$.

Because of the complicated nature of (4.69), which becomes a cubic function in t and η, simply examining the gradient of welfare at the point where $t = 0$ is not enough to rule out that a larger horizontal TBT may increase domestic welfare, while comparative static analysis is likely to prove excessively tricky. For that reason, Appendix 4.1 summarises the welfare effects of varying the TBT from zero to the value at which firm 2 leaves the market completely, for a range of assumed values of η at steps between 0.05 and 0.95. The conclusion is clear: the downward gradient of national welfare with respect to t continues up to the point where firm 2 leaves the market for all values of η between 0.05 and 0.95. This implies that the regulator in country 1 will never prefer marginal rises in t to shift profits to firm 1.

What about the possibility that the regulator might choose to exclude firm 2 altogether? Firstly, we note that, as T is increased to $T_{\#}$ and beyond, firm 2's market share gradually falls to zero, and then stays there. There is no sudden shift of market share towards firm 1 caused by firm 2 exiting the market. Secondly, when T passes $T\#$, the profit shift towards firm 1 ceases. Therefore the marginal effect of raising T on country 1's welfare diminishes. This implies that totally excluding firm 2 is unlikely to be an attractive strategy for regulator 1.

We can therefore suggest proposition 4.8:

PROPOSITION 4.8: *Where basic production costs of the two firms are the same, the cost to consumers of a pure, horizontal technical barrier to trade will outweigh the profit-shifting gain to local producers.*

This conclusion may not apply in all model formulations, notably in a multiple-country model, where a subset of countries may 'gang up' on others.[28]

It is also worth noting that the horizontal TBT formulation which has been examined here is in terms of an increased variable cost. Alternatively, a horizontal TBT could, in principle, involve placing an additional fixed cost upon the foreign firm: this could have quite complicated implications for the behaviour and regulation of the domestic firm, which I do not examine here.[29]

4.5.2 Interaction with vertical regulation

The previous section suggests protectionist horizontal trade barriers are unlikely to be attractive in an identical cross-hauling duopoly even when there is no vertical product regulation. When the possibility of vertical regulation (which improves standards experienced by consumers) is introduced, this conclusion is likely to be strengthened. In

[28] Wallner (1998) showed that, in the case of a Cournot tripoly, two large countries would choose to institute a mutual recognition agreement between themselves, but still imposing costs on the firm from a third country.

[29] Effectively, if the horizontal TBT places a large enough fixed cost on the foreign firm, the domestic firm would, under many circumstances, engage in a limit pricing strategy (and so would not charge as high prices as a pure domestic monopoly). This could be seen as a surrogate means of regulating a monopolist, though it would be less attractive if other forms of regulation (including setting minimum vertical quality standards) were available.

Detailed examination of this possibility is seen as beyond the scope of this chapter.

section 4.5, *Table 4.2*, it was shown that, in many circumstances, in our model, a cross-hauling duopoly will be regulated to raise standards to the point where profits are zero, producing the highest possible quality-adjusted output, $Z^{\#}$, where firms do not exit the market. Imposing a horizontal TBT on firm 2 at this point would raise its cost of producing, while if firm 1 increases its share of total output (keeping Z at $Z^{\#}$), this means raising its cost of supply. Such a solution is highly unlikely to be welfare-increasing.

4.5.3 Cost differences between countries

Even 'pure' vertical standards may of course have a protectionist element if production costs differ. In this case, the country with the lower marginal costs of raising quality may have incentives to raise its vertical quality standards above the socially optimal level for what we are defining as protectionist, rather than simply strategic reasons: higher minimum standards may raise the market share of the domestic producer at the importer's expense.

To see how this can happen, consider the case where the two firms are initially unregulated and produce quality-adjusted output X at the same price. However, firm 2 has higher marginal costs of raising quality and lower marginal costs of raising crude output Y than its rival. Formally, $b_2{=}\psi b_1$, in which case raising quality is more expensive for firm 2 than firm 1 if $\psi > 1$. If unregulated marginal costs are the same, it is easy to show that

$$a_2 = \psi^{(\beta-1)/\beta}. \tag{4.70}$$

....

Derivation of Equation (4.70):

Unregulated marginal costs (from equation (4.5)):

$$MC_1 = (a_1/\beta)((a_1/b_1)((1-\beta)/\beta))^{\beta-1} = (a_2/\beta)((a_2/\psi b_1)((1-\beta)/\beta))^{\beta-1} = MC_2;$$

$$(a_2/a_1)^{\beta} = \psi^{\beta-1}. \tag{4.70}$$

....

In this case, in the absence of regulation (denoted with subscript D) the less quality-suited firm 2 will set a lower quality than firm 1:

$$Q_{1D}/Q_{2D} = \psi^{1/\beta} \quad . \tag{4.71}$$

....

Derivation of Equation (4.71):

Unregulated quality chosen by supplier f is

$$Q_{fD} = (((a_f/b_f)(1-\beta)/\beta))^{\beta} X_{fD}.$$

But we assume unregulated costs for the two firms are initially the same, so they produce the same quantity. Also $a_1 = 1$. Hence

$$Q_{1D}/Q_{2D} = (1/b_1)/(a_2/b_2) = (1/a_2)/(b_1/b_2) = \psi^{(1-\beta)/\beta}/(\psi^{-1}),$$

$$= \psi^{1/\beta}.$$

....

To analyse what happens in this case, first, consider a situation where the globally optimal regulatory standard Q^*_{1G} in country 1 lies between Q_{2D} and Q_{1D}. In this situation, raising the regulatory standard Q_{1R} at the margin will raise the costs of the importing firm f_2, lowering its market share and profits, but not affect the costs of f_1. Since in this situation demand will shift towards f_1, its profits will actually improve as Q_{1G} is raised (up to the point where $Q_{1R} = Q_{1D}$). In the absence of international cooperation, the regulator will only take account of the (rising) consumer welfare and f_1's rising profits, and hence will keep raising Q_R at least to Q_{1D}, even if this is above the globally optimal level. In this case, $Q_{1R} > Q^*_{1G}$ and we clearly have not just strategic distortion but (on our narrow definition) protectionism as well, since the higher standard reduces trade and benefits local profits at the expense of foreigners.

What about the case, though, where $Q^*_{1G} > Q_{1D}$? It is fairly easy to show that, once Q_{1R} is raised above Q_{1D}, market shares of the two firms cease to change any more. The ratio of marginal costs of the firms beyond this point is given by

$$MC_2/MC_1 = a_2\theta^{(1-\beta)/\beta}, \tag{4.72}$$

which is constant, and since prices depend only on nmarginal costs and profit markup, the shares of the two firms and η, once Q_{1R} rises above Q_{1D}, further rises in Q_{1R} will not affect firms' market shares, with marginal costs and prices rising at proportionally the same rate for both firms, so there is no profit-shifting motive.

....

Derivation of (4.72)

We concentrate on the point where firm 2 is forced to raise its quality to that which firm 1 would choose freely, Q_{1U}. At this point, firm 1's marginal cost is given by

$$MC_{1U} = (1/\beta)((1/b)((1-\beta)/\beta))^{\beta-1} = (1/\beta)(X_{1U}/Q_{1U})^{(1-\beta)/\beta}. \qquad (4.5)$$

Firm 2's marginal cost is

$$C_{2R} = aX_{2R}^{1/\beta}Q_{1U}^{(\beta-1)/\beta} + bQ_{1U} \ ,$$

$$\begin{aligned} MC_{2R} &= dC_{2R}/dX_{2R} = (a_2/\beta)X_{2R}^{(1-\beta)/\beta}Q_{1U}^{(\beta-1)/\beta} \ , \\ &= (a_2/\beta)(X_{2R}/Q_{1U})^{(1-\beta)/\beta}; \\ MC_{2R}/MC_{1U} &= a_2(X_{2R}/X_{1U})^{(1-\beta)/\beta}. \qquad (4.72) \end{aligned}$$

....

Hence the next proposition:

PROPOSITION 4.9: *Where firms' marginal costs of raising quality differ, there may be a profit-shifting motive for the regulator in the country with the lower marginal cost of raising quality to raise vertical standards above the global optimum. However, this motive only exists if the global quality optimum lies below what the domestic firm in* *that country would choose if unregulated.*

It follows from the above discussion that, while a profit-shifting motive for introducing cost-increasing pure, horizontal TBTs is conceivable, the circumstances in which this is likely to occur, and the degree to which it is likely to apply are greatly reduced compared to the implications of previous studies (e.g. Baldwin, 2001, Wallner, 1998).

4.6 Prohibitive costs of providing different standards to different markets

We have so far assumed producers are able to supply at different qualities to different markets. Generally speaking this is the case (for example, the same producers can provide left- and right-hand drive cars, or TV sets for sale in the UK and USA), though usually at a cost. It is worth considering the effects of the extreme alternative case, where the cost of supplying different qualities to different markets is prohibitive.[30] In this case, if a firm is to supply both markets, it must produce at the same quality for both. This does produce somewhat more complicated solutions: I shall concentrate on the case where there are two countries but just one producing firm, in the exporting country.

Under autarky, the optimal quality standard in the exporting country would be given by

$$d\pi_d/dQ_d + dU_d/dQ_d = 0, \tag{4.73}$$

where d refers to the exporting country's domestic market. The first term is negative,

[30] An example being the claim by US soya producers that separately labelling GM and non-GM soya for sale abroad would be prohibitively expensive.

the second positive.

I shall assume consumers' tastes are identical and that the cost structure is such that this is also the global optimum standard Q_d^*.

Now consider a mutual recognition agreement. The analysis proceeds much as above: the exporting country regulator sets quality standards for both countries, and since he will take account of the (negative) effect of regulations on the exporting firm's profits, but not of the (positive) effect on foreign consumers' utility, he will seek to set

$$d\pi_d/dQ_d + dU_d/dQ_d + d\pi_f/dQ_d = 0. \tag{4.74}$$

Given $d\pi_f/dQ_d < 0$ (bearing in mind that we are now assuming there is only one firm, so no profit shift) and $d_2\pi_f/dQ_d^2 < 0$, it is fairly trivial to show that this will result in a standard $\widetilde{Q}_d$ lower than the socially optimal Q_d^*. In general, we would expect the larger the export markets relative to the domestic market, the greater the incentive to the regulator to set suboptimal standards.

Now consider what happens where there is no mutual recognition, but non-cooperation between the regulators. Assume the exporting country regulator has initially set Q_d. When the regulator in the importing country raises its quality standards Q_f, it does not care that the foreign firm has to raise quality in both countries (and so makes less profits than with a lower standard). Hence the regulator will choose to raise quality, up to the point $Q_f = Q_d + \varphi_f\{Q_d\}$, at which the firm would exit the market. φ_f is given by solving the equation

$$\pi_d\{Q_d\} = \pi_d\{Q_d + \varphi_f\} + \pi_f\{Q_d + \varphi_f\}. \tag{4.75}$$

In this case, the point at which the firm exits the export market will depend upon Q_d, and upon the relative size of the two markets - a firm will much more readily abandon a small market, implying that, ceteris paribus, φ_f will be less the smaller the export market.

This produces a bargaining game between the two countries' regulators, the outcome of which will involve a degree of uncertainty. If the importing country regulator sets its standard above $Q_f = Q_d + \varphi_f\{Q_d\}$, the firm will not be prepared to export. The exporting country's regulator, in turn, will not set Q_d higher than the level Q_d^H, where

$$U_d\{Q_d^H + \varphi_f\{Q_d^H\}) + \pi_d\{Q_d^H + \varphi_f\{Q_d^H\}\} + \pi_f\{Q_d^H + \varphi_f\{Q_d^H\}\} = U_d\{Q_d^*\} + \pi_d\{Q_d^*\}, \tag{4.76}$$

in other words it will only go above Q_d^* so long as it makes enough profits from sales abroad to compensate it for the loss of profits at home. For this reason Q_d^H is likely to be higher the larger the foreign country. Standards in the importing country will exceed Q_d^H by $\varphi_f\{Q_d^H\}$. At the other extreme, the minimum level the exporting country's regulator would ever set is Q_d^L , which satisfies

$$d\pi_d\{Q_d^L + \varphi_f\{Q_d^L\}\}/dQ_d + dU_d\{Q_d^L + \varphi_f\{Q_d^L\}\}/dQ_d + d\pi_f\{Q_d^L + \varphi_f\{Q_d^L\}\}/dQ_d = 0, \tag{4.77}$$

where the only difference from the mutual recognition level $\widetilde{Q}_d$ is given by the fact that the foreign regulator will maintain somewhat higher quality (and hence lower profits) abroad.

Between these two extremes, the outcome quality levels will be determined by bilateral bargaining, reflecting the bidding process and the sizes and institutions of the countries. It is not possible to come to a firm conclusion as to whether the outcome will exceed or fall short of the globally optimal regulation level.

The firm conclusions we can come to from this section are

PROPOSITION 4.10: *Where only one country produces the good, mutual recognition will produce quality below the global optimum, and the importing country will be unambiguously worse off than under non-cooperation.*

PROPOSITION 4.11: *When goods cannot be produced at different qualities for different markets and there is no cooperation, goods will be produced to the standard set in the importing country, which will exceed that in the exporting country. The latter however will set a ceiling on how high the importing country can set standards without exports ceasing. There will be a bargaining game to determine the two standards.*

Looking at the current standoff between the EU and the USA over separate labelling of GM foodstuffs, the block to trade looks like a disequilibrium phenomenon while negotiation proceeds. The EU, as the expected importer of GM soya, would clearly be better setting testing and labelling standards independently. The USA by contrast would like a mutual recognition agreement, under which it could export GM soya with suboptimal safeguards. The current standoff will presumably continue until there is a clear understanding of whether mutual recognition will be enforced.

4.7 Conclusion

The WTO Agreements recognise the danger of regulatory protection when setting national standards, but also acknowledge legitimate reasons for such standards. The idea that regulations are trade reducing seems to result from counterfactual studies which implicitly assume standards are purely cost-increasing, with no effect on quality experienced by consumers. The conclusions of this literature are contradicted by the (largely ignored) empirical studies such as Swann et al (1996) which show increasing use of standards tends to go with increased trade. At the other end of the literature is a small amount of theoretical work, mainly based on the Shaked/Sutton differentiated consumers with oligopoly model, which indicates that strategic policy distortions are likely in the presence of trade, and suggests that mutual recognition will increase welfare.

Unlike previous studies, this paper looks at more classical monopolistic distortions. On the functional forms investigated, unregulated monopoly power leads to suboptimal quality as well as quantity of goods supplied. Regulation increases both quantity and quality available, and there is therefore a valid economic reason for quality regulation of a form which actually increases trade.

It is further shown that where the sole supplier is foreign, there can potentially be an incentive for the domestic regulator to set an excessive minimum standard, reducing profits but benefiting consumers (though this may be limited by the nonnegative profit constraint). This strategic distortion, however, does not conform to traditional ideas of protectionism. On the contrary, it will actually lead to excessive trade volumes, and does not necessarily involve bias against foreign producers. This conclusion holds even when producers can only produce a single quality for both markets.

When there are two suppliers (one domestic, one foreign), then, at least on the assumptions of this paper, the result is that standards will be raised above the global optimum: however, in many cases, the degree to which this can happen is strongly limited by the assumed nonnegative profit constraint.

Mutual recognition in the case where only one country is an exporter is tantamount to allowing the exporting country to set global standards. In this case, the overregulation when the importing country sets its standards will be replaced with underregulation: the net effect on global welfare is ambiguous (though profits gain while consumers in all countries lose).

Mutual recognition in the case of balanced two-way trade is more complicated, since there are two opposite-signed effects at work: on the one hand, there is an incentive for regulators to allow lower than optimal domestic standards, to boost exporters' profits at the expense of foreign consumers. On the other hand, there is a profit-shift effect of increasing market share by forcing up standards is enough to prevent regulators from undercutting each other on standards. Numerical simulations show that, given the functional forms in this paper, the profit shift effect outweighs the cost-cutting effect, and mutual recognition will lead to standards marginally higher than a single global regulator would choose, though these are less high than under noncooperative standard-setting.[31] The implications are that mutual recognition, while not globally optimal, is often welfare-improving, though it may reduce, rather than increase, trade.

A key result of this analysis is that market structure is central in determining the best form of regulatory regime (assuming a single, global regulator is infeasible). Mutual recognition looks much more attractive in cases where trade is reasonably balanced in both directions. It may be less attractive in the case of trade in new products (where a single producer holds the monopoly), or of North-South trade, which is more driven by factor endowments.

[31] Except where the nonnegative profit intervenes, in which case mutual recognition and noncooperative setting result in the same standards.

As for assessing current regulations: actually disentangling how far these regulations really comprise regulatory protection may not be an easy task. This paper casts a somewhat sceptical light on the tendency to assume that regulations are trade-impeding and should be tackled under the auspices of the WTO or other trade bodies. Assessment of the welfare effects of harmonisation or mutual recognition should not be carried out on the assumption that regulations are purely cost-increasing, since the above analysis indicates that if regulators are seeking to maximise national welfare it is unlikely they will introduce barriers of this kind, and indeed national variations in standards may genuinely reflect differences in national preferences with regard to risk, quality etc. To infer, as some studies have done, that a high proportion of Trefler's (1995) 'missing trade'[32] is due to horizontal regulatory barriers is probably incorrect. Indeed, the absence of international cooperation is actually likely to lead to over-regulation of standards which increases, rather than reducing, trade volumes.

It is likely that regulation will be higher in sectors which are dominated by imports: this is more likely to be ostensibly for reasons of raising consumer utility, though where the cost of such regulations falls largely upon foreign firms there is an incentive to over-regulate (there is a parallel with the tax competition literature). However, this over-regulation will probably increase, not decrease trade volumes.

In the light of these arguments, it may be that policymakers have been too ready to view quality regulations simply an issue of protection, to be dealt with through international trade negotiations. It may be more appropriate to view it as an issue of international policy coordination, to avoid a natural bias towards overregulation where production is global but regulation is national, but also to avoid a bias towards un-

[32] 'Missing' in the sense that trade generally falls far short of what gravity models predict

derregulation (which may show up as inadequate testing or labelling or the deliberate introduction of product incompatibilities) where standards are set primarily by the exporting country.

In conclusion, mutual recognition needs to be assessed on a case-by-case basis, taking account of market structure. In addition, it may well be that mutual recognition makes most sense when it is only one aspect of a package involving elements of both harmonisation and mutual recognition (so that only countries which meet certain minimum standards are allowed into the mutual recognition agreement). In practice, this does seem to be the route policymakers have followed (e.g. with the European Single Market).

Policy distortions will also be affected by the degree of flexibility producers have to change specifications to supply different markets. Where there is little such flexibility, then there may be a bargaining game between different countries in setting regulations between those (primarily importing) countries who favour over-regulation and those (exporters) who favour underregulation. Trade may temporarily be obstructed as part of this bargaining process (as in the GM foods case in recent years), but to interpret this just as protection on the part of the importing countries is to miss the strategic bias in policies of the exporting countries, as well.

A few cautions should be added at this point. There are aspects of trade under imperfect competition which require some further investigation. For example, many industry standards are produced either by industry associations or by the industry in conjunction with government bodies (the latter in the cases where compulsory regulations are applied). However, it would be too simplistic to assume that regulatory standards are fully voluntary and protectionist[33] by the industry players themselves: first, they may be simply a response to the threat of legislation. Moreover, there is a question why a government should rubber stamp welfare-reducing standards. However, there may well be scope for analysing the regulatory process as a principal-agent game, where the government desires higher quality for its citizens but only the firms concerned possess the relevant information.

There is also some scope for analysing the effects of limit pricing by a colluding oligopoly - depending upon whether national standards make entry easier or harder. Both these topics go somewhat beyond the scope of this paper, as does the extension of the model to a multi-country model.

[33] There is a possible argument that quality standards are a means of imposing higher fixed costs on new entrants. However, against this, centrally imposed standards may increase product compatibility, hence making entry easier.

APPENDIX 4.1: Welfare and pure, horizontal trade barriers

In the main text, I established that, for all values of $\eta < 2$, the marginal effect on domestic welfare of a small technical barrier to trade on the foreign firm in an identical, cross-hauling duopoly is always negative. However, to show that this applies over the full range of feasible barriers (up to the point where the foreign firm, 2, exits the market) and over a range of demand elasticities requires numerical simulation.

The model below is simulated using GAMS.

Gross consumer utility

$$V = \gamma Z^{\eta}.$$

Equating price to marginal utility, net consumer utility

$$\begin{aligned} U &= V - R, \\ &= \gamma(1-\eta)Z^{\eta}. \end{aligned}$$

Revenue

$$R = \gamma\eta Z^{\eta}.$$

Firm 1's share of the market

$$S_1 = 1/(1+\theta).$$

Given a constant marginal cost, $\overline{MC}$, firm 1's profit

$$\pi_1 = S_1(R - \overline{MC}Z).$$

Domestic welfare

$$W_1 = U + \pi_1.$$

Now introduce a horizontal TBT, $T = t\overline{MC}$. This allows us to derive θ and Z, once we have assumed a value for η.

$$\theta = (1 - \eta(1 + t))/((1 + t) - \eta).$$

$$Z = [(2 + t)\overline{MC}/\gamma\eta(1 + \eta)]^{1/\eta - 1}.$$

We are interested in the range $0 < \eta < 1$. Also note that firm 2 exits the market at the point where $\theta = 0$. This will occur at value t^*, where

$$\begin{aligned} 1 - \eta(1 + t^*) &= 0; \\ t^* &= (1 - \eta)/\eta. \end{aligned}$$

I start by assuming $\gamma = 1$ and $\overline{MC} = 1$ (without loss of generality in either case).

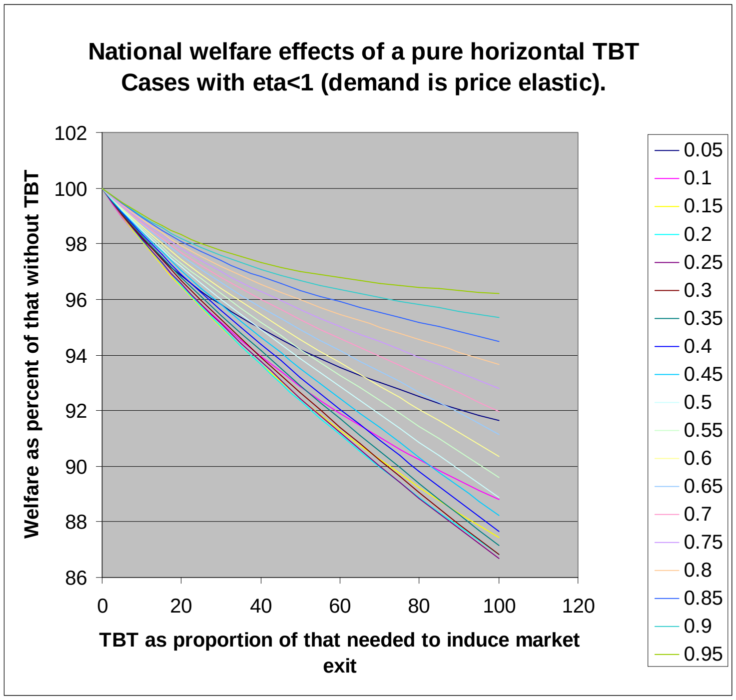
Simulation results: price elastic demand.

National welfare is calculated over a range of values of η between 0.05 and 0.95. This corresponds to a price elasticity for Z of between 1.05 and 20. The technical barrier to trade is scaled here relative to t^* (the value which makes firm 2 exit the market), so that the horizontal scale is $100t/t^*$.

With price elastic demand, a pure, horizontal TBT is never welfare-increasing.

Price inelastic demand.

It is worth noting that, with price inelastic demand ($\eta > 1$) the above first order



condition equations would yield negative values for net consumer utility. Consequently, I assume these elasticity values are ruled out.

APPENDIX 4.2: Properties of the Cournot-Nash model with constant elasticity demand

Constant elasticity demand models are more complicated in their properties than linear demand functions (which explains the fact that the latter are far more frequently used in duopoly models): however, the constant elasticity demand model is more easily combined with a Cobb-Douglas quality model than is a linear demand function, which is why I have chosen this functional form here.

Plotting the functions (4.24a and b) numerically shows the shapes of the two firms' best response curves. Typically, these bend back on themselves, so that when one firm produces very low levels of output, its produce is a strategic complement to its rival firm, while at higher levels of output they become strategic substitutes. These results are in line with Collie's (1996) findings.

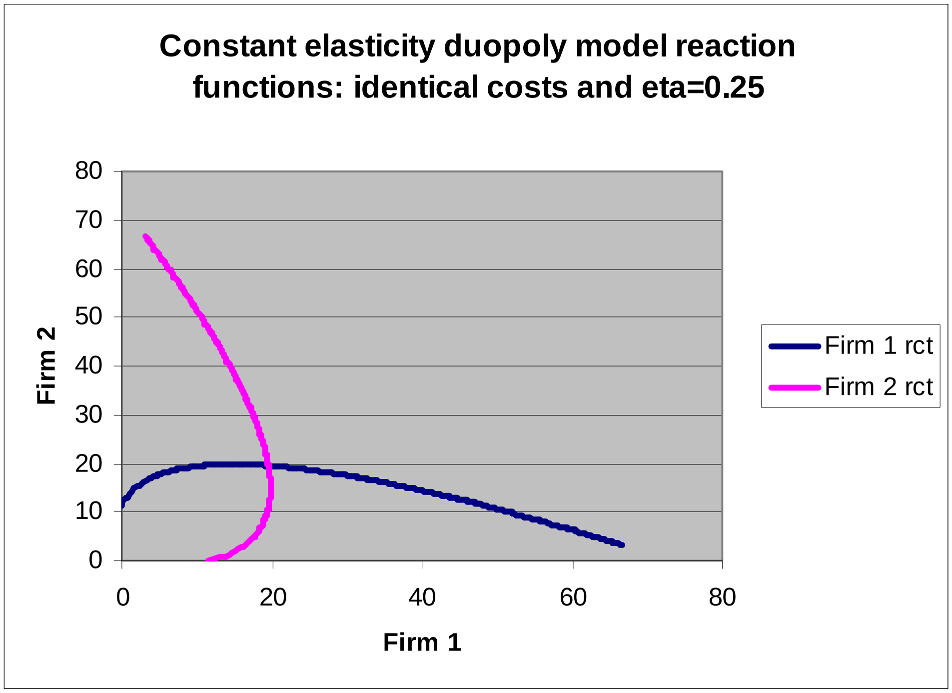
Despite the curved reaction functions, there will be at most one equilibrium where both firms produce positive output, as given by equations (4.25-4.26), which will occur as long as the cost ratio for the two firms satisfies (4.26a).

Uniqueness

Note that $\theta = (1 - \eta M)(M - \eta)^{-1}$, where M is MC_2/MC_1. First of all, in the unregulated case, marginal costs are constant, so M is constant, which implies there will be an unique value of θ.

Now consider the case where each firm f produces to a constant quality $\overline{Q}_f$.

$$MC_1 = (1/\beta)(X_1/\overline{Q}_1)^{(1-\beta)/\beta}, \tag{4.30}$$



and similarly for firm 2. Consequently

$$M = MC_2/MC_1 = \kappa\theta^{(1-\beta)/\beta}, \text{ where}$$
$$\kappa = (\overline{Q}_1/\overline{Q}_2)^{(1-\beta)/\beta} \text{ and is constant.}$$

Consequently

$$\begin{aligned}
\theta &= (1-\eta M)(M-\eta)^{-1}, \\
&= (1-\eta\kappa\theta^{(1-\beta)/\beta})/(\kappa\theta^{(1-\beta)/\beta}-\eta); \\
\kappa\theta^{1/\beta} - \eta\theta &= 1 - \eta\kappa\theta^{(1-\beta)/\beta}; \\
\kappa\theta^{1/\beta}(1+\eta\theta) &= 1+\eta\theta; \\
\theta^{1/\beta} &= 1/\kappa,
\end{aligned}$$

which will give an unique solution for θ.

Note also that, if the two firms produce with identical costs, their equilibrium outputs will be strategic substitutes (in other words, the two best response curves are both backward-sloping at the point where they intersect). We start by totally differentiating (4.24a), giving

$$\begin{aligned} 0 &= (\eta-1)(X_1+X_2^c)^{\eta-2}(dX_1+dX_2) \\ &\quad +(\eta-1)(\eta-2)X_1(X_1+X_2^c)^{\eta-3}(dX_1+dX_2) \\ &\quad +(\eta-1)(X_1+X_2^c)^{\eta-2}dX_1, \end{aligned}$$

$$\begin{aligned} &[(\eta-1)(X_1+X_2^c)^{\eta-2}+(\eta-1)(\eta-2)X_1(X_1+X_2^c)^{\eta-3} \\ &+(\eta-1)(X_1+X_2^c)^{\eta-2}]dX_1 \\ = \quad & -[(\eta-1)(X_1+X_2)^{\eta-2}+(\eta-1)(\eta-2)X_1(X_1+X_2)^{\eta-3}]dX_2, \end{aligned}$$

$$\begin{aligned} &[(X_1+X_2)+(\eta-2)X_1+(X_1+X_2)]dX_1 \\ = \quad & -[(X_1+X_2)+(\eta-2)X_1]dX_2, \end{aligned}$$

$$dX_1/dX_2 = -[(X_1+X_2)+(\eta-2)X_1]/[2(X_1+X_2)+(\eta-2)X_1].$$

This will have a negative sign (X_1 and X_2 are strategic substitutes) as long as $[(X_1 + X_2)+(\eta-2)X_1]$ and $[2(X_1+X_2)+(\eta-2)X_1]$ have the same sign. Substituting $X_2 = \theta X_1$, the numerator and denominator become $X_1[\theta + \eta - 1]$ and $X_1[2\theta + \eta]$ respectively. The second of these terms is clearly going to be positive, so that implies X_1 and X_2 are strategic substitutes as long as $\theta + \eta - 1 > 0$, which means $\theta > 1 - \eta$.

In a Cournot-Nash equilibrium we have established

$$\theta = (MC_1 - \eta MC_2)/(MC_2 - \eta MC_1),$$

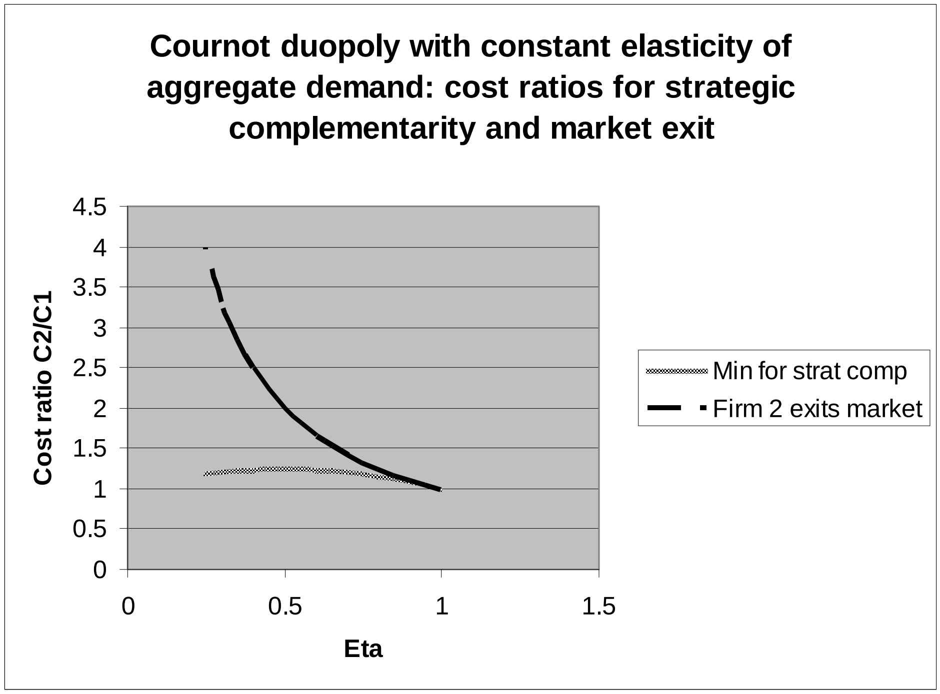
so this implies

$$\begin{aligned}(MC_1 - \eta MC_2)/(MC_2 - \eta MC_1) &> 1 - \eta; \\ (1 - \eta M)/(M - \eta) &> 1 - \eta,\end{aligned}$$

where $M = MC_2/MC_1$. Since for $0 < \eta < 1$ we can only have positive X_1 and X_2 if both $(\eta MC_2 - MC_1)$ and $(\eta MC_1 - MC_2)$ are both negative. Hence, multiplying both sides by $(M - \eta)$, the condition becomes

$$\begin{aligned}(1 - \eta M) &> (1 - \eta)(M - \eta), \\ \eta M + (1 - \eta)M &< 1 + \eta(1 - \eta), \\ M &< (1 + \eta - \eta^2).\end{aligned}$$

Since we are assuming $0 < \eta < 1$, when $MC_2 \leq MC_1$ the two firms' outputs will always be strategic substitutes at the equilibrium point. It is therefore only where MC_2 exceeds MC_1 (or when regulation or other policies increase MC_2 compared to MC_1) that the



possibility of strategic complementarity emerges.

Note that if $MC_2 \geq MC_1/\eta$, firm 2 will exit the market anyway. However, the chart shows that as η falls below 1 there is an increasingly significant range of possible values of MC_2/MC_1 for which the firms' outputs will be strategic complements.[34]

Stability

There is a question mark over the stability of the Cournot-Nash equilibrium in the constant elasticity case (in other words, would the firms always return to the equilibrium, if they followed an iterative Cournot process following a shock. Stability requires firm1's reaction function to slope downwards more steeply than firm 2's, if drawn with firm 1's output on the horizontal axis. In other words, we want $-(dX_1/dX_2) > -1/(dX_2/dX_1)$,

[34] The most significant effect of strategic complementarity is that it greatly increases the likelihood that the firms will behave in a de facto collusive manner. (Thanks to Vasileis Zikos for this point).

which implies $-(dX_1/dX_2) \times (-(dX_2/dX_1)) > 1$. But

$$-(dX_1/dX_2) = [(X_1 + X_2) + (\eta - 2)X_1]/[2(X_1 + X_2) + (\eta - 2)X_1],$$

and

$$-(dX_2/dX_1) = [(X_1 + X_2) + (\eta - 2)X_2]/[2(X_1 + X_2) + (\eta - 2)X_2],$$

neither of which exceeds 1, so the stability conditions are not satisfied.

Whether this is a significant drawback of the model depends upon the interpretation being given to the Cournot-Nash equilibrium (effectively, whether it is seen as the outcome of an sequence process of disequilibrium moves, or as the product of simultaneous decisions). To cite one recent text: ‘The modern reinterpretation of the Cournot game is that it involves simultaneous choice of outputs in a single period. Firms select output only once, and neither firm ever gets the chance to react to its opponent. Instead we construct and use the best-response functions only to find the Nash equilibrium quantities.’[35]

[35] Church and Ware: Industrial Organization: a strategic approach (McGraw Hill, 2000). Page 281.

APPENDIX 4.3: Numerical simulation model for effects of elasticity and share parameters in a cross-hauling duopoly model.

The model is programmed in GAMS, and calculates solutions under a variety of regulatory regimes for regulatory quality given a variety of assumptions regarding β, the Cobb-Douglas value share parameter attached to quality and η, the inverse of the price-elasticity of demand. Simulations also confirmed that varying b, the linear cost scalar for quality, and γ, the market size parameter, do not affect the ratios of the various quality standards derived by the model, and so these have been dropped from the grid search. Consequently, I concentrate on the case where $b = 1$ and $\gamma = 10$. Values investigated for β and η are $0.3, 0.4, 0.5, 0.6, 0.7$ and 0.8. Solutions for values outside this range proved harder to compute in the mutual recognition case, due to the nonlinearity of the formulae involved.

Unregulated behaviour of the duopoly

I start by calculating

$$\begin{aligned}\Psi &= \beta\gamma\eta(1+\eta);\\ \upsilon &= (1-\beta)\eta/(1-\beta\eta).\end{aligned}$$

From these, I derive

$$Q_U = \Psi^{1/(1-\eta)} 2^{(2-\eta)/(\eta-1)} ((1/b)(1-\beta)/\beta)^{1/(1-\upsilon)}. \tag{4.28}$$

Behaviour of a duopoly under noncooperative regulation

I start by deriving the parameters

$$K_1 = (\gamma\eta/2)\Psi^{\beta\eta/(1-\beta\eta}2^{(1-2\beta)/(1-\beta\eta)}; \quad (4.34)$$

$$K_2 = 2(1-\eta)/\eta; \quad (4.36a)$$

$$K_3 = \beta(1+\eta)/2. \quad (4.36b)$$

The formula for Q_{RC} is then given by

$$Q_{RC} = ((K_2 + 1 - K_3)\upsilon K_1/b)^{1/(1-\upsilon)}. \quad (4.40)$$

Point of exit for firms

The quality standard at which firms exit the market is then given by

$$Q_{\#} = ((1 - K_3)K_1/b)^{1/(1-\upsilon)}. \quad (4.38)$$

Global optimum standard

The standard chosen by a single global regulator (which corresponds to the global optimum) is

$$Q_G = (((K_2/2) + 1 - K_3)\upsilon K_1/b)^{1/(1-\upsilon)}. \quad (4.42)$$

Standard under mutual recognition

The standard chosen by regulators under mutual recognition is harder to solve for, and I have opted for setting out the problem as a set of simultaneous equations, rather than solving a single, reduced-form version. I start by defining

$$K' = (\upsilon/\eta)\Psi^{\beta/(1-\beta\eta)}2^{(1-2\beta)/(1-\beta\eta)}, \quad \text{(from 4.31)}$$

where K' is (υ/η) times the ratio in equilibrium of combined sales of the two firms, Z to the quality set by the regulators, $Q_{MR}^{\upsilon/\eta}$. Consequently, our first equation is

$$Z_{1M} = (\eta/\upsilon)K'Q_{1M}^{\upsilon/\eta}, \text{ from 4.31.} \tag{i}$$

Note that

$$dZ_{1M}/dQ_{1M} = K'Q_{MR}^{(\upsilon-\eta)/\eta}, \text{ differentiating 4.31.} \tag{ii}$$

Our third equation relates to the effect of changing just one country's standard, while keeping the other's constant :

$$dZ_{1M}/dQ_{1M} = (1/2)dZ/dQ_{RC}, \text{ from H} \tag{iii}$$

For firm 1's revenue in each market

$$dR'_{1M}/dQ_{1M} = (\gamma\eta^2)(Z_{1M}^{(\eta-1)}/2)(dZ_{1M}/dQ_{1M} + 2(Z_{1M}/\eta)dS_1/dQ_{1M}), \text{ from 4.47a.} \tag{iv}$$

where dS_1/dQ_{1M} is the marginal effect of changing the quality standard in country 1, Q_{1M}, on firm 1's market share. Likewise, the effect on firm 1's variable costs in each market

$$\begin{aligned} dVC'_{1M}/dQ_{1M} &= (1/\beta)2^{-1/\beta}(Z_{1M}/Q_2^c)^{(1-\beta)/\beta)}(dZ/dQ_{1M} + 2Z_{1M}dS_1/dQ_{1M} \\ &\quad +(\beta-1)Z_{1M}/Q_2^c), \text{ from 4.47b.} \end{aligned} \tag{v}$$

For the marginal effect on firm 1's fixed cost, associated with each market

$$dFC/dQ_{1M} = b. \tag{vi}$$

The marginal effect of changing Q_{1M} on firm 1's profits in each market is consequently

$$d\pi_{1,c}/dQ_{1M} = dR'_{1M}/dQ_{1M} - dVC'_{1M}/dQ_{1M} - dFC/dQ_{1M}. \tag{vii}$$

The marginal effect of changing Q_{1M} on consumer surplus in country 1 is

$$dU_M/dQ_{1M} = \gamma\eta(1-\eta)Z_{1M}^{\eta-1}dZ/dQ_{1M}. \tag{viii}$$

The marginal effect on country 1's welfare is the sum of the marginal effects of changing Q_{1M} on consumer surplus in country 1 and on firm 1's profits in the two markets:

$$dW_1/dQ_{1M} = dU_M/dQ_{1M} + 2d\pi_{1,c}/dQ_{1M}. \tag{ix}$$

The standard the regulator will choose under mutual recognition will be the value of Q_{1M} in the above equations for which

$$dW_1/dQ_{1M} = 0. \tag{x}$$

Using GAMS, I solve for the solution to (i)-(x) for each of 36 points on the grid of $\{\beta, \eta\}$. These values can then be compared with those for Q_U, Q_{RC}, Q_G and $Q_{\#}$. Since all outcomes differ greatly in scale when β and η are altered, I have normalised results by expressing them all relative to Q_U.

$Q_{\#}/Q_U$	$\eta =$	0.3	0.4	0.5	0.6	0.7	0.8
$\beta =$	0.3	2.10	2.01	1.94	1.87	1.81	1.75
	0.4	2.24	2.13	2.03	1.94	1.86	1.78
	0.5	2.43	2.28	2.15	2.03	1.93	1.83
	0.6	2.72	2.52	2.34	2.17	2.03	1.89
	0.7	3.19	2.90	2.64	2.41	2.20	2.00
	0.8	4.13	3.66	3.24	2.87	2.53	2.22

Q_G/Q_U	$\eta =$	0.3	0.4	0.5	0.6	0.7	0.8
$\beta =$	0.3	1.83	1.79	1.75	1.73	1.70	1.68
	0.4	1.82	1.78	1.75	1.72	1.69	1.67
	0.5	1.81	1.77	1.74	1.71	1.68	1.66
	0.6	1.81	1.76	1.72	1.69	1.67	1.65
	0.7	1.80	1.75	1.71	1.68	1.66	1.64
	0.8	1.79	1.74	1.70	1.67	1.64	1.62

Q_{RC}/Q_U	$\eta =$	0.3	0.4	0.5	0.6	0.7	0.8
$\beta =$	0.3	3.77*	3.75*	3.75*	3.79*	3.86*	3.98*
	0.4	3.71*	3.67*	3.66*	3.69*	3.75*	3.88*
	0.5	3.64*	3.59*	3.56*	3.58*	3.64*	3.76*
	0.6	3.58*	3.51*	3.46*	3.46*	3.50*	3.62*
	0.7	3.51*	3.42*	3.36*	3.33*	3.35*	3.46*
	0.8	3.45	3.33	3.24	3.19*	3.19*	3.25*

* denotes values where the nonnegative profit constraint will intervene to prevent the regulator from achieving Q_{RC}. In these cases, the regulator will set $Q = Q_{\#}$.

Q_{MR}/Q_U	$\eta =$	0.3	0.4	0.5	0.6	0.7	0.8
$\beta =$	0.3	1.85	1.82	1.78	1.75	1.72	1.69
	0.4	1.86	1.82	1.78	1.75	1.72	1.68
	0.5	1.86	1.82	1.79	1.75	1.72	1.69
	0.6	1.86	1.83	1.79	1.76	1.73	1.69
	0.7	1.87	1.83	1.80	1.76	1.73	1.70
	0.8	1.87	1.84	1.80	1.77	1.74	1.71

We can replace Q_{RC} with $\widetilde{Q}_{RC}$, the profit-constrained level set by noncooperative regulators, and Q_{MR} with $\widetilde{Q}_{MR}$, the profit-constrained level set by regulators under mutual recognition. In all cases examined, both $\widetilde{Q}_{RC}$ and $\widetilde{Q}_{MR}$ exceed the global optimum, Q_G. $\widetilde{Q}_{RC}$ either exceeds $\widetilde{Q}_{MR}$ or the two are the same.

$(\widetilde{Q}_{RC} - \widetilde{Q}_{MR})/Q_U$	$\eta =$	0.3	0.4	0.5	0.6	0.7	0.8
$\beta =$	0.3	0.24	0.20	0.16	0.12	0.09	0.06
	0.4	0.38	0.31	0.24	0.19	0.14	0.10
	0.5	0.57	0.46	0.37	0.28	0.20	0.14
	0.6	1.85	0.69	0.55	0.42	0.30	0.20
	0.7	1.32	1.07	0.85	0.64	0.46	0.30
	0.8	1.57	1.49	1.44	1.10	0.79	0.51

It follows that mutual recognition lowers standards compared to noncooperation in cases where β is relatively high and especially when η is relatively low. We can also see that $\widetilde{Q}_{MR}$ exceeds Q_G at all grid points investigated, which suggests that the introduction of mutual recognition is a move towards the global welfare-maximising quality standard.

$(\widetilde{Q}_{MR} - Q_G)/Q_U$	$\eta =$	0.3	0.4	0.5	0.6	0.7	0.8
$\beta =$	0.3	0.02	0.03	0.03	0.02	0.02	0.01
	0.4	0.03	0.04	0.04	0.03	0.03	0.01
	0.5	0.05	0.05	0.05	0.05	0.04	0.02
	0.6	0.06	0.06	0.07	0.06	0.06	0.03
	0.7	0.07	0.08	0.08	0.08	0.07	0.06
	0.8	0.08	0.10	0.10	0.11	0.10	0.09

Chapter 5

Search and the Path Dependency of Trade

This chapter presents an alternative to the traditional view that trade decisions are made under perfect information. With differentiated products and suppliers of variable reliability, detailed knowledge of trading partners is important for many types of goods and services, yet although there is a relatively new literature exploring the nature of matching in trade and evidence for its existence, the implications for trade policy and the dynamics of trade flows have not, to date, been explored. In the presence of imperfect information, path dependency may conceivably be just as important on the demand as the supply side of trade. Search theory indicates that not only will the current pattern of trade reflect past costs and policy decisions, but the price elasticity of import demand will be path-dependent. Equally importantly, today's trade policy decisions will have important implications for future trading patterns and likely future policy decisions.

To investigate these implications, I build on existing matching models of trade to incorporate search. I draw a number of propositions, many of which are new to this literature, linking trade volumes and elasticities to the parameters of the search process and to the past history of trade between countries. If economies are seen as moving from being relatively closed initially,[1] then contract periods and the availability of finance will greatly affect growth of trade. The behaviour of trading firms depends to a large extent upon whether they are already well-matched or still searching for partners. Countries with a large initial number of well-matched firms will show relatively low price elasticities of demand for imports and exports, and in particular for trade with new partners. Apparent home bias in current trade patterns may well reflect past, rather than present, trade costs and protection.

While there are many applications of this theory, I focus here particularly upon the implications for the sequencing and timing of trade liberalisation decisions. It is shown, using a fairly simple example, that match-searching theory strengthens the argument that global welfare is likely to be enhanced by liberalising trade multilaterally rather than by stepwise bilateral deals. However, individual countries may lose from this route, and I investigate the circumstances under which bilateral deals may serve as stepping stones towards global liberalisation.

5.1 Outline of the chapter

The structure of this paper is as follows. In section 5.2, I review the relatively recent literature on matching models of trade. I then develop in section 5.3 a theoretical 'match-searching' model. This is a very basic model of the search process, which I use to derive a number of key results expounded as propositions. In section 5.4, I investigate the

[1] Trade increased from 6 per cent of global GDP in 1950 to 15 per cent by the mid 1990s (source: Maddison, unpublished).

significance of the path-dependency of match-searching models of trade for sequential trade liberalisation agreements.

Section 5.5 suggests other possible applications of the model. Finally, in section 5.6, I briefly consider more realistic but complicated search models. These are seen as extensions/modifications of the basic model, incorporating consumer search or including networking between firms. Many of the basic properties of the match-searching model carry across to these situations.

5.2 Background: historicity in demand and supply-side models of trade

The notion of path dependency on the supply side of international trade is a familiar one, developed from the infant industry argument and running through the more recent literature on 'learning by doing', scale and agglomeration economies in trade, which can broadly be labelled the 'New Trade

Theory'.[2] However, there has been much less recognition of the importance of history and path-dependency on the demand side.

Two important characteristics of import demand are:-

1) In general countries trade far less between each other than the theory would predict even when account is taken of transport costs.[3]

[2] See eg Grossman and Helpman (1993)

[3] This was most notably shown by McCallum (1995) who demonstrated that, after correcting for size of economy and distance effects, trade between Canadian provinces exceeded that between Canadian provinces and US States by a factor of around 20. This discrepancy was referred to by Trefler as 'missing trade'. Other studies (e.g. Anderson and van Wincoop, 2003) find much smaller residual border effects.

2) Trading patterns between countries frequently follow historical patterns. Hence, for example, the UK trades relatively more with India and Australia, France with Algeria or Cote D'Ivoire.[4]

Much of the current literature ascribes these patterns to either technical barriers to trade[5] or to exogenous differences in demand patterns, or argues that transactions costs are underestimated in the gravity literature.[6] However, the idea of habit formation in preferences has gradually been introduced, at least for aggregate import demand.[7]

I argue these observed patterns may, to a large extent reflect not exogenous differences in preferences, but the rational response of firms and consumers to a situation where their information on trading partners is incomplete, reflecting in turn low historic trade volumes. This implies that import demand might best be seen in terms of matching and searching theory. To date, such a theory has been developed primarily for the case of inter-firm trade. This approach assumes that each firm's products have differentiated characteristics - however, unlike the 'love of variety' model,[8] it is not variety of choice that purchasing or selling firms are looking for, but rather the best attainable match for their individual requirements. The obstacle to finding that best match is that firms have only imperfect information. For example in Rauch and Trindade (2003) firms are

[4] Rauch (1999) estimates a cross-country gravity model, with products divided into homogeneous and differentiated products. Incorporation of dummies for colonial ties and common language is strongly supported in the case of the latter products, much less so in the former (indicating that historical trade patterns persist much more where goods are differentiated and matching/searching is an important element of trade).

[5] For the economic significance of this assumption see LeJour et al (2001). A wider discussion of technical barriers to trade is in Maskus and Wilson (2001).

[6] Obstfeld and Rogoff, 2000.

[7] While I am not aware of specific evidence on habit formation in trade volumes between any pair of countries, there is some evidence of habit formation with regards to aggregate imports. For example, De la Croix and Urbain (1998) estimate non-durable import demand for France and the USA, finding strong support of habit formation (compared to a standard life-cycle model) at least in the latter case.

[8] Dixit and Stiglitz (1977).

only able to tell whether a potential partner is better than a certain threshold match quality: if a firm already has ties to the region, or if there are common language ties or strong historic trading links the threshold will be higher. Companies are more likely to set up trading ties with countries with which they have some initial familiarity, even if there are other, less familiar countries, where potential profits would be higher if perfect information were available. Another consequence of the one-off matching models currently discussed in the literature[9] is that firms will not all initially find good potential matches in one country even when there is a change in the average factor prices in that country relative to other countries: in this way the relative inelasticity and persistence of trade patterns are explained.[10]

Such ties, as well as existing patterns of networking may potentially explain observed trading patterns.[11] They also naturally generate a degree of imperfect competition in trade, since a firm which has a good match with a foreign partner possesses a degree of monopoly power, as does a country with good historic trade ties with a second country.

Nevertheless, I argue that the above models do not go far enough in the sense that they treat the relative degree of information firms have about foreign partners as exogenous. In reality, it is probably more sensible to see information as a valuable commodity, for which people will search if the cost of searching is low enough relative to the potential gains, and the history of search determines familiarity. Costs of searching may differ according to many factors, including transport costs and existing language and other ties, but also according to costs of borrowing (information can be seen as a form of capital)

[9]Though this characteristic is not shared by the match-searching model derived in this paper. The reason import demand is not fully price-elastic in a match-searching model is that not all domestic-domestic matches are of equally high quality.

[10]See Rauch and Casella, 2003.

[11]Evidence of similar informational effects in determining cross-border capital flows is presented by Portes and Rey (1999).

and according to the flexibility of the two trading partners. If this model is combined with a history where transport costs were much higher, and protectionist barriers much greater in the past than today, then it is quite conceivable that today's observed border effects in trade may reflect the ongoing informational effects of past barriers.

5.2.1 Match-searching in trade

In this chapter, I introduce the assumption that firms acquire information by a search process over time. I start off with a simple model: this search is in the form of a series of successive matches with trading partners, each for a fixed contract period. A firm does not know the quality of a match until it enters into it. At the end of the contract period it will decide whether to continue the existing partnership, or to start another search. The cost of searching is the risk of having a series of poor-quality partnerships, while the benefit is the possibility of eventually finding a much better match.

This initial model is deliberately simplified in that it concentrates on modelling the matching between firms rather than other elements of trade, and excludes important elements of networking which may affect the search process. The aim is to draw out the main properties of this basic model, some of which are quite powerful. I then consider to what extent they carry over to more complex models.

DEFINITION 5.1: *I define a match-searching model as one in which a firm searches for the most profitable partner by undertaking a succession of matches, each for a fixed contract period, until a satisfactory match is found.*

The key result of this approach is that a firm will choose to search for a new partner if its existing match quality falls below a reservation level. This is shown to depend essentially upon interest rates and the minimum contract period, as well as upon relative prices.

5.2.2 A simple model of match-searching

In one-off matching models (see Rauch and Casella, 2003), trade takes place between two firms, one upstream, u, and one downstream, d, and the extent and profitability of that trade is directly proportional to the quality of the match between those firms. Match quality, μ_{ud} is assumed to be randomly drawn from a uniform distribution between zero and unity. In a simple matching model the firms make a one-off random choice of match. A match-searching model differs from this framework in that matches are for a given contract period of c years, and it is assumed initially that a firm can only investigate a new partner by entering into a contract with it, and burning its bridges with its former partner. However, after the first contract period, the firms are again free to repeat the random matching process if their initial match falls short of a reservation quality μ_R.[12]

To set up a basic theoretical model, I start by assuming that firms are distributed uniformly, in terms of some key characteristics, along the perimeter of a circle,[13] circumference length 2. The circle is simply a diagrammatic representation of a simple probability distribution in which firms are evenly and uniformly distributed in terms of their characteristics, and no firm is intrinsically superior to another. Each firm aims to match with the firm directly opposite on the circle[14]: match quality, μ_{ud}, is equal to

[12] It is worth noting that, unless relative prices change, if a firm had accurate information about the distribution of potential match quality, then if it once decided to abandon a partner it will never return to that partner, except perhaps temporarily (see Section 5).

[13] This is an adaptation of Salop's model of qualitative differences between firms, and uses a similar initial set-up to Rauch and Casella's (2003) model, but differs in assuming that repeated matching is feasible.

[14] This could be taken as a schematic representation of complementarity between firms.

the circumference distance between the two firms, and hence is distributed uniformly between zero and unity with $\mu_{ud} = 1$ being the perfect match quality. We assume that both the volume of output of the two firms and the level of profits of each of the two firms is proportional to this match quality. Hence

$$Y_u, Y_d = \alpha\mu_{ud} \tag{5.1}$$

$$\pi_u, \pi_d = \beta\mu_{ud} \tag{5.2}$$

where Y_u, Y_d represent the real output of each firm (defined here to be equal, so that one unit of the final product requires one unit of production at both upstream and downstream stages). Trade between the firms in real terms will equal Y_u. π_u, π_d are the profits of the two firms, which in the simple version of the model are equal, the proceeds from the match being split evenly.

Starting initially with a single-country model, the match-searching process is as follows. In the first period, each firm type u will seek a partner type d selected randomly from the pool of available firms. Firm u knows accurately the distribution of potential partners, but not the exact characteristics of any one firm d (and vice-versa). The match quality is unformly distributed between zero and unity, so that average expected initial match quality is $\mu_{ud1} = 1/2$. Average output and profitability of firms in this initial period are therefore

$$\overline{Y}_{u1}, \overline{Y}_{d1} = \alpha/2; \tag{5.3}$$

$$\overline{\pi}_{u1}, \overline{\pi}_{d1} = \beta/2. \tag{5.4}$$

The first contract period lasts for c years. At the end of that period, each firm can either renew its contract or start afresh with a new, randomly-chosen match. No firm is assumed to be inherently superior to any other: it is simply match quality which affects efficiency. A firm which fails to find an initially good match, therefore, has as good a chance as any other firm if it renews the search process. It is also assumed for simplicity that firms have infinite lives.

I assume the industry comprising all firms types u and d is small in comparison to the economy as a whole, and that wages and prices can be taken as exogenously given and constant, as are interest rates, r per annum. These partial equilibrium assumptions simplify the analysis considerably. In particular, they imply that the reservation match quality, μ_R, above which firms will choose to stick with their existing partner, will be constant over time. In addition, the symmetry of the two firms u and d and the 50-50 split of profits imply that the decision to stick together or renew search will be mutual, and that once firms have found a suitable partner they will stay together permanently.[15] Importantly, I also assume for simplicity that a firm has accurate prior knowledge about the probability distribution of match quality with potential partners, even though it lacks information on the quality of an individual match.

The series of consecutive search or stick decisions can be represented as a tree of nested probabilities. At the end of each period of the search process, a firm which had

[15] The analysis is considerably complicated by introducing circumstances where one firm which thought it had a satisfactory match might be jilted by its partner.

still been searching in the previous period will assess whether its current match is worth sticking with ($\mu_{ud} \geq \mu_R$, which will occur with probability $1 - \mu_R$) or whether it should again renew search (probability μ_R). After n periods, the probability that it has still not found a satisfactory match is $1-(\mu_R)^n$, so the proportion of firms which will have found satisfactory partners by period $n+1$ is $1-(\mu_R)^n$ while the proportion still searching will be $(\mu_R)^n$.

Looking in more detail at period $n+1$ the expected profit for those firms which are still searching can be written as $\phi\beta/2$, where ϕ is a conversion factor due to the fact that the length of the contract period may not equal 1. Expected profit for those firms who start initially by searching but which have found a satisfactory partner will equal $(\phi\beta/2)(1+ \mu_R)$; in other words, it exceeds the expected profit of searching firms by $(\phi\beta\mu_R/2)$. Expected profit over all firms in period $n+1$ will therefore be

$$\pi^e_{Sn+1} = (\phi\beta/2)\{1 + \mu_R - (\mu_R)^{n+1}\} \tag{5.5}$$

==

Derivation of equation (5.5)

$$\pi^e_{Sn+1} = (\phi\beta/2)\mu_R^n + (\phi\beta(1+\mu_R)/2)(1-(\mu_R)^n)\},$$

$$\pi^e_{Sn+1} = (\phi\beta/2)\{\mu_R^n + (1-(\mu_R)^n) + \mu_R - (\mu_R)^{n+1}\}.$$

==

By contrast, if initial match quality is μ_{ud}, then if the firm chooses from the beginning to stick with its initial partner, its profit in each period will be $\phi\beta\mu_{ud}$ .The net expected benefit B^e_{Sn+1} in period $n+1$ of having started by searching rather than not searching is

$$B^e_{Sn+1} = (\phi\beta/2)\{1 + \mu_R - 2\mu_{ud} - (\mu_R)^{n+1}\} \tag{5.6}$$

==

Derivation of equation (5.6)

$$B^e_{Sn+1} = \pi^e_{Sn+1} - (\phi\beta\mu_{ud}/2) = (\phi\beta/2)\{1 + \mu_R - 2\mu_{ud} - (\mu_R)^{n+1}\}.$$

==

Assuming a constant reservation match quality μ_R, and constant interest rate r per annum, which, crucially, can be converted to an interest rate ρ per contract period, where

$$\rho = (1 + r)^c - 1, \tag{5.7}$$

it is possible to derive the expected net present value N^e_S (to the beginning of the search process) of profits for a firm which chooses to start by searching. This is a geometric progression, which can be summed to yield discounted present values

$$N^e_S = (\phi\beta/2\rho)(1 + \mu_R - 2\mu_{ud}) - (\phi\beta/2)(\mu_R/(1 + \rho - \mu_R)). \tag{5.8}$$

==

Derivation of equation (5.8)

$$
\begin{aligned}
N_S^e &= \sum_{n=0}^{\infty}(\phi\beta/2)\{1+\mu_R-2\mu_{ud}-(\mu_R)^{n+1}\}/(1+\rho)^{n+1}, \\
&= \sum_{n=0}^{\infty}(\phi\beta/2)\{1+\mu_R-2\mu_{ud}\}/(1+\rho)^{n+1}-\sum_{t=1}^{\infty}(\phi\beta/2)(\mu_R/(1+\rho))^{n+1}, \\
&= (\phi\beta/2)\{1+\mu_R-2\mu_{ud}\}/\rho-(\phi\beta/2)[1/((1+\rho)/\mu_R)-1)].
\end{aligned}
$$

==

When $\mu_{ud} = \mu_R$, $N_S^e = 0$. After carrying out some manipulation, it is possible to show that this is a quadratic equation in μ_R. Of the two solutions, only the smaller one will fall below unity. Hence, after a little more manipulation we can write

$$
\mu_R = 1+\rho-\sqrt{\rho(1+\rho).} \qquad (5.9)
$$

==

Derivation of equation (5.9)

At any particular value of μ_{ud},

$$
N_S^e = (\phi\beta/2\rho)(1+\mu_R-2\mu_{ud})-(\phi\beta/2)(\mu_R/(1+\rho-\mu_R)). \qquad (5.8)
$$

But when $\mu_{ud} = \mu_R$, $N_S^e = 0$;

$$
\begin{aligned}
(\phi\beta/2\rho)(1+\mu_R-2\mu_R) &= (\phi\beta/2)(\mu_R/(1+\rho-\mu_R)); \\
(1-\mu_R)/\rho &= \mu_R/(1+\rho-\mu_R); \\
(1-\mu_R)(1+\rho-\mu_R) &= \rho\mu_R; \\
1+\rho-\mu_R-\mu_R-\rho\mu_R+\mu_R^2-\rho\mu_R &= 0; \\
\mu_R^2-2(1+\rho)\mu_R+(1+\rho) &= 0;
\end{aligned}
$$

$$
\begin{aligned}
\mu_R &= [2(1+\rho)\pm\sqrt{4(1+\rho)^2-4(1+\rho)}]/2; \\
&= (1+\rho)\pm\sqrt{(1+\rho)(1+\rho-1)}.
\end{aligned}
$$

===

This expression is decreasing in ρ (for positive values of ρ), and consequently leads to our first proposition:

PROPOSITION 5.1: *The reservation match quality μ_R depends only on interest per contract period ρ, which is a function of the interest rate r and length of contract period c. Specifically, the shorter the contract period and the lower the interest rate, the nearer μ_R will be to unity.*

The implications of this in practice can easily be calculated. For example, with $c = 1$ year and $r = 5$ per cent per annum, the reservation match quality μ_R will equal 0.82, and average match quality in the long run will be $(1 + \mu_R)/2 = 0.91$. By contrast, with c=10 years and r=15 per cent per annum, $\mu_R = 0.54$ and average long-run match quality is 0.77.

While total profits and output in the first period of search for those firms who choose initially to search are the same for all values of r and c,[16] in the long run both will be higher the lower is r and the lower is c. This is because with lower r or c firms will have a higher reservation match μ_R, and so will be prepared to keep searching longer, leading eventually to a better average quality of match. Subsequent average match quality increases over time. Average output per firm and profits correspondingly also increase, and in the long run both are higher the lower is r and the lower is c. We would also expect, of course, that convergence to the long run value will be faster the shorter is the contract period c.

5.3 Implications of match-searching for trade

I have shown how the match-searching process in a closed economy moves towards a long-run equilibrium, in which firm match quality varies only over a limited range from μ_R to unity. Modelling of trade is more complicated, but I will concentrate in this section upon the opening up of a formerly autarkic economy to international trade for the first time. Specifically, I allow upstream and downstream firms for the first time to seek matches in a second country. I will assume that the potential maximum profit of an international pairing in the absence of transport costs or tariffs is π', which is greater than the maximum feasible for domestic-only partnerships by a factor $(1 + \epsilon)$. However, transport costs and tariffs take proportion τ of this profit, so the maximum profit available to an international pair of companies is $(1 - \tau)\pi'$. If a pairing with a foreign firm is made at random, the average quality match for a trading firm will again

[16] This follows since match quality in the first period of search is assumed to be random.

range from 0 to 1, and annual profits for an individual firm will be evenly distributed between 0 and $(1-\tau)(1+\epsilon)\beta/2$.

Crucially, I will initially assume that this extra profitability opportunity applies equally to both upstream and downstream firms in the home country (which we will denote by u_h and d_h), and that there is a ready supply of foreign partners. These assumptions maintain the symmetry of the supplier/purchaser relationship, so that with a 50-50 profit split, firms u_h and d_h are in agreement over whether to maintain their current relationship or to start searching abroad.

In the previous, one country, case the expected present value of future profits of a firm which chose to search was shown to be equal to the profits earned by a firm sticking with its match partner with match quality μ_R, as determined by equation (5.9).

By analogy, a firm which searches abroad will have an expected present value of future profits equivalent to a firm which has a constant foreign match quality μ_{RF} also satisfying equation (5.9).

But the expected profits of a foreign match quality μ_{RF} will equal $(1-\tau)(1+\varepsilon)$ times the expected profits of the marginal existing match at home, μ_R. It follows that, if the economy has reached equilibrium in autarky before starting to trade, there will be no firms at home with match quality less than μ_R. If this is the case, and if $\varepsilon > 1/(1-\tau)-1$ (i.e. there is no profit advantage to trade) then no firms will seek overseas partners .

A key conceptual difference in this analysis is between firms who have already found match partners, and those who are still searching.

DEFINITION 5.2: *A firm is defined as initially searching if at the start-point of our analysis it has not found a satisfactory partner,* $\mu > \mu_R$*. Otherwise it is defined as initially matched.*

An economy is defined here as mature if all firms have found satisfactory partners.[17]

Of initally matched firms, a small potential profit advantage from a foreign partner, ϵ, will only outweigh the advantages of avoiding the costs of search for those firms whose matches were only marginally better than the initial reservation match quality, μ_R. Most other firms will not find it worthwhile starting a search unless ϵ is considerably larger than this.

PROPOSITION 5.2: *For $\epsilon > 0$, all initially searching firms will choose their next partner from abroad. By contrast, among initially matched firms, the proportion choosing to abandon their existing partner to search abroad will only gradually increase as ε increases.*

Henceforth, for simplicity, I will assume transport costs and tariffs are zero (where there is trade), so $\tau = 0$. In these circumstances, the last firms will abandon home pairings only when $\varepsilon \geq (1/\mu_R) - 1$, ie when

$$\varepsilon \geq \{1/[1 + \rho - \sqrt{\rho(1 + \rho)}\} - 1. \tag{5.10}$$

Firms will choose to search abroad if

$$\mu_{u_h d_h} < \mu_{RF}/(1 + \varepsilon). \tag{5.11}$$

Figure 5.1 represents diagramatically the proportion of firms seeking a foreign partner

[17]In practice, of course, no economy will ever reach complete maturity, but in an economy where the great majority of firms have found satisfactory partners, we would expect most of the properties to be close to those of a mature economy.

when a mature autarkic economy opens up to trade. In the initial case (shown by the bold diagonal line) the share of firms seeking foreign matches increases steadily as ε increases from 0 to ε^*, where ε^* is the value which makes equation (5.10) an equality.

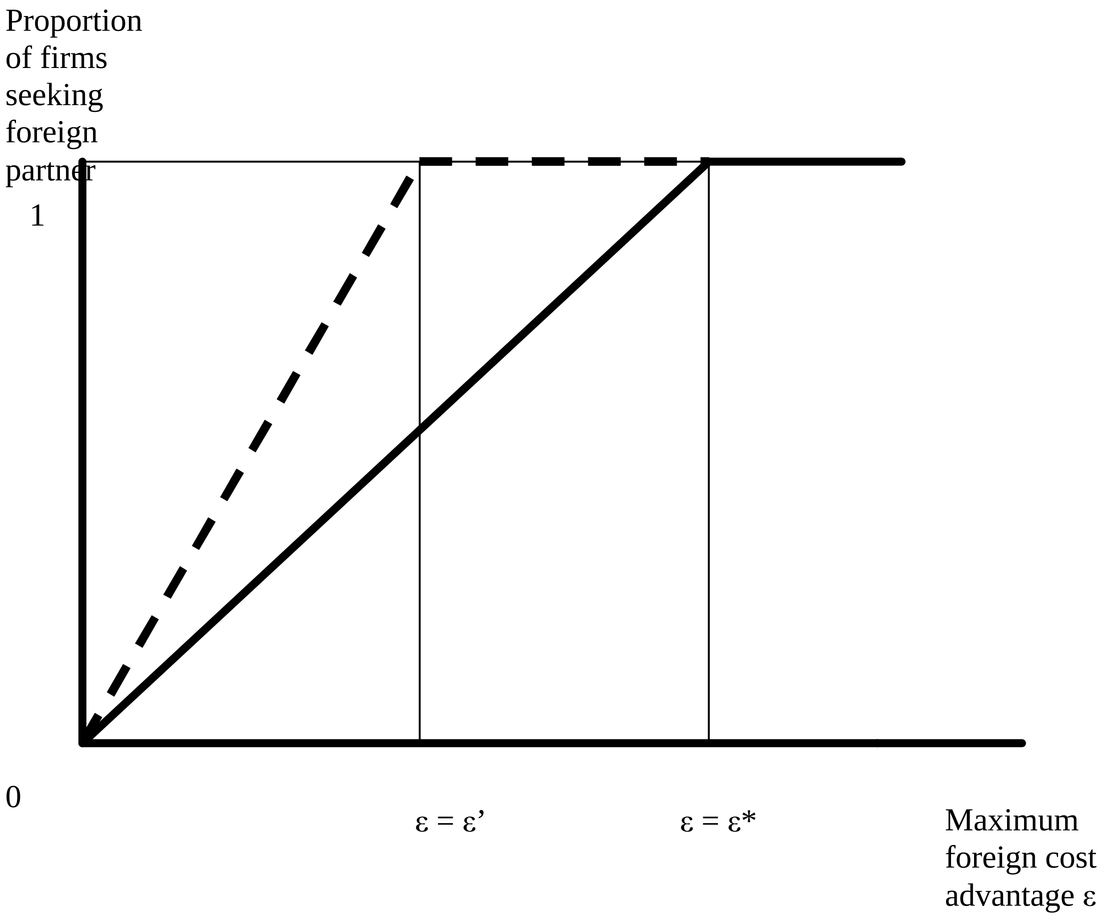


Figure 5.1: effect of a fall in the per contract period discount rate on the proportion of firms seeking a foreign partner related to the foreign cost advantage.

Now if we allow the per-contract-period discount rate ρ to fall from ρ_0 to ρ_1, due either to a fall in the interest rate r or a shortening of the contract period c, then the value of ε at which all firms look abroad will fall from ε^* to ε', and the curve showing the response of the proportion of firms seeking foreign matches in response to changes in ϵ becomes much steeper.

The implication is that the price sensitivity of imports and of exports increases the less 'lumpy' foreign contracts are (the lower is c), and also the lower the interest rate, r.

Next, it is worth considering what happens if the country is not in a long-run equilibrium at the time when the trade liberalisation takes place. In the above analysis, it was assumed all firms had found 'satisfactory' long-run partners, before the option of looking abroad for partners was introduced. By contrast, it is possible that some firms were still searching for a partner: in this case, the firm does not need to compare the potential profits from a foreign partner with those if its existing partner, but only with those of the expected return from the next domestic partner if it continues to search at home. Consequently, while price sensitivity of import demand for matched firms (those with long-term domestic partners) is relatively low, all searching firms will switch abroad if the average price advantage of foreign versus domestic partners, $\varepsilon > 0$.

Another way of putting *proposition 5.2* is that searching firms who have not yet found stable domestic partners will be very price-sensitive in choice of their next partner, but many initially matched firms will not. A related conclusion is that the greater the rate of new firm startups in an economy, the greater the price-sensitivity of imports.

5.4 Path dependency and implications for the sequencing of trade liberalisation.

The difference in behaviour between initially matched and initially searching firms underlies the path dependency of import demand. Once a search process has gone on for long enough, a high proportion of established firms will have found partners and become matched. Once this has happened, they will be much less sensitive to the arrival of new potential trade partners.

This has important implications concerning the sequencing and timing of trade liberalisation with other countries. If country A liberalises trade initially only with country B, then, if trade with B has a price advantage $\varepsilon_B > 0$, some or all of the firms in A will start looking for partners in B (depending on whether their initial match in A was good enough to outweigh the cost advantages of entering into search). Now consider that A subsequently decides also to liberalise trade with country C, which has an even larger cost advantage $\varepsilon_C > \varepsilon_B > 0$. If this second liberalisation takes place very quickly after the liberalisation with B, due to the presence of contract periods, many firms in A may not even have reached the stage of starting their foreign search, and will automatically choose the most cost-effective foreign partner: i.e. in country C. If the second liberalisation takes place slightly later, so that many firms have already started their trial matches with firms in B, then we would expect proportion μ_R of these to reject their partners in B at the end of the first match even in the absence of the second liberalisation. These firms, again, will be very price-sensitive and will choose firms from C for their next partners. By contrast, a proportion $1 - \mu_R$ of those firms who had started an initial match with firms in B will have found their first foreign partner satisfactory, and would be less price-sensitive in deciding whether to start trading with C.

If the second liberalisation does not take place until much later, then it is worth noting that as time progresses, fewer and fewer firms in A would still be searching B for a new partner: more would have found satisfactory ones. Consequently, the later is the second liberalisation, the greater the lasting trade advantage country B has over country C.

LEMMA 5.1: *Other things equal, the proportion of firms in a pair of countries which are searching will fall over time following a trade liberalisation between them.*

From this follows:

PROPOSITION 5.3: *The price sensitivity of a country's trade share with another country, and its vulnerability to being displaced by a new partner, is less the more established is trade between the two initial partners.*

PROPOSITION 5.4: *The price sensitivity of imports from a third country is lower, and hence the level of optimal tariffs is higher,*[18] *when a customs union between two countries is established rather than recent.*

5.4.1 A numerical example

A worked example shows the importance of the historical sequencing of trade liberalisation deals. Let us examine a three country example, starting with complete autarky. The model is a partial equilibrium model, in which an industry consists of partnerships between upstream firms, u, and downstream firms, d. The overall price PFi of the final good (which is the product of pairs of firms $\{u, d\}$) is normalised at unity in all three markets, $i = A$, B and C. PF_i consists of the upstream price, Pu_i plus the downstream price Pd_i. However the relative upstream and downstream costs vary: I assume that, in equilibrium under autarky, $P_{uA} = 0.4$, $P_{uB} = 0.5$ and $P_{uC} = 0.6$. This implies that of the three countries, A is the most competitive in the upstream part of the industry and the least competitive in the downstream part, while C is most competitive in downstream and least competitive upstream. There is one factor only, labour. The model approach here is partial equilibrium, where the wage rate W is set at unity in all three

[18] It is worth noting that for optimal tariffs to be non-zero the world supply price also has to vary with respect to demand by country c: i.e. export supply curves have to slope upwards.

countries, and total expenditure on the industry's final products is assumed to be a constant amount X, equal in all three countries.

The model here is slightly more complicated than that outlined above. For any firm f of type h ($h = u$ or d) , maximum potential total output is given by

$$Y_f^* = \gamma_{ih} L_f^\delta \tag{5.12}$$

where γ_{ih} is a productivity scale parameter, depending on country and industry and δ is the elasticity of output with respect to labour input L_f, and assumed to be somewhere between zero and unity. It is assumed that each firm also consumes a fixed amount F_{ih} of its output per annum to run. Overall output of f and its chosen partner g will fall short of Y^* depending upon the match quality μ_{fg}, where potential values of μ are uniformly distributed between zero and unity (as above). We assume

$$Y_f = \mu_{fg}^{1-\delta} Y_f^* \tag{5.13}$$

It is not difficult to show that, in this model, if wages are set at unity,

$$L_f = \mu_{fg} (\delta \gamma_{ih} P_{ih})^{1/(1-\delta)}, \tag{5.14}$$

$$Y_f = \mu_{fg} \gamma_{ih} (\delta \gamma_{ih} P_{ih})^{\delta/(1-\delta)}, \tag{5.15}$$

and hence we can derive profits

$$\pi_f = \mu_{fg} \gamma_{ih}^{1/(1-\delta)} P_{ih}^{1/(1-\delta)} (\delta^{\delta/(1-\delta)} - \delta^{1/(1-\delta)}) - F_{ih} P_{ih}. \tag{5.16}$$

==

Derivation of equations (5.14)-(5.16)

$$\begin{aligned} Y_f &= \mu_{fg}^{1-\delta} Y_f^*, && (5.13) \\ &= \mu_{fg}^{1-\delta} \gamma_{ih} L_f^{\delta} \text{ from (5.12).} \end{aligned}$$

$$\partial Yf/\partial Lf = \delta \mu_{fg}^{1-\delta} \gamma_{ih} L_f^{\delta-1} = 1/P_{ih};$$

$$L_f = \mu_{fg}(\delta \gamma_{ih} P_{ih})^{1/(1-\delta)}, \quad (5.14)$$

$$\begin{aligned} Y_f &= \mu_{fg}^{1-\delta} \gamma_{ih} L_f^{\delta} = \mu_{fg}^{1-\delta} \gamma_{ih} \mu_{fg}^{\delta} (\delta \gamma_{ih} P_{ih})^{\delta/(1-\delta)}, \\ &= \mu_{fg} \gamma_{ih} (\delta \gamma_{ih} P_{ih})^{\delta/(1-\delta)}. && (5.15) \end{aligned}$$

$$
\begin{aligned}
\pi_f &= P_{ih}Y_f - L_f, \\
&= \mu_{fg}\gamma_{ih}^{1/(1-\delta)}\delta^{\delta/(1-\delta)}P_{ih}^{1/(1-\delta)} - \mu_{fg}(\delta\gamma_{ih}P_{ih})^{1/(1-\delta)}, \\
&= \mu_{fg}\gamma_{ih}^{1/(1-\delta)}P_{ih}^{1/(1-\delta)}[\delta^{\delta/(1-\delta)} - \delta^{1/(1-\delta)}]. \qquad (5.16)
\end{aligned}
$$

==

It follows that, where prices are constant, output will be proportional to match quality, as before, as will profits before deducting fixed costs.

Firms face an annual interest rate of r and have a match contract period of c, as before. Consequently, we can calculate the reservation match quality for the search process, μ_R as in equation (5.9) above. The number of firms of each type, upstream and downstream in country i, will equal N_i, and output of the upstream and downstream partners in any pair will be equal.

In equilibrium, profits (after deducting fixed costs) for a firm with the reservation match will equal the expected present discounted value of profits for a new entrant firm, which in turn will equal zero so that at the margin there is no incentive on firms to enter or leave the industry. From this we are able to derive a value for γ_{ih}.[19]

Starting with $r = 5$ per cent per annum and $c = 5$ years, we have a value of $\mu_R = 0.68$ (as shown in *Table 5.1*). We will assume total initial demand in each country, $X = 1000$, and prices accruing to the upstream and downstream sections of the industry are as suggested before. In a long-run autarkic equilibrium, average match quality will equal

[19] First we note that $\gamma_{iu}/\gamma_{iu} = (P_{iu}/P_{id})^{-\delta}$. We can substitute from this into equation (5.16) noting that where the number of firms is in equilibrium the net profits of a firm on the reservation match quality will equal zero. Hence $\gamma_{ih} = [F_{ih}/(\mu_R(\delta^{\delta/(1-\delta)} - \delta^{1/(1-\delta)}))]^{1-\delta}P_{ih}^{-\delta}$.

$(1+\mu_R)/2 = 0.84$. For simplicity we assume the output elasticity with respect to variable labour, $\delta = 0.5$, and that the fixed cost $F_{ih} = 1$ for all firms, which gives us the following values for γ_{ih} and N_i:

Table 5.1: pre-trade equilibrium values for number of firms, output, labour and profit in three-country model.

Country & industry	Price	Gamma	N of firms	For avg firm Net Output	Labour	Profit
A & u	0.4	3.83	682	1.47	0.49	0.09
A & d	0.6	3.13	682	1.47	0.74	0.14
B & u	0.5	3.42	682	1.47	0.62	0.12
B & d	0.5	3.42	682	1.47	0.62	0.12
C & u	0.6	3.13	682	1.47	0.74	0.14
C & d	0.4	3.83	682	1.47	0.40	0.09

We now assume countries A and B initiate a free trade agreement between themselves, but excluding country C with which they still do not trade. This is a partial equilibrium model, in which the industry comprising firms u and d is small, so we assume no effect on wages. Consequently the marginal cost at which a new firm will be expect to be able to enter the market and supply profitably is the same as the pre-trade price: in other words, an upstream firm in A will be able to supply at price 0.4 and a downstream firm in B will be able to supply at price 0.5, so that the price for the combined final good in the two countries falls from 1 to 0.9. However, some downstream firms in country A and some upstream firms in country B will have such good (pre-trade) matches that they will continue to produce even after their output price falls. The proportion staying open in this way is given by the formula

$$\Psi_i = (1 - \mu_R(P_{iu0} + P_{id0})/(P_{iu1} + P_{id1}))/(1 - \mu_R) \tag{5.17}$$

and works out at 76 per cent of the initial firms in both cases. The firms in these good initial matches will reduce output since their final prices fall. Total output from surviving existing matches is therefore reduced to around 63 per cent of its value under autarky. With total expenditure on the good assumed to be fixed (i.e. a Cobb-Douglas upper level utility function), in the new long-run equilibrium total final demand rises by 11.1 per cent. The net result is that downstream firms in country B take an eventual 43 per cent of the downstream market in country A, and upstream firms in A take a similar share of the market in B.

Now consider what happens if countries A and B decide subsequently to open up to free trade with country C as well. C has an underlying comparative advantage (before taking account of match quality) in the downstream industry compared to both A and B. Various dates of liberalisation are considered in *Appendix 5.1 Table 1*. The price of each stage of production falls to 0.4, set by the price charged by new entrants to upstream production in A and downstream production in C. According to equation (5.17), in each country, just over 46% of the original pre-trade domestic-domestic matches can still be profitable. Output of domestic-domestic matches in each country is reduced to 30% of the pre-trade levels. This is irrespective of the timing of the second liberalisation deal.

The trade between A and B, when trade with C is liberalised, will depend crucially upon the timing of the second trade liberalisation: if trade with C is liberalised only one contract period (5 years) after trade between A and B, then only proportion $(1-\mu_R) = 32$

per cent of pairings between firms in A and B will be of reservation match quality or more, before liberalisation of trade with C. The remaining 68 per cent will switch demand very easily to a new, more profitable trading partner. By contrast, after 4 contract periods, the proportion still searching will be reduced to just 21.4 per cent. 73 per cent of these $A - B$ matches will survive the opening up of trade with C. Taking account of the reduced output of each of these firms as prices fall, trade between A and B is 59 per cent of its level before liberalisation of trade with C.

Inspecting *Appendix 5.1 Table 1* we can see that, if trade between A/B and C is only liberalised 20 years after trade between A and B, then output of the upstream industry in B will remain at 84 per cent of its initial level, even though it has higher underlying costs compared to the industry in C, whereas if the liberalisation with C took place just 5 years after that between A and B, output of B's upstream industry would be just 34 per cent of pre-trade levels, and if the liberalisations were simultaneous it would be just 24 per cent.

Even though long-term prices (after trade between all three countries is liberalised) and consumer welfare are the same regardless of the sequence and timing of liberalisation, there are at least two forms of welfare costs of delaying the second liberalisation. Firstly, the profits of the upstream firms in B which continue to produce because of the delayed liberalisation with C will be less than the profits of the upstream firms in C which would have taken their place given earlier liberalisation. We could call this the ongoing informational trade diversion effect. Secondly, however, in the intervening years, firms in both A and B will have spent effort (and foregone production) in a search for partners in A/B which was effectively wasted when the possibility of finding more cost effective partners in C was allowed. This could be termed the intermediate search diversion cost.

DEFINITION 5.3: *'Informational trade diversion' is the trade which takes place between one country and a second, when trade with a third party is potentially more profitable, because the costs of searching for information on partners in a third party outweigh the potential profits from comparative advantage.*

DEFINITION 5.4:*'Search investment diversion' is the additional cost incurred on partners who search for a match in one country under a preferential trading agreement when they could potentially have searched for more profitable matches elsewhere given non-discriminatory trade policies.*

PROPOSITION 5.5: *In a match-searching model, if two countries who have already liberalised trade between themselves delay liberalising trade with a third country, there will be welfare costs from both search investment diversion and informational trade diversion.*

5.5 Other areas of application

5.5.1 Search information as capital

We can view information on potential matches as an important, but neglected, form of human capital. Our model suggests that there are strong parallels between the economics of accumulation of search information and that of other forms of capital. The 'lumpiness' of a match (i.e. the length of contract period in our model) is an important aspect of the cost of accumulation of capital. Our model indicates that import demand elasticities and export supply elasticities should be lower for 'lumpy' products, and also lower during prolonged periods of high interest rates. The latter property really results from the idea that information is a form of capital, involving finance to cover the investment in attaining better information by searching. In addition, since new firm startups may well be lower when interest rates are lower, this tends to reinforce the previous hypothesis that periods of low interest rates globally are likely to favour trade growth and liberalisation.

In general, we would expect that imports and exports should be more price sensitive the shorter are foreign contracts and/or the lower the interest rate, as well as the better-developed are financial institutions. This is to some extent borne out by historical research: Rousseau and Sylla (2001), examining the history of 17 countries over the 1850-1997 period, found a strong link between finance and economic growth and trade, especially prior to the Great Depression. Countries with more sophisticated financial systems engaged in more trade and were better integrated. Econometric analysis and case studies suggested that 'economic growth and the increasing globalization of the Atlantic economies might indeed have been 'finance-led'.'

We would also expect the financial climate to affect countries' behaviour with respect to trade: other things being equal, the lower are interest rates, the lower are optimal tariffs and the greater is the likelihood of more open trade policies.

5.5.2 Dynamics of trade

The dynamics of trade are another area where match-searching has potential application. The issues of the dynamics of trade adjustment and the importance of history in determining trade flows in this model are also worthy of investigation. It is worth noting that, in this model, if there is a one-off trade liberalisation, a firm will face a decision whether to stick with its existing domestic partner or to enter into a search process, and unless relative prices subsequently change that decision will not change subsequently.

Consequently, a firm which is going to enter trade will do so quickly (at the next end of contract period) after the trade liberalisation.

PROPOSITION 5.6: *All firms who are going to enter into trade following removal of trade barriers will do so as soon as their current contracts expire. However, after the initial increase in trade volumes from firms entering the search process, trade will continue to increase more gradually until a new equilibrium is reached.*

This latter proposition is related to the increase in output volumes as the search process procedes, as noted in *proposition 5.2*. It can be shown that, when $\varepsilon < (1/\mu^R) - 1$, total output in the first period of entering trade will only increase if[20]

$$\varepsilon > (2\mu_R - 1)/(1 - \mu_R). \tag{5.18}$$

As r and/or c are reduced to zero, μ_R will tend towards 1 and first period output is more likely to increase for any price advantage to trade. [21]

As for effects on output: the short run impact of trade liberalisation on output for a country which is in long-run equilibrium before engaging in trade, will be a reduction if the price advantage to trade, ε, is relatively small and if interest rates are high and the contract period long. By contrast, the long run effect on total output across countries, as match quality improves with search, will be positive.

[20] The proof of this is that, if the economy is in a long-run equilibrium pre-trade, then only firms whose (pre-trade) match quality lies between μ_R and $(1+\varepsilon)\mu_R$ will choose to search. Average pre-trade output of these firms is $\alpha(2+\varepsilon)\mu_R/2$. By contrast, average match quality for the first post-trade match is 1/2 and average output is $\alpha(1+\varepsilon)/2$.

[21] For larger values of ε, total output in the first period will only increase if $\varepsilon > \mu_R$.

5.5.3 The effects of variations on the match-search formulation

The model developed above is rather simple in a number of respects. It assumes there are no specific costs attached to forming a partnership, whether foreign or domestic, but that the quality of a potential match can only be assessed by entering into a trial contract of period c. Introducing a fixed cost for searching in addition to this would raise the overall cost of searching relative to sticking with an existing partner, and so tend to lower the reservation match quality μ_R, encouraging fewer firms to start a search for a foreign partner once trade is liberalised, and to settle on an eventual partner sooner. A lower reservation match quality would mean greater variation in the initial quality of domestic matches. The consequences of these changes are to lower the price elasticities of trade, making the model less neoclassical in its properties.

Other potential changes would be more likely to increase trade price elasticities. For example, as an alternative to picking a random foreign partner for a trial period, a searching firm could expend money (e.g., hiring an agent) to gain better information on the potential match quality. This would only be done if it lowered the search costs (which in turn would raise μ_R making trade more price elastic). It would also raise the possibility that, if two domestic firms investigated foreign partners and found the combined potential profits from their respective overseas matches were less than joint profits from sticking together, they could return to each other temporarily for a contract period c, before renewing search. Again this would serve to lower search costs and make trade more price elastic. It would also mean that not all firms who eventually want to trade would necessarily start doing so during the first contract period.

Extension of this model would suggest that firms could investigate a number of potential foreign partners (with diminishing returns to search, since each new partner costs money to investigate but the probability of its being a better partner than the next best in the set investigated falls). Such models would involve a lot of bargaining between a lot of firms (including the original domestic partner) with possibilities of jilting - in consequence they are likely to be complicated.

Another possible modification would be to allow for a constant probability of firm death δ (perhaps with the constraint that this always happens at the end of a contract). On the one hand, this would be rather similar to raising the per contract period discount rate ρ to $\rho + \delta$, so discouraging search and lowering μ_R for firms with existing partners. This would make the model less neoclassical in the sense that trade between firms with existing partners would be less price elastic. On the other hand, in each period there would be a proportion of new firms (or newly bereaved firms) entering the market searching for the first time. These would be very price sensitive in terms of choice of foreign partner. In the very long run, these new firms would dominate demand, though it may take a long time for this to happen.

Although the match-searching process outlined here applies to inter-firm trade, similar principles could potentially apply to the sale of final consumer goods as well, though with key differences, such as the fact that many consumers purchase commodities from the same suppliers. An investigation into the implications of searching for preferred suppliers by heterogeneous consumers may well produce important insights into the behaviour of import demand over time. Again the key conclusions of the importance of history in determining current import patterns and the importance of sequencing and timing of current trade policy decisions are likely to be similar.

The simple model I have set up assumes that firms can only use information they have individually acquired. In practice, there are strong reasons to believe there will be some information-sharing between certain subsets of firms. Mechanisms by which this networking will take place include ethnic or family ties between firm owners, the presence of trade associations, the movement of key staff between firms and the employment of firms to act as agents in the matching process.[22] Clearly, networking can take a wide variety of forms, partly determined by historical, institutional and sociological factors, and the precise nature of the process by which information spreads can have significant effects upon how a country engages in international trade.

The negative aspect of networking is that, if information is freely available to association members, there is a free-rider problem regarding the initial search for downstream partners. Firm f has little incentive to search for new partners (outside the network's existing pool of partners), since it is likely the benefit of the discovery will accrue to another association member rather than itself. Consequently, establishing a new network pool may be difficult. It follows that, in the presence of network effects, trade with new overseas partners is likely to be suboptimal, unless there is a good system for reimbursing members of the network who do the searching. This tends to imply that there may be welfare benefits to policies which actively promote trade search.

A further related aspect of networking is that, once a network has become established and has developed a good set of matched partners in two countries, say A and B, the very fact that equilibrium matches between A and B are better than in a solo match-search model means that it may be even more difficult for a third country, C, to break into the market, even after trade is formally liberalised. In this way, networking will reinforce

[22] See the articles by Rauch, Feenstra et al and McLaren in the (1999) JIE symposium on Business and Social Networks in International Trade, as well as the introduction by Feenstra and Rauch (1999).

many of the conclusions of the sections above regarding informational trade diversion.

The precise way in which a network is set up may well determine how condusive it is to search. This may be a way in which institutional culture of countries may be reflected in their responsiveness to trade liberalisation. Another related extension worth investigating is that the search process may also be aided by clustering of firms of a given type in a given locality, or by the use of signals by firms to indicate their type.[23]

A final suggested extension is Bayesian search, where firms estimate the profitability of trade with a foreign country only by either searching there themselves, or by observing the success or failure of other firms searching for partners there. As successful matches are observed with a foreign country, a firm will revise its Bayesian prior about the profitability of trade. A Bayesian model of search for trade which incorporates information from observing other firms may well have similar implications to the networking model discussed in the previous section: namely, that one firm's search for foreign partners will carry external benefits in terms of information. Such models will tend to give welfare benefits to active trade-promotion policies.

5.6 Conclusions

This paper builds on a recent literature which seeks to explain import demand patterns in terms of imperfect information, particularly in the case of interfirm trade in differentiated products. I seek to draw out the potential implications of this class of model by setting

[23] There is a considerable literature on agglomeration economies and the supply-side reasons for clustering of firms (see e.g. Krugman, 1991 and 1995). However, it may well be that the concentration of firms of a particular type in a particular locality (such as high-quality steelmakers in Sheffield, UK) may serve as a signal to potential customers aiding the search process. A cluster which arises for geographical or sociological reasons may be reinforced by the fact that its presence becomes known aiding matching (see e.g. the history of the surgical steel cluster in Sialkot, Pakistan, discussed in Schmitz, 1999).

out a basic match-search model and investigating its properties. This match-search model goes somewhat further than existing models (e.g. Rauch and Casella, 2003 or Rauch and Trindade, 2003) in the sense that the degree of information on matches is treated as endogenous, being the result of a repeated search of each firm for a good partner by matching successively with various partners for a succession of fixed-period contracts until a good quality match is eventually found. However, perfect information will never be achieved, since searching is potentially costly in terms of output and profits foregone in poor-quality short-term matches. As a result, a firm will be reluctant to give up a reasonably good existing match, especially if contract periods are long and interest rates are high.

The consequences of this type of model both for explaining observed current trade patterns and for analysing the effects of trade policy are potentially significant. It is no surprise that observed trade patterns between countries do not tally easily with comparative advantage, and that considerable 'home bias' and two-way trade in the same commodity class are common. Such features may well represent, at least in part, the vestiges of past changes in alternative production efficiency, transport costs, trade protection and exchange rate movements. Many firms which developed a market foothold at a time when their home market was relatively sheltered may well be able to maintain it even when that protection is removed. Likewise, firms will gain export and import markets at times when comparative advantage, exchange rate fluctuations or bilateral trade deals favour them may well continue to export or import even when patterns of competitiveness change drastically.

While existing matching models of trade do acknowledge verbally the existence of historical factors in influencing trade links, there is perhaps a failure to emphasise that today's policy decisions are tomorrow's historical factors. Trade diversion from a preferential trading agreement may well persist as informational diversion well after the preferential agreement has been scrapped. This is perhaps an important argument in favour of multilateral over bilateral trade liberalisation.

Some of the static and dynamic features of the match-searching framework are perhaps shared by other potential models of import demand, such as habit-formation or informational capital models. However, I suggest there are distinctive features of match-searching models which may have significance for understanding trade policy issues. In particular, there is a key difference between import demand by firms still searching for a satisfactory partner, and demand by firms who have already found such a good partner. In the former case, their demand is very sensitive to changes in prices of relative supply sources, while in the latter demand may be much less price-sensitive. A consequence is that long-standing trade blocs may well have lower import price elasticities and higher optimal tariffs than newer trade arrangements. Countries which are attempting to break into new export markets may find themselves needing to compete keenly on price with other new entrant countries, while established producers may not have the same price-sensitivity.

I then investigate variations on the search process. While some of the assumptions of the basic match-search model here are simplified (such as infinite firm life), and may overstate the degree to which firms can benefit by entering into a match-searching process of trade, on the other hand, there may be incentives for firms to use alternative information-acquiring processes, such as employing agents[24], or copying known competitors with similar characteristics, or by firms in one country congregating in one section

[24] See Rauch and Watson (2002)

of the market, in order to speed the match-search process. Multinational firms, which move into a new country with a list of pre-existing preferred suppliers and purchasers may also be by-passing the match-search process by making use of existing information (though with some costs, in the sense that they will be importing parts from existing overseas suppliers rather than finding potentially cheaper local sources), and presumably gaining a rent from their ability to re-use existing information across the world. Networking between firms is an important variation on the match-searching process: on the one hand, there is potential for reducing search costs and improving eventual match. On the other hand, many types of network structure will introduce a free-rider problem, so that firms are reluctant to initiate a search process, and trade will be suboptimal in the absence of positive trade promotion policies.

Appendix 5.1.

Table 1: Importance of the order and timing of trade liberalisation for eventual net export patterns

Initial situation pre-trade

Country	Industry	Production	Consumption	Net Export
A	u	1000	1000	0
	d	1000	1000	0
B	u	1000	1000	0
	d	1000	1000	0
C	u	1000	1000	0
	d	1000	1000	0

After trade liberalisation between A and B

Country	Industry	Production	Consumption	Net Export
A	u	1811	1111	700
	d	411	1111	-700
B	u	411	1111	-700
	d	1811	1111	700
C	u	1000	1000	0
	d	1000	1000	0

If A and B liberalise trade with C after 20 years

Country	Industry	Production	Consumption	Net Export
A	u	3269	1250	2019
	d	240	1250	-1010
B	u	240	1250	-1010
	d	843	1250	-407
C	u	240	1250	-1010
	d	2666	1250	1416

If A and B liberalise trade with C after 5 years

Country	Industry	Production	Consumption	Net Export
A	u	3269	1250	2019
	d	240	1250	-1010
B	u	240	1250	-1010
	d	342	1250	- 908
C	u	240	1250	-1010
	d	3168	1250	1918

If A and B liberalise trade with C in year 1

Country	Industry	Production	Consumption	Net Export
A	u	3269	1250	2019
	d	240	1250	-1010
B	u	240	1250	-1010
	d	240	1250	-1010
C	u	240	1250	-1010
	d	3269	1250	2019

If trade were always liberalised

Country	Industry	Production	Consumption	Net Export
A	u	3750	1250	2500
	d	0	1250	-1250
B	u	0	1250	-1250
	d	0	1250	-1250
C	u	0	1250	-1250
	d	3750	1250	2500

Chapter 6

Conclusions/Afterword

This thesis consists of a number of papers looking at various aspects of the current debates around trade policy: as such, it is not an attempt to answer a single question. Consequently, the summaries of the chapters need to be looked at individually.

However, repeating some of these findings in brief:

Chapter 2, with John Whalley, is a comparison of short-run and long-run trade models in decomposing changes in observed skilled/unskilled wage inequalities. The focus is on the UK between 1979 and 1995. The use of general equilibrium decomposition techniques means that we are fitting a model simultaneously to changes in output, prices and wages, rather than estimating a reduced-form mandated wage equation, as in most of the literature to date. The latter technique may be flawed as the implicit values of output changes, say, in an equation based on Stolper-Samuelson linking trade prices to wages may not correspond to actual observed output changes.

This decomposition work found first that decompositions are very different depending upon whether a short-run model or a long-run model is used to explain the observed changes. This means that there is a good deal of ambiguity in how we can interpret the results seen.

In the long-run model, the usual Heckscher-Ohlin result of factor price insensitivity holds, so that the rise in relative supply of skilled labour has no effect on skill premia. The factor-bias of technical change has no effect, while the effects of observed world price increases are very large. The long-run model can only be made consistent with the observed output and income changes if the sector-bias of technical change is in the opposite direction: for UK total factor productivity in the unskilled-intensive sector to have risen faster than in the skill-intensive sector, so damping the tendency of output to switch. This is in contradiction of what data on computerisation would suggest.

By contrast, in a short-run model, the rise in the relative supply of unskilled labour now has a sizeable damping effect on inequality. Factor-biased technical change will raise relative skilled wages. The effect of trade is less marked though still quite substantial. The sector-bias in technical progress is relatively minor.

In our alternative Ricardo-Viner model, the effects are even more marked than in the partial mobility case. Factor-biased change is the main cause of insensitivity in inequality, offset by endowment changes. Sensitivity analysis shows that, even when only a small proportion of value added is linked to fixed factors; the model is greatly changed compared to the Hecksher-Ohlin formulation.

I discuss a number of reasons why we believe for the short-run model decomposition to be the more plausible.

Chapter 3 looks at the economics of enlarging the EU single market. The approach is based on general equilibrium approach of Baldwin *et al* (1997) and LeJour et al (2001), but introducing a model-consistent framework of calibration and simulation, assuming that the 1997 residual country bias in trade between the EU and CEECs reflects resource costs of regulatory differences which can be eliminated by entry to the single market. The regulatory barriers which would be needed to explain such differences would be of the order of 7 to 15 per cent on most goods: consequently, entry into the EU's Single Market would have large effects in terms of increasing trade between the EU and CEECs - in fact simulations suggest that Poland's trade with the EU could double. As a result, welfare in the CEECs could rise by 11.5-20 per cent (Poland being the largest gainer) while the existing EU countries would not lose from enlargement. Output would rise almost across the board for all industries in the CEECs.

I go on to mention some grounds for doubting whether this interpretation of the existing trade patterns between the EU and CEECs (as reflecting regulatory policy differences and bureaucratic border costs) is totally realistic. Nevertheless, the paper concludes on an optimistic note.

Chapter 4, which was written somewhat later, takes a more critical look at the border cost issue. In particular, I look (probably for the first time in the literature) at the implications for trade when regulation is to counter the effects of a classical monopoly reducing quality of goods. I set up a simple framework in which quality and output combine to produce a quality-adjusted measure of this output: on certain fairly restrictive assumptions it is shown that a regulator can increase consumer welfare by driving up product quality. I also show that this will apply (though with greater algebraic complexity) in many less restrictive model formulations.

Where one country exports the good and the other imports, the exporting country will tend to side with the monopolistic producer, and desire below-optimal regulation (from a global viewpoint), while the importing country will desire excessive regulation. In an identical cross-hauling duopoly, both countries will opt for excessive regulation if there is no cooperation. Under mutual recognition, both will set just marginally higher-than-optimal standards.

In general, with no cooperation trade is actually greater than globally optimal. This is a conclusion quite at odds with the standard literature. The welfare implications of mutual recognition depend upon whether trade is balanced (as in the cross-hauling duopoly case) or unbalanced (as in the case of an exporting monopolist. In the former case, mutual recognition seems to be reliably welfare-improving compared to noncooperation. By contrast, with unbalanced trade, mutual recognition leads to under-regulation and a fall in trade, with benefits to the producing firm and losses to consumers.

I then look at differences in country costs or horizontal regulations and show that the circumstances in which these lead to a profit-shifting bias against trade are far more restricted than the current literature suggest. Finally, I investigate a case where a supplier has to produce goods at the same standard for each market: this leads to a bargaining game between the two countries' regulators. Mutual recognition can lead to under-regulation: I suggest that this is a warning in the case of the current dispute over regulation, testing and labelling of genetically modified foodstuffs.

Chapter 5 builds on a recent literature (notably by Rauch and Casella) linking import demand patterns to imperfect information, particularly in the case of interfirm trade in differentiated products. I seek to draw out the potential implications of this class of model by setting out a basic match-search model and investigating its properties.

The consequences of this type of model are potentially very significant. Observed home bias and two-way trade in the same commodity class may well represent, in part, past changes in production efficiency, trade protection and exchange rates. Firms which developed in a sheltered home market may well survive even after protection is lifted.

Firms which gained export and import markets may well continue to export or import even when patterns of competitiveness change drastically.

Today's policy decisions are tomorrow's historical factors. Trade diversion from a preferential trading agreement may well persist as informational diversion well after the preferential agreement has been scrapped.

There is a key difference between import demand by firms still searching for a satisfactory partner, and demand by firms who have already found such a good partner. In the former case, their demand is very sensitive to changes in prices of relative supply sources, while in the latter demand may be much less price-sensitive. A consequence is that long-standing trade blocs may well have lower import price elasticities and higher optimal tariffs than newer trade arrangements.

To draw the chapters together to some extent: the paper in Chapter 5 may well indicate a direction in which trade analysis may need to move to better understand the patterns noted in the preceding chapters. In particular, if, as Chapter 4 indicates, regulation is not necessarily likely to impede trade in the way assumed in the earlier paper in Chapter 3, the questions still arise - what explains the substantial bias uncovered by gravity work (and confirmed by the Dixit-Stiglitz calibrations in chapter 3), and what will be the welfare effects of harmonisation or mutual recognition agreements?

Chapter 5 indicates that, where search is by individual firms in a match-searching framework, past trade barriers may well have a negative effect upon trade even after they are removed. Removal of trade barriers today will also have less effect than standard trade theory might indicate, unless cost differences are large. However, if sharing of information between firms is ruled out, trade patterns will be efficient in the sense that firms are acting rationally upon the information they have to hand, and there are no external costs or benefits involved. By contrast, when we allow for networking effects (where information can be passed from one firm to another), there is the important issue of whether a firm can fully internalise the value of informational gains from searching (i.e. of whether it can recoup from other firms the value they gain from information it passes on). Assuming mechanisms for doing this are imperfect, then we would expect there to be a free-rider problem: effectively trade/matching information is a public good for all members of the network. It is likely that, if trade had historically been more costly than today, the market will result in under-provision of trade information, since no one firm will wish to undertake a search for partners in a new country unless costs look very low, and so trade may well be much less than socially optimal.

To speculate: this may n fact indicate that the welfare analysis of policy harmonisation in Chapter 3 may well be on the right lines but the primary reason may be rather different than laid down in that chapter. Trade between, say, the EU and Eastern Europe may be low not because current barriers are high, but because they have not so far been low enough to stimulate the entry into those markets of networks of Western firms - and since trade in those circumstances is suboptimal, the removal of trade barriers is likely to have quite sizeable welfare benefits.

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