APPLIED GENERAL EQUILIBRIUM ANALYSIS OF TRADE AND ENVIRONMENTAL ISSUES

BY

LISANDRO ESTEBAN ABREGO-CARDOZA

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Abstract

This thesis uses general-equilibrium numerical-simulation techniques to analyse trade and environmental issues. It tries to take applied general equilibrium modelling in these areas beyond their traditional confines in a number of ways. These include endogenous incorporation of international capital flows into trade models, decomposition of observed economic outcomes, and computation of bargaining solutions and non-cooperative equilibria. Chapter 1 analyses the welfare, income distribution and macroeconomic implications of trade liberalisation and increased indirect taxation in El Salvador. It is found that these policies have little effect on welfare and income distribution, but a significant impact on macroeconomic aggregates. Chapter 2 examines trade liberalisation when foreign direct investment (FDI) flows and international capital income taxation are present, using data for Costa Rica. The main finding is that, once FDI flows and its taxation are taken into consideration, trade liberalisation can hurt a small open economy, whose optimal policy is no longer free trade but a combination of taxes and subsidies on imports. Chapter 3 deals with the decomposition into trade and technology constituents parts of recent increased wage inequality in the UK. It analyses how decomposition is affected by the way in which labour markets are modelled. It is found that when labour markets are perfectly competitive, the main force behind increased wage inequality is technological change, with trade playing only a small role; but when labour market inflexibilities are taken into account, any of the two factors considered can become dominant, depending on the parameter specification used in the model. Chapter 4 examines the incentives for developing-country participation in possible future negotiation on trade and the environment, assumed to break down on North-South lines. It finds that developing countries will do better if they negotiate jointly on trade and environmental policies than if they negotiate over trade policy only. However, negotiations accompanied with side payments of cash will be even better for them. Finally, Chapter 5 analyses the role of adaptation responses to damage from externalities. Using a hierarchy of models calibrated to UK data, we compare internalisation effects in the presence of these responses with a case where they are absent. We find that taking account of adaptation responses significantly reduces the level of full-internalisation taxes and the associated welfare gains from externality correction.

INTRODUCTION

There has been ample use of applied general equilibrium (AGE) models to analyse trade and environmental issues both in a static and dynamic framework. Amongst the many features these models share, we can identify three here, which are also common to similar models used in other fields. First, when addressing open economy issues, AGE models are usually build under the assumption that factors of production—especially capital—are intersectorally mobile, but internationally immobile. Second, they generally concerned themselves with doing counterfactual experiment analysis of *ex-ante* policy changes. Third, applied general equilibrium work typically focuses on Walrasian competitive equilibria only.

The present work takes AGE models dealing with trade and/or environmental issues beyond these traditional confines. First, we build a trade model incorporating endogenous determination of international capital flows in the form of foreign direct investment. Second, we move beyond counterfactual experiment analysis and use general equilibrium techniques to decompose *observed* economic outcomes derived from different sources into constituent parts attributable to each source. Third, we go beyond traditional Walrasian competitive equilibria, and compute both bargaining solutions and non-cooperative equilibria. In a similar vein, we also use modelling techniques to endogenously determine the optimal size of specific policy instruments, with the full set of general equilibrium conditions serving as constraints.

The thesis is organised in five main chapters. With the exception of Chapter 1, where we use a conventional model, each Chapter builds a structure departing from traditional AGE modelling in any of the three ways just described. We use these models with the aim of complementing theoretical discussions and contribute to policy analysis. Chapter 1 uses a traditional general equilibrium trade model to examine the effects of trade liberalisation and indirect tax reform in El Salvador. Our analysis here is exclusively policy-oriented, and we do not claim any methodological or thematic novelty for it. The only new aspect about it is its application to the Salvadorean economy—for which the issues in question have not been addressed within a general equilibrium framework. We examine the welfare, income distribution and macroeconomic effects of both trade liberalisation and value-added tax reform. Our finding is that the welfare and income distribution consequences of both policies are quite small, and that their main impact is on the macroeconomic side (government budget and external sector).

In Chapter 2, we modify and extend this simple trade model to incorporate both foreign direct investment (FDI) and international capital income taxation (ICIT). To the best of our knowledge, no previous calibrated general equilibrium models have been used to examine trade issues when FDI flows or ICIT are present. In the absence of adequate Salvadorean data on sectoral FDI, we apply this model structure to the economy of Costa Rica, for which we examine the welfare effects of unilateral trade liberalisation and compute the optimal import tariff structure. Our principal findings are that, with FDI flows and ICIT present, full import tariff elimination hurts the Costa Rican economy, whose optimal tariff structure in fact consists of a combination of import tariffs and import subsidies of relatively small size.

Chapter 3 uses general equilibrium modelling to conduct decomposition, *ex post* analysis. Here, we deal with the phenomenon of increased wage inequality recently documented for a number of OECD countries (most notably the US and the UK), and which has been linked both to rising trade with low-wage countries (e.g. Wood, 1994) and technological change (e.g. Lawrence and Slaughter, 1993). We examine the UK case, and use a generalised version of the Heckscher-Ohlin trade model to decompose the observed change in wage inequality over the period 1976-90 into portions due to trade and technological change. We do this under alternative labour market institutional frameworks, and find that decomposition results are sensitive to the way the labour market is modelled. Specifically, we find that when wages are fully flexible and labour markets clear, technology is the main force behind the increase in wage inequality. But when real wages are downwardly rigid, the dominant factor can be any of the two, depending on the model parameterisation used.

Chapter 4 uses a model incorporating cooperative an non-cooperative solution concepts to analyse the interaction between trade and environmental issues in an strategic setting. We examine the incentives for less developed countries (LDCs) to participate in possible future linked trade and environment negotiation in the World Trade Organization (WTO). It is suggested that these negotiations will largely break down on developed-developing country lines. We use a North-South model of trade and environment where LDCs are the custodians of environmental assets and can use the leverage this gives them in exchange for trade concessions by developed countries. The latter are assumed—due to their higher income—to attach a large value to the environmental assets owned by LDCs, and can use trade policy threats to improve environmental management by developing countries. We go beyond conventional Walrasian competitive equilibria, and compute both cooperative (bargaining) and non-cooperative solutions over trade only, and over trade and the environment jointly considered. We find that developing countries would gain by moving from negotiations only on trade towards linked negotiations, with gains being larger if they are compensated with side payments of cash.

Chapter 5 deals exclusively with environmental issues, and develops a hierarchy of models to analyse the significance of adaptation responses to various environmental externalities. We compute optimal internalisation policy instruments both in the presence and absence of adaptation responses to environmental damage. We find that the presence of adaptation makes a substantial difference to both the optimal size of internalisation instruments and the welfare gains from internalisation, driving both of them downwards in comparison with the traditional case where adaptation is absent. Our conclusion is that not taking into account adaptation responses to environmental damage can seriously mislead analyses of the consequences of internalising environmental externalities.

Finally, Chapter 6 summarises and draws some conclusions.

CHAPTER 1

GENERAL EQUILIBRIUM ANALYSIS OF TRADE AND INDIRECT TAX REFORM IN EL SALVADOR*

During the last decade, El Salvador has undergone a series of policy changes, resulting from the implementation of structural adjustment reforms. These changes have affected virtually every aspect of its economy—from price control and exchange rate policy, to tax, trade, financial reform, and privatisation. The reforms have substantially increased the role of market forces and made the economy more open.

As in many other developing countries that have gone through similar policy reforms, the expectation was that structural adjustment would foster growth (e.g. Corbo *et al.*, 1987). In fact, the growth performance of the Salvadorean economy during the 1990s has significantly improved, averaging about 5.3% a year (during the 1980s GDP contracted by 1.0%). Though few would challenge the view that policy changes since 1989 have something to do with this improved performance, it is difficult to establish the contribution of the various reform components. Policy-makers in El Salvador seem to have identified trade liberalisation as the single most important reform item and main contributor to recent growth. Accordingly, after an initial significant liberalisation effort, they have taken additional steps to deepen trade reform.

Critics of structural adjustment in El Salvador, in turn, have attacked trade liberalisation on different fronts, but especially on the grounds of its (likely, at least) negative macroeconomic effects (e.g., increased budget deficit from lower tariff revenue, and increased trade imbalance from higher imports).[1] Although Salvadorean policy-makers have taken some measures to counterbalance adverse macroeconomic effects by increasing indirect taxation and allowing the exchange rate to depreciate, critics point to the negative distributional effects of these.

In this Chapter, we analyse the welfare, income distribution and macroeconomic effects of deepening trade liberalisation in El Salvador. We also examine the effects of specific measures adopted partly to offset unwanted macroeconomic effects—such as increased value-added taxation. We use an applied general equilibrium model to analyse these policy changes. The model—which has been calibrated to a 1990 data set—disaggregates economic activity into 15 sectors, and identifies three separate factors of production (capital, urban labour and rural labour) as well as two household groups (one deriving income mostly from capital and the other whose income comes mainly from labour). The lack of more disaggregated data does not allow us to do a more detailed analysis of distributional issues.

[1]They also argue that enhanced growth has resulted mainly from the civil war ending (in 1992) rather than from economic policy reforms.

The trade reform numerical simulations we carry out consider alternative closure rules for both foreign sector and government sector. One set of closure rules has the purpose of calculating the welfare impact of liberalising trade in a theory-consistent fashion; whereas the other tries to examine broader effects of this policy given the specific characteristics (or circumstances) of the Salvadorean economy.

The specific issues this Chapter focuses on are the following. In the area of trade reform, we examine the effects of different degrees of trade liberalisation, according to the reform stages established by Salvadorean policy-makers. We first simulate the effects of moving to a tariff structure with rates between 0 and 15%, which El Salvador has already adopted. We also analyse the effects of taking this process further by adopting a two-rate tariff structure of zero and 6% as well those of a hypothetical movement to complete free trade. On the tax-reform side, we examine the impact of the 30% increase of the VAT rate that took place in El Salvador in 1995. The latter tries to assess the ability of increased indirect taxation to offset some adverse macroeconomic effects of trade liberalisation and the distributional consequences of higher indirect taxes.

The structure of the Chapter is as follows. In Section 1.1 we briefly describe some aspects of structural adjustment reform in El Salvador. Section 1.2 presents the structure of the model, while Section 1.3 discusses the nature of the data we use. Section 1.4 analyses simulation results, and, finally, Section 1.5 summarises and draws some conclusions.

1.1 Some Aspects of Structural Adjustment Reform in El Salvador

1.1.1 Trade and Exchange Rate Policy

Like the rest of Central America, ever since the creation of the Central American Common Market (CACM) in 1960, El Salvador followed a growth strategy based on industrialization through import substitution, especially of consumer goods. In terms of trade policy, this strategy was implemented via the imposition of high tariff rates for consumer goods, on the one hand, and of low import taxes for intermediates and capital goods, on the other. Tariff protection for import substitutes during this period was thus characterized by a high average level and dispersion (Table 1). This was complemented with the existence of export taxes on those goods in which El Salvador had at the time a strong comparative advantage, such as coffee, cotton and sugar. With manufacturing exports being also indirectly taxed, the result was a trade regime penalising all exports.

In 1989, in the context of broader structural adjustment reforms, the strategy of import substitution was partially abandoned, as the country embarked on more open trade policies, intending to foster growth mainly through export expansion. Since then, all import quantitative restrictions and regulations—except those having to do with security and health considerations—have been eliminated, while tariff rates have been drastically lowered, especially for consumer goods (Table 1). By 1992, El

Salvador had adopted a 5-20% tariff structure. Simultaneously, all export taxes have been scrapped. As a result, both the level of protection and its dispersion have been significantly reduced, with disprotection for key export goods (such as coffee) almost disappearing. Columns 2 and 4 of Table 1 show the new pattern of incentives by the early 90s.

There has been a strong belief by Salvadorean policy-makers that trade reform has been an important element in the country's improved economic performance during the 90s. Accordingly, there has been a great deal of enthusiasm for further deepening trade liberalisation. In 1995, the Salvadorean government announced that they were aiming at moving to a zero tariff for intermediate and capital goods, and a 6% tariff for consumer goods, by 1998. Though trade reform has proceeded at a slower pace than this—especially at the top of the tariff structure—, significant changes have taken place. El Salvador has nowadays a tariff range of 0-15%, a dramatic change in relation to the end of the 80s. The expectation is that trade reform will significantly boost economic growth mainly through export expansion (MIPLAN, 1989).

El Salvador's initial trade reforms and new trade liberalisation plans have been accompanied by changes in its exchange rate regime. First, in 1989-90, multiple exchange rates were completely abolished, though the exchange rate continued to be fixed by the government. Then, in 1990, El Salvador abandoned its fixed exchange rate regime in favour of one of managed floatation—under which the Central Bank tried basically to avoid an overvaluation of the domestic currency. This because there

Table 1. El Salvador: Nominal and Effective Tariff Protection

Percentages

	Nominal Protection 1987	Nominal Protection 1993	Effective Protection 1987	Effective Protection 1993
Coffee	- 25.0	0.0	- 28.1	-1.3
Cotton	0.0	5.0	- 11.1	4.0
Other agriculture and mining	4.8	7.3	- 2.6	7.0
Processed food	50.4	13.4	199.1	30.4
Beverages and tobacco	225.7	16.8	1409.0	21.2
Textiles	54.2	13.0	121.7	20.4
Apparel, leather and footwear	86.6	26.7	225.6	18.2
Wood and furniture	124.8	13.5	371.1	18.6
Paper and printing	52.8	4.9	105.1	2.4
Chemical prod.	14.3	5.7	7.1	4.6
Rubber, plastic and minerals	37.6	9.3	69.7	6.1
Iron and steel industry	17.6	8.6	17.3	9.3
Machinery and equipment	29.0	9.3	56.6	10.3

Sources: World Bank (1989) for 1987, and Abrego (1994) for 1993.

was some pressure for the currency to rise against the dollar, due to an oversupply of the latter brought about by remittances and foreign aid. With this, during 1989-93, the exchange rate experienced a nominal devaluation of approximately 70%. By 1994, however, policy-makers in El Salvador began having second thoughts regarding its exchange rate regime. These were formally converted into policy action at the beginning of 1995, when the Salvadorean government announced its plans to move again to a fixed exchange rate. In the last four years, the nominal exchange rate has remained basically fixed. As El Salvador's inflation has been above that of its main trade partners, this has implied a real appreciation of the local currency.

1.1.2 Taxation

Structural adjustment reforms in El Salvador have affected public finances especially through the revenue side—where a far-reaching tax reform has been implemented. This has comprised eventually all taxes that were in effect when adjustment reforms were launched in 1989, namely the income tax, property tax, sale tax, and—as already described—international trade taxes.

Income tax reform has had to do with both personal and company taxation. Reforms to the personal income tax have led to a new tax code. The main characteristic of the new income tax is its much lower marginal and average rates, which have been cut roughly by half. At present, the maximum marginal and average rates are 30% and 25%, respectively. The tax has also been simplified by dramatically reducing the number of income brackets, and eliminating a great deal of exemptions, most of them linked to the import-substitution strategy.

Company taxation, in turn, has also comprised the reduction of marginal and average rates, though less substantially. A very important change has been the abandonment of the multiple-rate system in favour of a flat-rate system. Another key change has been the scrapping of the classical system of corporate taxation—where profits were double taxed—in favour of one where taxation takes place at company level only. These reforms have been accompanied by the elimination of the property tax, which was applied to net assets both at company and personal level.

As to indirect taxation reform, this have comprised the substitution of the turnover tax by a value-added tax. The VAT has very few formal exemptions, and do not apply to capital goods sales. Set initially at 10% in 1992, its rate was increased to 13% in June, 1995—partly with the goal of compensating the loss of revenue stemming from further trade liberalisation—where it still remains.

1.2 The Model

The model that we present is based on that built by Devarajan *et al.* (1994) for Cameroon—which is a static, small open economy model. Our version of this model contains 15 production sectors, 2 consumers, and 3 factors of production (capital, rural labour and urban labour). The model assumes that goods produced domestically and goods available in the rest of the world are imperfect substitutes for each other, both on the import and on the export side. This implies that, for each good, three different markets are distinguished: the market for imports, the market for exports and the market for domestic goods sold at home. World prices are assumed to be fixed both for import and export goods. As to the third market, demand and supply are endogenously determined. It is assumed that the three markets are perfectly competitive, and that full employment prevails in factor markets.

1.2.1 Supply

In order to model differences between output produced for the domestic and export market, supply in the model is determined in two stages. In the first stage, it is assumed that producers maximize profits from producing a composite good. In the second stage, this composite good is divided between the domestic and export market, depending on relative prices. This good is assumed to be produced by a fixed proportion combination of value added and intermediate inputs. Thus, the production function for the good in question is given by

$$X_j = \min\left(Q_j, \frac{Z_j}{a_{ij}}\right) \quad j = 1, 2, ..., 15, \tag{1.1}$$

where X_j is gross output, Q_j is value added, Z_j is intermediate inputs in sector j and a_{ij} denotes the fixed amount of good i required to produce a unit of j. Value added, in turn, is produced by a combination of capital, urban labour, and rural labour according to a Cobb-Douglas technology

$$Q_j = \prod_k F_{kj}^{\alpha_{kj}} \quad k = u, r, \kappa; \quad \sum_k \alpha_{kj} = 1, \tag{1.2}$$

where F_{kj} represents the quantity of factor k used by the jth sector, and α_{kj} is the share of factor k's income in total valued added in sector j.

As to intermediate inputs, they are also required in fixed proportion

$$Z_j = \sum_i a_{ij} X_j. \tag{1.3}$$

Profit maximization subject to (1.1), (1.2) and (1.3) leads to the following factor demand function

$$F_{kj} = \frac{P_{v_j} \alpha_{kj} X_j}{w_k \psi_{kj}}, \tag{1.4}$$

where P_{v_j} is the price of value added, w_k is the average factor price, and ψ_{kj} is a parameter taking account of the fact that factor prices differ across sectors (which Devarajan *et al.* (1994) interpret as a factor-market-distortion parameter).

The technology that transforms output for domestic market into output for the export market is described by the following CET function (for convenience, the elasticity subindex has been omitted)

$$X_j = [\beta_j (E_j)^\eta + (1 - \beta_j)(D_j)^\eta]^{\frac{1}{\eta}}, \tag{1.5}$$

where $\eta = (1 + \epsilon_1)/\epsilon_1$, ϵ_1 being the elasticity of transformation. D_j and E_j is output produced for the domestic and export market, respectively, and β_j is a distribution parameter.

Cost minimization subject to (1.5) yields the following export supply function

$$E_j = D_j \left[\frac{(1-\beta_j)P_{E_j}}{\beta_j P_{D_j}} \right]^{\frac{1}{1-\eta}}, \tag{1.6}$$

where P_{E_j} and P_{D_j} are export and domestic goods prices, respectively, expressed in local currency.

1.2.2 Demand

There are three different sources of demand: foreign demand for export goods, domestic demand for the domestic good, and domestic demand for imports. Because of our small country assumption, we do not need an elaborate treatment of foreign demand, and concentrate on the discussion of domestic demand. It is assumed that imports and domestic goods are imperfect substitutes for each other (Armingtion assumption). This implies that, for each sector, there is a composite commodity, C_j, which is a CES aggregation function of imports (M_j) and domestically-produced goods (D_j) (the elasticity index is again omitted):

$$C_j = \left[\alpha_j M_j^{-\sigma} + (1-\alpha_j) D_j^{-\sigma} \right]^{-\frac{1}{\sigma}}, \tag{1.7}$$

where α_j is a share parameter and $\sigma = 1/(1+\epsilon_2)$, ϵ_2 being the elasticity of substitution between domestic goods and imports.

Cost minimization subject to (1.7) yields import demand as a function of the domestic good price, P_{D_j}, and the imported good price, P_{M_j}:

$$M_j = D_j \left[\frac{\alpha_j P_{D_j}}{(1-\alpha_j)P_{M_j}}\right]^{1+\sigma} \tag{1.8}$$

As to the components of domestic final demand, household consumption is derived from the maximization of a Cobb-Douglas utility function subject to each household's budget constraint, yielding

$$CH_{hj} = \mu_{hj} I_h (1-s_h)(1-t_h)/P_{c_j}, \tag{1.9}$$

where μ_{hj} is the share of good j in total consumption by household h, I_h is household income, s_h is the average propensity to save by household, t_h is an average income tax rate, and P_{c_j} is the price of composite good j.

Government demand, in turn, is assumed to be exogenously given, and is made up by the purchase of goods and services, plus transfers to households

$$GD = \sum_j \phi_j CG + \sum_h TR_h, \tag{1.10}$$

where ϕ_j is the share of good j in aggregate government consumption of goods and services, CG, and TR_h denotes government transfers to households.

Finally, although this is a static model, we must accommodate for investment occurring during the period of analysis. Aggregate investment, which is exogenously set equal to aggregate savings, is made up of fixed capital investment, V_1, and inventory investment, V_2:

$$I = V_1 + V_2. \tag{1.11}$$

As to fixed capital formation, we consider only gross investment, as no recent depreciation data is available for El Salvador. Fixed investment by sector of destination and origin is given by the following expressions, respectively

$$P_j K_j^d = m_j V_1, \tag{1.12}$$

$$K_j^s = \sum_i b_{ji} K_i^d, \tag{1.13}$$

where P_j is the price of a unit of capital installed in sector j, K_j^d is fixed investment in sector j, m_j denotes the proportion of aggregate fixed investment done by sector j, K_j^s is fixed investment by sector of origin, while b_{ji} represents the share of capital good j in fixed investment in sector i.

Finally, inventory investment is specified as a fixed proportion of gross output

$$V_2 = \sum_j \delta_j X_j P_{x_j}, \tag{1.14}$$

where δ_j is the ratio of the value of inventory investment to gross output in sector j, and P_{x_j} is the price of gross output.

1.2.3 Prices

As indicated earlier, the model incorporates the small open economy assumption and thus considers world prices for imports and exports to be exogenous for all goods. Domestic import and export prices are, respectively, given by

$$P_{M_j} = R P_{M_j}^f (1 + t_{M_j}), \tag{1.15}$$

$$P_{E_j} = RP^f_{E_j}, \tag{1.16}$$

where $P^f_{M_j}$ and $P^f_{E_j}$ denote the world price of imports and exports, respectively, R is the exchange rate, and t_{M_j} is the tariff rate applied to good j.

Prices for composite good, C_j, and gross output, X_j, are given by

$$P_{c_j} = (P_{D_j}D_j + P_{M_j}M_j)/C_j, \tag{1.17}$$

$$P_{x_j} = (P_{D_j}D_j + P_{E_j}E_j)/X_j. \tag{1.18}$$

The valued-added price is, in turn, the price of sectoral output net of intermediate inputs and indirect taxes:

$$P_{v_j} = P_{x_j}(1 - t_{x_i}) - \sum_i P_{c_j}a_{ij}, \tag{1.19}$$

where t_{x_i} represent either an excise tax—applied to alcoholic drinks and tobacco, and which we model as a production tax—or a production subsidy—granted to some agricultural activities and utilities.

The price per unit of capital, P_j, is given by

$$P_j = \sum_i P_{c_i}b_{ij}. \tag{1.20}$$

Finally, we will use the producer price index as our aggregate price index, P:

$$P = \sum_j \theta_j X_i, \tag{1.21}$$

where θ_j is the proportion of total output accounted for by sector j.

1.2.4 Income

Factor incomes are made up of domestically-generated income, Y_k, and income from abroad, F_k, i.e.

$$Y_k = \sum_j w_k \psi_j F_{kj} + RF_k. \tag{1.22}$$

We distinguish two types of households according to their income composition between labour income and capital income. We label these labour and capitalist households, respectively. Here, we also consider separately the existence of remittances as well as government transfers. Mapping the distribution of factor income into the distribution of income between the two households, and adding remittances and government transfers, we get

$$I_h = \sum_k \lambda_{kh} Y_k + RN_h + TR_h, \tag{1.23}$$

where I_h denotes household income λ_{kh} represents the share of factor k's income going to household h, and N_h and TR_h are remittances from abroad and government transfers, respectively.

Government derives its revenue, GR, from taxes, transfers from abroad and other non-tax revenue (such as revenue from domestic transfers, services provided by the government, etc.):

$$GR = \sum_h I_h t_h + t_{co} L + \sum_j RP^f_{M_j} M_j t_{M_j} + \left(\sum_j P_{x_j} X_j - \sum_i P_{c_j} a_{ij} X_j \right) t_{v_j}$$

$$+\sum_j t_{x_i} P_{x_j} X_j - t_{v_j} P_j K_j^d + NTR, \tag{1.24}$$

where t_{co} is an average corporate tax rate, L is corporate income, t_{v_j} is the value-added tax rate, and NTR represents non-tax revenue. (The second last term in (1.24) takes account of the fact the capital goods are exempt from the value-added tax). Corporate income is, in turn, given by

$$L = \gamma \sum_j w_\kappa \psi_j F_{\kappa j}, \tag{1.25}$$

where γ is the fraction of capital income generated by corporations in the economy as a whole (the subscript κ refers to the factor capital).

1.2.5 Market Clearing Conditions

Equilibrium in the goods market implies that supply equals demand for each commodity, i.e.

$$C_j = INT_j + \sum_h CH_{jh} + CG_j + I_j. \tag{1.26}$$

In the labour market, full employment of each factor is assumed, so that aggregate demand for each input type must equal aggregate supply:

$$\sum_j F_{kj} = F_k^s. \tag{1.27}$$

where F_k^s is the supply of factor k, which is exogenously given.

1.2.6 Macroeconomic Closure

Regarding closure rules,[2] the model is savings-driven in that investment in the period of analysis equals aggregate savings—which is the sum of households savings (S^p), government savings (S^g) and foreign savings (S^f):

$$INV = S^p + S^g + RS^f, \tag{1.28}$$

The first two components of the right hand side of (1.28) are defined as

$$S^p = \sum_h s_h(1 - t_h)YH_h, \tag{1.29}$$

$$S^g = GR - GD, \tag{1.30}$$

while the third component is determined from the identity for the balance of payments current account:

$$\sum_j P_j^f M_j + \sum_k Y_k^f = \sum_j P_j^f E_j + \sum_h N_h + TRF + S^f. \tag{1.31}$$

We use different closure rules involving the three savings types,[3] depending on the particular issue we are interested in. Closure rules differ when we simulate the impact of trade liberalisation. Here, in order to isolate the welfare effect of trade reform, we keep government revenue constant and endogenise one tax rate (the corporate tax rate); as to the foreign sector, we fix foreign savings and allow the exchange rate to

[2]On the general issue of closure rules in applied general equilibrium models see Dewatripont and Michel (1987).

[3]On foreign sector closure rules, see Whalley and Yeung (1984); de Melo and Robinson (1989); Devarajan *et al.* (1994).

vary;[4] while to keep private savings constant, we endogenise the household savings rate, h_{s_h}. Government expenditure, in turn, is always fixed as well as international transfers and factor income from abroad.

Although this closure rule is very useful from an analytical standpoint, it does not necessarily reflects the situation of the Salvadorean economy in the last few years. On the external sector, the relevant feature of this economy is its ability to finance an increasing trade deficit through aid, capital inflows and, especially, remittances. To capture this, in our second trade liberalisation simulation, foreign savings are endogenously determined. Since transfers and factor income from abroad are fixed, the endogenisation of foreign savings is equivalent to keeping the trade balance free. On the other hand, we keep the exchange rate fixed, reflecting the plan of pegging that variable announced by the Salvadorean government in February, 1995. Similarly, we endogenise both government revenue and private savings—which implies that household savings rates and the corporate tax rate are now exogenous. For the model to be exactly determined, one more variable must be determined exogenously. Our choice is to make aggregate fixed-capital investment exogenous.

1.3 Data and Model Calibration

The social accounting matrix (SAM) that feeds the model is based mainly on data from the Banco Central de Reserva de El Salvador (1993) (Henceforth BCR,

[4]An external sector closure rule similar to this is also used in Devarajan *et al.* (1994).

1993) and Ministerio de Planificacion de El Salvador (1991) and (1994) (Henceforth MIPLAN, 1991 and 1994, respectively). In BCR (1993), a new system of national accounts for El Salvador has been built. This system, set up for the year 1990, contains an input-output table, together with income and expenditure accounts for households, corporations (both private and public), government and the rest of the world. In fact, it amounts to a SAM with a rather different format. We combine this data with information from household consumption expenditure and employment surveys done by MIPLAN (1991) and MIPLAN (1994) as well as with some macroeconomic accounts. With the necessary adjustments, this data readily produce a SAM with the disaggregation and consistency required by our model.

The input-output table contained in BCR (1993) is a 1990 updated version of the 1978 table, and classifies economic activity into 44 sectors. The updating was performed by a combination of survey data and RAS. We have aggregated this table into 15 sectors, trying to keep separately key sectors in agriculture and manufacturing in the Salvadorean economy.

As to income and expenditure by different institutional sectors, since the aggregation presented in BCR (1993) is not always the same as required for our SAM (some transactions in BCR are too aggregated and others present a very different disaggregation), we have complemented their data with information from consumption and employment surveys done by MIPLAN (1991 and 1994). This has been the case for household consumption and income as well as for the distribution of remunerations by sector between rural and urban labour. The consumption survey done by MIPLAN is for 1990-91, while the employment survey is for 1992-93. The obvious result is that BCR and MIPLAN magnitudes do not match. Therefore, in order to maintain SAM balances, we have used MIPLAN's data to compute shares only and have kept the corresponding aggregate magnitudes provided by BCR.

When the foregoing data combination has not been sufficient, we have complemented it with balance of payments and government finance accounts. This has been done especially with regard to transfers among institutional sectors as well as government non-tax revenue. When appropriate, we have again followed the procedure of using the complementary information to compute shares only, while preserving the original aggregates.

As to other data required for our model, such as sectoral capital stocks, trade elasticities and other parameters, they have been obtained as follows. In the absence of adequate data, capital stocks have been computed by assuming a uniform return to capital of 20%. This is a procedure that has also been used in some of the applied public finance literature (e.g. Ballard *et al.*, 1985). On the other hand, lacking a capital composition matrix, we used the associated vector, which gives the share of each capital good in aggregate investment demand.

The elasticity values we use for the Armington and CET functions are based on (guess) values used by Hinojosa-Ojeda *et al.* (1994) for a group of Central American countries. As Devarajan *et al.* (1994), we have also followed their practice of

Table 2. El Salvador: Benchmark Selected Model Parameters

	Import share, α	Export share, β	Trade Elast, $\epsilon_1 = \epsilon_2$	Import Tariff, t_M*	Value-added tax, t_v
Coffee	0.000	0.392	6.0	0.000	0.087
Cereals	0.309	0.950	2.2	0.003	0.000
Fruits and vegetables	0.223	0.786	1.9	0.051	0.000
Other primary	0.332	0.841	1.9	0.003	0.025
Processed food	0.271	0.836	1.8	0.047	0.052
Sugar	0.115	0.620	3.0	0.101	0.025
Beverage and tobacco	0.131	0.871	1.7	0.138	0.058
Textiles	0.247	0.731	1.2	0.128	0.034
Apparel	0.099	0.784	1.2	0.167	0.047
Leather and its prod.	0.092	0.907	0.9	0.080	0.026
Paper and printing	0.430	0.663	1.7	0.054	0.050
Chemical prod.	0.498	0.760	1.5	0.069	0.010
Other manuf.	0.371	0.978	0.6	0.086	0.025
Construction	0.000	0.000	n.a.	n.a.	0.000
Services	0.172	0.806	1.8	n.a.	0.010

* Ratio of tariff revenue to imports. Tariffs in this column are lower than those presented in Table 1 because they take into account the existence of both exemptions and free trade within the CACM.

n.a.: not applicable.

using, for a given sector, the same values for Armington and CET functions. They also assign larger elasticity values to agricultural goods, trying to reflect the higher degree of homogeneity between agricultural goods abroad and their counterparts consumed domestically. We adopt this practice as well. On the production and preferences sides, we use Cobb-Douglas functional forms.

Reinert and Roland-Holst (1992) and Shiells and Reinert (1993) have estimated Armington elasticities for manufacturing activities using data for the United States. They produce estimates which are generally lower than those we use here.[5] Though their sectors and ours do not exactly match, their estimates are smaller on average by about one third than those presented in Table 2 for manufacturing activities. For some of our sectors—leather and other manufacturing—the estimates they present are larger than our values. As part of our trade liberalisation simulations, we do sensitivity analyses on the trade elasticity values, and find that using the US estimates for manufacturing activities has only a minor effect on welfare and aggregate income results.

Finally, shift and share parameters have been obtained through the conventional calibration procedures used in applied general equilibrium modelling. These consist of using the exogenous elasticity estimates to determine values for other parameters in the model, so that the benchmark year constitutes an equilibrium (e.g. Mansur and Whalley, 1984; Shoven and Whalley, 1994). Table 2 presents the parame-

[5] We became aware of the existence of these estimates only after this Chapter had been written.

ters we use for the Armington and CET functions as well some additional information for the benchmark year.

1.4 Simulation Results

1.4.1 Trade Liberalisation

In this section we describe simulation results from the following scenarios of trade liberalisation:

1. Reducing the maximum tariff for consumer goods from 20% to 15% and the minimum duty for intermediate and capital goods from 5% to zero. This corresponds to the tariff changes implemented between 1995 and 1998.

2. Setting a single tariff of 6% for consumer goods and a zero-tariff for intermediate and capital goods. This corresponds to the longer-term trade-reform plan announced by the Salvadorean government in February, 1995.

3. Completely eliminating all import tariffs.

We have performed these simulations using the two closure rules described above.

Trade Liberalisation with Fixed Foreign Savings and Fixed Government Revenue

In order to isolate the impact of trade liberalisation on welfare, we fix foreign and private savings as well as government revenue (equal-revenue yield) for the three trade liberalisation scenarios considered. The counterpart of fixing government revenue and private savings is the endogenisation of the corporate income tax rate and labour houselods' propensity to save. Finally, with fixed foreign savings, the exchange rate has been allowed to vary (the producer price index being the new numeraire).

Table 3. El Salvador: Welfare and GDP Impact of Alternative Tariff Changes

	0-15% Tariff Structure	0-6% Tariff Structure	Free Trade
Equivalent variation as a % of income			
All households*	0.25	0.34	0.39
Labour households	1.47	1.85	2.02
Cap. households	-1.61	-1.59	-1.68
Change in GDP (%)	0.16	0.19	0.21

* As a % of GDP.

Welfare and Income Level

The movement from a tariff structure of 5-20% towards a 0-15% structure would seem to imply a greater dispersion of protection. However, partly because of the lower average protection level, our simulation results show that this will still have a positive impact on aggregate welfare (Table 3). Once this movement has been made, the welfare gains from moving towards complete free trade are very modest (welfare rises by 0.14% of GDP). Moving from the current tariff structure towards that aimed at by the Salvadorean government (of 0-6%) would mean a welfare increase of only 0.09%. The trade liberalisation impact on GDP follows a very similar pattern. These results suggest that the efficiency gains of reducing tariff protection fall exponentially once a relatively low tariff level has been achieved, a result consistent with other findings in the literature (see, e.g. Whalley and Srinivassan, 1986).

We have performed sensitivity analysis on the trade elasticity values, using estimates based on those produced by Reinert and Roland-Holst (1992) for manufacturing activities, while leaving those for primary goods unaltered. In this new set of simulations, we also move downwards the elasticity for services by about 50%. Using these new set of values changes welfare and GDP results very little indeed (they generally change up to the third digit after the decimal point, and by roughly one point for each scenario of trade liberalisation). Since we are in a second-best world (there are factor market distortions and non-optimal taxes and subsidies), it is not straightforward to determine the reasons for this insensitivity. However, the fact that not all estimates by Reinert and Roland-Holst are smaller than our central case values is probably of some significance.

Table 4. El Salvador: Distribution Effects of Full Tariff Elimination

Percentages of aggregate factor and household income

	Benchmark	New Equilibrium
Factor income		
Rural labour	11.83	12.05
Urban labour	21.44	21.32
Capital	66.73	66.63
Household income		
Labour households	41.97	42.82
Cap. households	58.03	57.18

Income Distribution

Welfare results in Table 3 also show that only labour households benefit from trade liberalisation—a reflection of changes in income distribution are adverse to capitalist households. However, for our model disaggregation at least, the distributional impact of reducing tariffs is quite modest for all scenarios of trade liberalisation. Absolute returns increase for all factors under the three scenarios of trade liberalisation considered, with rural labour being the main winner and urban labour the main relative loser—as shown by Table 4 for the full-tariff elimination scenario. The overall return to labour relative to that of capital also increases slightly in all cases.

This pattern of changes in factor returns is closely related to that of movements in output and employment across sectors. In the case of rural labour, the rise in its return is the result of output expansion in agriculture, which is an intensive user of that input; while the behaviour of the return to urban labour is explained mainly by the contraction of manufacturing and construction and services, its main users. The decline of these sectors is also responsible for the fall in the return to capital relative to the aggregate wage rate.

These factor return movements seem to be consistent with traditional trade theory predictions, such as those made by the Stolper-Samuelson theorem (e.g. Jones and Neary, 1984). In effect, it is the factor used intensively in the sector whose relative price went down—manufacturing—the one that ends up losing. However, there are not absolute losers here.

As to household income, in line with the foregoing, the winners are labour households (Table 4). Thus, at an aggregate level, trade liberalisation has a small but progressive impact on income distribution. At a more specific level, this seems to be still the case since rural labour wins, and rural households in El Salvador are poorer than their urban counterparts (Gregory, 1992).

Macroeconomic Aggregates

The foregoing results indicate that the efficiency and distributional impact of trade liberalisation would be positive. The same cannot be said about its macroeconomic effects (Table 5). On the one hand, government savings would tend to fall. In our model, this does not show up since by fixing government revenue we have fixed also its savings. However, given that revenue from personal income and indirect taxes exclusive of tariffs decline, corporate tax revenue must more than double (in all cases), in order to keep total revenue constant. Clearly, such a change in corporate taxes would be infeasible in practice.

Table 5. El Salvador: Selected Macroeconomic Effects of Trade Liberalisation

Percentage changes with respect to benchmark

	0-15% Structure	0-6% Structure	Free Trade
Private savings	-4.07	-4.49	-4.81
Corporate tax revenue	108.99	118.91	126.12
Personal income tax revenue	-2.16	-2.39	-2.56
VAT revenue	-0.70	-0.77	-0.81
Tariff revenue	-85.84	-94.05	-100.00
Other tax revenue	-0.40	-0.56	-0.68

We should highlight two results here. First, despite the GDP expansion, revenue from the personal income tax falls. This is due to the changes that have taken place in income distribution, which has lowered income for capitalist households—El Salvador's main tax payers. Second, even though absorption has remained roughly constant, indirect tax revenue exclusive of tariffs declines. This comes from the contraction of manufacturing and services, the main sources of this type of revenue in El Salvador.

On the other hand, aggregate private savings also decline, resulting again from changes in income distribution. With both foreign and public savings being held constant aggregate savings fall, and so does investment.

As to export expansion—the main channel through which El Salvador's policy-makers expect trade liberalisation to foster growth–, the effect of lower tariffs on it is indeed modest, ranging between 3.8% and 5.1%, depending on the extent of trade liberalisation.

Trade Liberalisation with Endogenous Foreign Savings and Government Revenue

As indicated above, over the last eight years, El Salvador has been able to finance an increasing trade deficit through a combination of foreign aid, capital inflows and family remittances. In fact, the plan for further deepening trade liberalisation that was announced by the Salvadorean government in February, 1995, could hardly have been made without the expectation that this flow of foreign resources—especially remittances—will be present, at least in the near future.

In this context, it is also interesting to examine the effects of further liberalizing trade once foreign savings—or the trade balance—are allowed to freely vary. We have simulated this scenario under the restriction that both fixed capital investment and the exchange rate stays constant. The latter is consistent with the policy of pegging the exchange rate that has been in effect in El Salvador since the beginning of 1995; the former is required for the model to be exactly determined, although—in principle–we could have chosen to fix a different variable. On the other hand, we must now endogenise government revenue; with government expenditure continuing to be fixed, the variable that equilibrates its budget is savings. Again, we have performed simulations for the three trade liberalisation scenarios identified above. Aggregate results are shown in Table 6.

Note that the expansion in GDP is now lower under all scenarios of trade liberalisation. This seems to be the result of smaller exports resulting from the exchange rate not having experienced a depreciation. The pattern of changes in production is also somewhat different. Under the movement toward a 0-15% tariff structure, agricultural GDP contracts while all other major sectors expand. This means that sectoral results are being dominated by the capital inflow that is generated in order to keep real investment constant. This inflow is quite high, implying an increase in the trade deficit of more than 10.7%. Note that exports even contract under the first scenario of trade liberalisation (0-15% structure).

On the other hand, now that government revenue has been allowed to vary, as expected, tariff removal has a negative impact on public savings. Though rather large, this is slightly lower than the fall in tariff revenue due to the increase experienced by receipts from both direct and other indirect taxes. The increase in indirect tax revenue is influenced by the rise in absorption brought about by trade liberalisation. Greater direct tax revenue, in turn, is basically the result of the change in income distribution, which now favour capitalists. Aggregate savings does fall, but somewhat modestly (around 2.4%), since foreign savings has substantially gone up, and income

Table 6. El Salvador: Trade Liberalisation Effects with Endogenous Foreign Savings

Percentage changes with respect to benchmark

	0-15% Structure	0-6% Structure	Free Trade
Income and trade			
GDP	0.10	0.13	0.15
Exports	-0.18	0.08	0.27
Imports	3.61	4.27	4.74
Trade deficit	8.83	9.95	10.77
Public finances			
Government revenue	-15.50	-16.99	-18.07
Personal income tax rev.	0.68	0.68	0.67
Corporate tax revenue	0.65	0.65	0.64
VAT revenue	0.08	0.070	0.07
Other tax revenue	0.08	-0.09	-0.20
Government savings	-1273	-1393	-1479
Other Savings			
Private savings	0.82	0.80	0.79
Foreign savings	20.08	31.64	34.24
Factor prices			
Rural labour return (1)	0.58	0.65	0.70
Urban labour return (2)	0.68	0.66	0.65
Capital return (3)	0.65	0.67	0.64
(1)/(3)	-0.07	0.00	0.05
(2)/(3)	0.03	0.02	0.003

distribution changes have allowed private savings to increase. The second movement is, however, quite modest, so that national savings experience a large contraction.

Now, if investment is to remain unchanged, there must be a replacement of national by foreign savings, as shown by Table 6. However, boosting public savings by rising taxes on sales, for instance, may contribute to avoid this, as we will see now.

1.4.2 Increased Value-Added Taxation

We have simulated the effects of the increase in the value-added tax rate from 10% to 13%, which took place in June, 1995. Results are presented in Table 7. Again, in order to take account of El Salvador's circumstances, we have kept the exchange fixed and allow foreign savings to vary. Since not all goods are subject to the VAT, uniformly rising its rate in all sectors being taxed has an impact not only on the general price level but also on relative prices.

Relative price changes, in turn, lead to movements both in the level and structure of output. Now, given that we are in a second-best world,[6] GDP ends up rising, though very slightly. This comes especially from the expansion agricultural activities, where most goods exempt from value-added taxation are. Manufacturing and services both contract in aggregate.

[6]On the welfare implications of policy changes in the presence of more than one domestic distorion, see, e.g. Bhagwati (1981); Lancaster and Lipsey (1996). For an applied general equilibrium perspective, see, e.g. Clarete and Whalley (1988).

Table 7. El Salvador: Macroeconomic and Distribution Effects of Increasing VAT

Percentage changes with respect to benchmark

	% Change
Macro aggregates	
GDP	0.03
Trade balance	-4.68
Tax revenue	7.02
Government savings	581.83
Private savings	-0.72
Foreign savings	-14.88
Income distribution	
Rural labour income share*	0.93
Urban labour income share*	-0.28
Capital income share*	-0.07
Labour households income share**	0.17
Cap. households income share**	-0.12
Rural labour return (1)	0.48
Urban labour return (2)	-0.68
Capital return (3)	-0.48
(1)/(3)	0.67
(2)/(3)	-0.19

* Share in GDP

** Share in household income

These movements in production have an impact on factor prices and income distribution. On the one hand, the expansion of agriculture causes the return to rural labour—an input used intensively there—to rise slightly, while the contraction of manufacturing and services—both intensive users of urban labour—leads to a fall in the urban wage rate. The return to capital also decreases, following the decline of manufacturing, its main user. Thus, factor income distribution changes in favour of rural labour. Though the ratio of the urban wage rate to the return to capital falls slightly, the increase in the rural wage rate is big enough to make labour as a whole a winner *vis-a-vis* capital. This is also reflected in terms of household income distribution, with labour households increasing their share, though very slightly (Table 7).

As to the trade balance, the increase in the VAT leads to a small rise of exports and a contraction of imports, improving the balance of trade —and current account (Table 7). However, rising the VAT rate to 13% does not fully compensate for the trade balance deterioration induced by moving to a 0-15% tariff structure. With a fixed nominal exchange rate, a full compensation would require rising the VAT by approximately 40.3% on average.

On the government finance side, tax revenue goes up by more than 7%, which —with expenditure being fixed—substantially rises government savings (Table 7). This is, of course, basically a direct result of the VAT increase. Direct tax revenue goes down due to the fall in capital income (the increase of labour income, which pay much less taxes, is not enough to offset this). Tariff revenue, in turn, falls as imports decline, while revenue from excise taxes goes down as a result of the fall in manufacturing output. Due to the contraction of manufacturing and a fall in consumption, the percentage increase in VAT revenue is below the increase in its rate.

The VAT rate increase from 10% to 13% would not be enough to fully compensate for the fall in revenue that would result from moving to a 0-15% tariff structure. According to our simulations, with flexible foreign savings and fixed exchange rate, to fully offset this, the required rise in the VAT rate would be of 40.4% on average (very similar to the increase needed to keep the current account balance unchanged). For complete liberalisation, the corresponding VAT increase would be of roughly 75%.

1.5 Concluding Remarks

This Chapter has used an applied general equilibrium model to analyse the welfare, distribution and macroeconomic effects of trade liberalisation in El Salvador as well as the effects from increased value-added taxation. We find that further unilateral trade liberalisation in this country produces quite small gains in terms of GDP and welfare. This is due to some extent to the fact that tariff rates are already relatively low and there is no much dispersion in the tariff structure.[7] Contrary to

[7] In our model we have considered perfectly competitive markets only. Taking account of imperfect competition and scale economies may rise the gains from trade liberalization as has occurred in other simulation exercises See, e.g. Devarajan and Rodrik, 1991; 1992 Harris, 1995.

the expectations of Salvadorean policy-makers in recent years, the export impact of trade liberalisation appears to be also modest. Thus, it would seem difficult to argue that trade liberalisation alone will turn exports into the engine of growth for the Salvadorean economy.

On the other hand, and contrary to the views of critics of structural reform in El Salvador, we find that the higher income level that trade liberalisation leads to will be more progressively distributed; this both in terms of factors and households, at least for the level of disaggregation in our model. This is basically in line with the predictions of traditional trade theory.

The macroeconomic impact of trade liberalisation seems to be negative. National savings—and even aggregate savings—tend to decrease, which do not favour long-run growth. Thus, trade reform would tend to favour consumption over capital accumulation, unless other measures are adopted. On the other hand, the fall in government savings may threaten fiscal stability. Trade liberalisation would also lead to a significant deterioration of the balance of trade—a consequence of a sharp rise in imports and a modest export expansion.

If not coupled by capital inflows, an increasing trade deficit may lead to a loss of international reserves and threaten balance of payments stability. In El Salvador, remittances, foreign aid and a return of private capital that had fled the country during the 1980s civil war have avoided this in recent years. Another alternative would lie in adopting certain domestic policies. Here complementary, fiscal measures, for example, may also come into play. Our simulations also show that the increase in the VAT rate that took place in mid 1995—partly intended to offset the loss of tariff revenue from trade liberalisation—will have a positive and significant impact on government finance and the balance of trade. This substantially offsets the negative macroeconomic effects of trade liberalisation.

On the other hand, raising the VAT rate may have less negative effects than often thought. In particular, output does not contract, and income distribution even seems to improve, though very slightly. This suggests that many of the presumed negative effects of higher value-added taxation in El Salvador—such as a worsened income distribution—, may come in fact from factors certainly related to the tax measure, but different from it (such as expectations, speculation, etc. and their effect on prices). On the other hand, we must bear in mind that our model yields 'long-run' results (i.e., once the economy has reached a new equilibrium); short-run effects may well be very different.

Turning again to the benefits of deepening trade reform, if one compares income gains to El Salvador from completely removing all tariffs (0.21% of GDP) with those from taxing current foreign direct investment, it turns out that the latter, though, also low, are much bigger (0.76% of GDP). This despite the fact that FDI in El Salvador can be considered to be quite low by Latin American standards, and its income is lightly taxed (a single rate of 20% is applied to foreign capital income)—at least by developed country standards.

This comparison indicates that attracting FDI—and taxing its income—may contribute to rising national income levels, perhaps as much as further trade liberalisation. If we bear in mind that trade liberalisation reduces the relative return to capital, the comparison might also suggest that trade reform could even be welfare-reducing—if it were to lead to an outflow of FDI and therefore loss of tax revenue and national income that offsets gains from improved resource allocation. In the next Chapter we explore this possibility using a modified version of the model employed in this Chapter to incorporate FDI flows and international capital income taxation. Due to data constraints on sectoral FDI flows, we calibrate the model to data for the economy of Costa Rica.

CHAPTER 2

TRADE LIBERALISATION IN THE PRESENCE OF FOREIGN DIRECT INVESTMENT AND TAX CREDITS

A well-known result from the "tariff-jumping" investment literature of the 1970s is that import-tariff-induced capital inflows will be immiserising for a small open economy (e.g. Brecher and Diaz-Alejandro, 1977). It is also well-known that this result relies crucially on the assumption that the host economy does not tax foreign capital (Bhagwati, 1973). As Bond (1991) has shown, if this assumption is lifted and taxes paid in the host country by foreign companies are credited in the source country against the corresponding domestic tax liability, tariff-induced capital inflows are no longer immiserising. Therefore, it will be optimal for a small open economy to impose a tariff on its imports—provided that the importable sector uses capital intensively.

The possibility of import tariffs being welfare-enhancing for a small economy may have some interesting policy implications for many developing countries which have embarked on outward-oriented growth strategies in the last fifteen years or so. First, unilateral trade liberalisation and foreign direct investment figure prominently in most LDCs' "new" growth strategies. Second, in many developing countries trade liberalisation has implied a reduction in tariff protection for the manufacturing sector, which tends to be relatively capital-intensive. This, as the Stolper-Samuelson theorem suggests, will tend to reduce the return to capital and thereby FDI inflows to these countries.[1] Third, the bulk of FDI in developing countries originates in developed countries, the majority of which uses the tax credit mechanism when taxing foreign-source income.[2]

In this context, unilateral trade liberalisation could deteriorate national welfare. Whether it does or not is an empirical question—which would depend on the relative strength of the positive effect of lower distortions resulting from freer trade, and the negative effect associated with the loss of tax revenue following lower FDI inflows. Incidentally, this possibility of welfare-reducing trade liberalisation could provide an explanation to some of the opposition that reforms seeking freer trade have faced in developing countries. In effect, this could be the case of the opposition by groups that would not necessarily or directly lose from the changes in relative prices and the relocation effects associated with trade liberalisation.

Although a lot of work has been devoted to the theoretical link between import tariffs and international capital flows (see e.g. Wong, 1996), model-based

[1]This would be more likely to occur in countries with relatively large domestic markets in which foreign companies have located to bypass an import tariff and serve the internal market.

[2]As of 1991, 15 out of 24 OECD countries offered their companies credits for taxes paid in countries with which a treaty to avoid double taxation was not in effect (see OECD, 1991). Since for capital-exporter countries a system of deductions is welfare-superior to full credits (Musgrave, 1969), this preference for the crediting system among developed countries is hard to explain. This is the case especially when capital flows are fundamentally unidirectional, as those between developed and developing countries. Scharf (1997) has suggested and analytically explored the idea that home countries prefer tax credits because they want to discourage international tax evasion.

empirical work endogenously linking capital flows to tariff changes in a general equilibrium setting—whether with foreign capital taxation or not— is quite scant. In fact, the only calibrated study that appears to have addressed this linkage is Goulder and Eichengreen (1992).[3] However, they focused exclusively on portfolio investment, without considering FDI. They also do not consider international capital income taxation.

This Chapter quantifies the welfare impact of unilateral trade liberalisation once its effect on FDI flows is taken into account and taxation of FDI is allowed for. For this, a multi-sector applied general equilibrium model integrating trade, capital flows and international capital income taxation is used. The model has been calibrated to a 1990-91 data set for the economies of Costa Rica and a group of OECD countries (those using the credit mechanism when taxing foreign-source income). We show that, with foreign capital taxation and the foreign-tax-credit system in force, free trade is no longer first-best for a small country such as Costa Rica, and that trade liberalisation may be harmful to it. We find that the optimal tariff structure for the Costa Rican economy would consist of a combination of relatively low import tariffs and subsidies.

[3]Some applied general equilibrium models seeking to quantify the effects of the North American Free Agreement (NAFTA) explored the likely impact of incorporating FDI flows, but did so in an *ad-hoc*, exogenous fashion. See Brown (1992); Francois and Shiells (1994). Damus *et al.* (1991) have studied the implications of the existence of tax credits for Canada but in a corporate tax reform context.

The Chapter is organised as follows. The next Section discusses the relationship between import tariffs, capital flows and welfare with and without tax credits. Section 2.2 describes recent trade liberalisation and FDI policy in Costa Rica. Section 2.3 describes the model used in our numerical simulations. Section 2.4 discusses the nature of the data used for the empirical implementation of the model. Section 2.5 analyses simulation results, and Section 2.6 summarises and concludes.

2.1 Tariffs, Capital Flows and Welfare

The relationship between unilateral tariff changes and international capital movements has been analysed in great detail in the theoretical international trade literature (see, e.g. Mundell, 1957; Jones, 1967; Wong, 1995). The dominant approach considers trade and capital movements to be substitutes for each other.[4] This approach is based on the traditional Heckscher-Ohlin model, in which countries differ in terms of factor endowments. As is well-known, in this model free trade leads to the equalisation of factor prices, which eliminates the rationale for factor movements. Hence free trade is a perfect substitute for factor movements. On the other hand, if factors move from where they are abundant to where they are scarce, the bases for trade are reduced, or disappear. Hence factor movements are a substitute for trade (Ruffin, 1984).

[4]Schmitz and Helmberger (1970), Markusen (1983), and Wong (1986) have presented models in which trade and capital flows are complements.

The interaction between tariff changes and capital movements was first formally presented by Mundell (1957). In a two-sector, two-factor model, invoking the Stolper-Samuelson theorem, Mundell shows that when a tariff is imposed by the labour-abundant country the return to capital is increased, and capital moves there; with perfect capital mobility, trade eventually disappears. This type of analysis later gave rise to the literature on "tariff-jumping" investment and its welfare consequences for a small open economy. The main conclusion of this literature was that the combination of capital inflows and distortionary tariff barriers in a small economy would result in immiserising growth. The idea had been suggested in Johnson (1967) and Bhagwati (1973), and was further developed by Minabe (1974), and Brecher and Diaz-Alejandro (1977) in a two-good, two-factor framework. It was generalised by Jones (1984), and especially by Neary and Ruane (1988). The second two authors lifted the restriction on the number of goods and factors, and extended the main result to the case in which capital inflows are entirely endogenous.

In all these models, however, the result of distortionary tariff changes leading to immiserising capital inflows relies crucially on foreign capital not being taxed by the host country. Bond (1991) presents a small open economy, general equilibrium model with foreign capital taxation and two (traded) goods, with the importable good being capital intensive. He uses a Heckscher-Ohlin structure both on the goods and capital side, i.e. he assummes that domestic and foreign goods are perfect substitutes as are domestic and foreign capital. Bond shows that if the foreign tax credit mechanism is present in foreign investors' home country, the optimal import tariff for a small, host economy is positive. As is well-known, under the foreign-tax-credit system, income taxes paid by companies operating abroad are fully credited against their home country tax liability—as long as their amount does not exceed such liability. In such a case, by taxing foreign capital income, host countries extract a gain in terms of tax revenue that would otherwise be captured by the home country.

As Bond indicates, by bringing with it tax revenue, foreign capital generates a kind of (positive) fiscal externality in the host country. The argument, as presented by Bond, runs as follows. For the host to capture all of the tax revenue associated with foreign capital income, its tax rate must be set at a level equal to that in the capital-exporting country. This, however, gives rise to a divergence between private and social cost of capital, i.e. the gross and the net rate of return, respectively. The latter is indeed the return required by foreign capitalists, which in equilibrium must be the same in the host and home country. Therefore, the optimal policy for the host consists of subsidising foreign capital at a rate equal to the income tax rate. As Bond (p. 321) puts it, "essentially, the home country wants to pay the taxes for the owners of imported capital and to impose no distortions in the goods market."

In practice, however, it might not be feasible for a country to subsidise foreign capital in such a direct way. On the other hand, as pointed out by Bond, some capital-exporting countries (such as the USA) do not grant credits for taxes that have actually not been paid. Under these circumstance, it might be easier and more effective for a capital-importing country to resort to an indirect form of subsidisation, such as an import tariff—provided, of course, that foreign capital locates in the import-competing sector. As the tariff will distort consumption decisions, it will be an inferior option to the direct subsidy—but still superior to free trade. In Section 6 we compare the performance of the direct subsidy *vis-à-vis* that of the tariff. The next section describes recent trade and FDI policy in Costa Rica.

2.2 Recent Trade and Foreign Investment Policy in Costa Rica

Like El Salvador, Costa Rica is a member of the Central American Common Market (CACM). This has contributed to both countries sharing similar trade and industrial policies at least since the creation of the CACM in 1960. Costa Rica also followed a growth strategy based on industrialisation through import substitution, supported by a tariff structure very similar to El Salvador's—high tariff rates for consumer goods, on the one hand, and of low import taxes for intermediates and capital goods, on the other. Costa Rica's trade regime was biased against exports some of which— such as coffee and bananas, for instance—were directly taxed.

Costa Rica has also experienced substantial structural adjustment reform—a process which started in the mid 80s, some five years before El Salvador. These reforms and Costa Rica's membership of the CACM have affected trade policy in a very similar way to El Salvador—tariff rates have been substantially reduced (Table

8), especially for industrial consumer goods and virtually all import quantitative restrictions and regulations have been eliminated. At the same time, the scope of export taxes has been greatly reduced,[5] and the level of export duties that still remains is now significantly lower.

Table 8. Nominal Import-Tariff Protection in Costa Rica

Percentages

	1987	1994
Primary sector	4.8	6.2
Food. bev. and tob.	59.1	15.1
Textiles and apparel	41.1	19.9
Paper and printing	27.3	4.9
Chemical products	12.2	5.7
Non-met. mineral prod.	23.8	9.3
Metal products	14.2	8.6
Other manufacturing	21.7	9.3

Source: Calculations based on SIECA (1993) and WTO (1995).

Simultaneously to this unilateral trade liberalisation, Costa Rica has also embarked on some reciprocal, regional trade liberalisation—which, incidentally, has entailed changes to the CACM treaty. Costa Rica signed a free trade agreement with Mexico in 1994, which went into effect at the beginning of 1995. It has also been engaged in negotiations to establish a free trade area with Colombia and Venezuela, though no formal agreement has been reached.

[5] Costa Rica still applies taxes to its exports of coffee, bananas, meat and livestock. See WTO (1995).

Costa Rica's trade reforms have been accompanied by changes in its foreign investment regime, seeking to make the country more attractive to foreign companies. The idea has been to foster growth not only by reducing distortions but also by increasing capital accumulation. Foreign investment is also supposed to be a response to the need of reducing unemployment and increasing productivity levels; the latter to the extent that FDI can give rise to technology transfer benefiting eventually domestic firms as well. Costa Rica's reforms of its FDI regime, however, have not been as far-reaching as those in the area of trade policy. They have consisted mainly of the abolishment of restrictions on international capital movements, and the partial lifting of foreign ownership restrictions in some economic activities. However, important foreign ownership restrictions still continue in place in activities such as banking and insurance, telecommunications, and energy (Nathan and Associates, 1994). Foreign investment in newspapers and advertising agencies is prohibited, while regulations in the transport and tourism sectors discriminate against foreign investors and set limits to their participation.

Recent Costa Rican efforts to attract FDI have focused on the subscription of bilateral investment treaties (BITs) with some developed countries. Among other things, these BITs provide national treatment to foreign investors, as well as the option of international arbitration in dispute settlement. They are also consistent with the World Trade Organization's provisions on Trade-Related Investment Measures (TRIMs), which ban the use of performance requirements. As of 1994, Costa Rica had established BITs with Switzerland and Germany, and was in the process of negotiating similar agreements with the United States and Spain. Regional free trade agreements—such as the one subscribed with Mexico in 1994—are also intended to make the country more attractive to foreign investors as they enlarge the size of the market in which Costa Rican goods can be sold duty-free.

Unlike many developing countries' foreign investment regime (see, e.g., UNCTAD, 1993), the Costa Rican FDI regime does not contain incentives available only to foreign investors. Some export promotion schemes benefit to a large extent foreign companies but they are also available to domestic firms. This is the case of duty-free trade zones and other very similar schemes presently being implemented in Costa Rica. They offer firms not only tariff exemptions for goods used in production but also generous tax holidays. Tax incentives for firms operating in duty-free trade zones in Costa Rica consist of full income tax exemption for 10-12 years, and 50 percent exemption for the following 4-6 years (WTO, 1995).[6] They also provide full exemption on taxes on capital and assets for an indefinite period of time. Though the main objective of these schemes is export promotion, firms operating in duty-free zones are allowed to sell up to 40 percent of their output in the domestic market (WTO, 1995).

[6]The fact that many developed countries use the credit mechanism when taxing foreign-source income often makes these income tax incentives largely ineffective when their beneficiaries are foreign companies.

The next Section describes the model used to simulate the effects of unilateral trade liberalisation on welfare in Costa Rica, once FDI responses and international capital income taxation are taken into consideration.

2.3 A Trade Model with Foreign Direct Investment and Capital Income Taxation

The model we use here is basically a variant of the one used in Chapter 1. The model has been changed in several directions, simplifying it in some aspects and making slightly more complicated in others. First, we have eliminated a number of model features non-essential to the point we want to make in this Chapter. Thus, we now only concentrate on import tariffs and capital income taxes. Similarly, the current version no longer includes a foreign exchange rate, and abstracts from the presence of differences in factor returns across sectors.[7] With macroeconomic and distributional elements no longer being an issue here, the model has also been simplified on those fronts. There is now only one type of good (consumption), one household, and two aggregate factors of production.

On the other hand, we now use a multi-country model structure, where world prices for goods (and factors) are endogenously determined. In this structure, capital is internationally mobile (and inter-sectorally mobile, as in the previous model). In fact, we now distinguish between domestic and foreign capital, and allow for the

[7] The latter implies that, in the empirical implemention of the model, units for factors of production are redifined in such a way that factors receive the same return in all sectors.

possibility of different returns to them. The capital allocation issue is now two fold—sectoral and international. The income tax regime in the new version is slightly more complicated in that there is now international capital income taxation, and countries use the tax-credit mechanism when taxing foreign source income. We turn now a fuller description of the new model version.

2.3.1 Production

There are two countries,[8] A and B, each producing n goods (n>1), some of which (at least) are tradable. Production technology is similar as in the previous model—in each country a fixed-proportion combination of value added and intermediate inputs is required (henceforth we use superscripts to denote countries, and omit subscripts to index sectors), with intermediate inputs, in turn, required in a fixed proportion:

$$X^A = \min\left(Q^A, \frac{Z^A}{a^A}\right); \tag{2.1}$$

$$X^B = \min\left(Q^B, \frac{Z^B}{a^B}\right), \tag{2.2}$$

$$Z^A = a^A X^A; \tag{2.3}$$

$$Z^B = a^B X^B. \tag{2.4}$$

[8]In the empirical implementation of the model we consider in fact three "countries," including a "Rest of the World." To keep notation as simple as possible and avoid repetition, throughout this section we abstract from this third region.

where X is gross output, Q is value added and Z represents intermediate inputs. The as denote the fixed amount of intermediate goods required to produce a unit of output.

Value added requires the use of two primary inputs, labour and capital, L and K, whose supply is assumed to be fixed. These primary inputs are combined according to a constant elasticity of substitution (CES) function:

$$Q^A(L^A, K^A) = \gamma^A[\alpha^A(L^A)^{-\sigma^A} + (1-\alpha^A)(K^A)^{-\sigma^A}]^{-\frac{1}{\sigma^A}}; \tag{2.5}$$

$$Q^B(L^B, K^B) = \gamma^B[\alpha^B(L^B)^{-\sigma^B} + (1-\alpha^B)(K^B)^{-\sigma^B}]^{-\frac{1}{\sigma^B}}, \tag{2.6}$$

where the Q^As denote value added, the γs are shift parameters, the αs are share parameters and the σs reflect the elasticity of substitution between labour and capital in each country (elasticity, $\epsilon_1 = 1/(1+\sigma)$).

Furthermore, it is assumed that labour is internationally immobile while capital can move freely across countries. Capital used in the production in each country is an aggregate of domestic capital (K_d) and foreign capital (K_m), which are viewed as imperfect substitutes.[9] This specification allows for the consideration of the phenomenon of cross-hauling in international capital flows, reflected by balance of payments data. The corresponding aggregate capital function is given by

$$K^A(K_d^A, K_m^A) = [\delta^A(K_d^A)^{-\rho^A} + (1-\delta^A)(K_m^A)^{-\rho^A}]^{-\frac{1}{\rho^A}}; \tag{2.7}$$

[9]This capital specification has also been used in some models of taxation in open economies (e.g. Wang and Pereira, 1994). In a dynamic setting, Bovenberg (1986) also uses an specification like this for investment goods.

$$K^B(K_d^B, K_m^B) = [\delta^B(K_d^B)^{-\rho^B} + (1-\delta^B)(K_m^B)^{-\rho^B}]^{-\frac{1}{\rho^B}}, \tag{2.8}$$

where the δs are share parameters and the ρs reflect the elasticity of substitution between domestic and foreign capital in each country (elasticity, $\epsilon_2 = 1/(1+\rho)$)

2.3.2 Capital Income Taxation and Factor Allocation

We assume that both countries tax their capital on a world-wide basis and grant credits for taxes paid abroad. The maximum amount of tax credit is the corresponding home country tax liability. Countries are assumed to apply the same tax rate to foreign-source and domestically-generated income. Taxation in each country does not discriminate between income from foreign capital and income from domestic capital generated internally. In each country, the rate of return is in principle different for domestic and foreign capital.

The equilibrium conditions for factor demand are as follows:

For labour,

$$\omega^A = P_x^A \frac{\partial Q^A}{\partial L^A}; \tag{2.9}$$

$$\omega^B = P_x^B \frac{\partial Q^B}{\partial L^B}, \tag{2.10}$$

where the P_x are output prices, and the ωs represent country wage rates.

For foreign capital,

$$\upsilon_m^A = (1-\tau^A) P_x^A \frac{\partial Q^A}{\partial K^A} \frac{\partial K^A}{\partial K_m^A}; \tag{2.11}$$

$$v_m^B = (1 - \tau^B) P_x^A \frac{\partial Q^B}{\partial K^B} \frac{\partial K^B}{\partial K_m^B} \tag{2.12}$$

where the v_ms are the net rates of return on foreign capital, and the τs denote the tax rates on capital income.

Equilibrium in the international allocation of capital requires that capital of a given nationality earns the same net return regardless of where is used (domestically or abroad). That is,

$$v_d^A = v_m^B \tag{2.13}$$

$$v_d^B = v_m^A \tag{2.14}$$

where v_d^i (i=A,B) represents the return to domestic capital in each country.

We also assume that there is perfect competition both in goods and factor markets, and that factors are fully employed.

2.3.3 Consumption and Trade

As in Chapter 1, imported and domestic goods, M and D, respectively, are assumed to be imperfect substitutes for each other. Traded goods consumed in each country are a composite, C, of M and D. Similarly, for exports we again use a Constant Elasticity of Transformation (CET) function.

Countries levy tariffs on their imports at rates t^A and t^B. Thus, the domestic price of imports inclusive of tariffs is

$$P_m^A = P_m^{f_A}(1 + t^A); \tag{2.15}$$

$$P_m^B = P_m^{f_B}(1 + t^B), \tag{2.16}$$

where the P_m^f are the import world prices faced by each country.

2.3.4 Income

It is assumed that revenue from income and trade taxes is returned to consumers in a lump-sum fashion. Thus, assuming also that $\tau^A > \tau^B$, and that profits from foreign capital are fully repatriated to the home country once the corresponding domestic income taxes have been paid, augmented income is given by

$$I^A = \omega^A L^A + r_d^A K_d^A + (1 + \tau^A - 2\tau^B) r_m^B K_m^B + \tau^A r_m^A K_m^A + t^A P_m^w M^A; \tag{2.17}$$

$$I^B = \omega^B L^B + r_d^B K_d^B + (1 - \tau^A) r_m^A K_m^A + \tau^B r_m^B K_m^B + t_m^B P_m^w M^B, \tag{2.18}$$

where the r_ds and r_ms are the gross rate of return on domestic and foreign capital, respectively.

2.3.5 Market Clearing Conditions

Equilibrium in the goods market requires

$$Y^A = D^A + M^A; \tag{2.19}$$

$$Y^B = D^B + M^B. \tag{2.20}$$

The clearing conditions are for factor markets are

$$L^A = L_S^A; \tag{2.21}$$

$$L^B = L_S^A, \tag{2.22}$$

for labour, with L_S^i denoting labour supply in each country; and

$$K^A = K_d^A + K_m^B; \tag{2.23}$$

$$K^B = K_d^B + K_m^A, \tag{2.24}$$

for capital.

2.4 Data and Parameter Calibration

The model described above has been calibrated to a 1990-91 data set on production, trade and FDI for the economies of Costa Rica and a group of OECD countries. The latter is made up of those countries which, as of 1991, offered credits for taxes paid by their foreign investors in countries with which they did not have an agreement to avoid international double taxation of capital income.[10] This suits also the case of Costa Rica, who, as of 1994, had not signed a treaty like that with any of the OECD countries included in our group, except Germany (who, in any case, uses the crediting mechanism with treaty-countries also). These countries are responsible

[10]These countries are: Australia, Denmark, Finland, Germany, Greece, Iceland, Italy, Japan, Netherlands, New Zealand, Spain, Sweden, Turkey, United Kingdom and the USA.

for more than 80 percent of FDI in Costa Rica. As mentioned earlier, the empirical implementation of the model also includes a "Rest of the World." OECD countries which do not use the foreign tax credit mechanism are included in the Rest of the World, together with developing countries.

The model contains 10 sectors and one household. We have aggregated the primary sector into one basically because of the lack of data on capital flows. In disaggregating the manufacturing sector—whenever data constraints have allowed us—, we have tried to separate those activities which have achieved a relatively high degree of development by Costa Rican standards. The model includes separately a non-tradeable sector (some non-traded services and construction) which, in Costa Rica (for 1991), has no international capital flows.

The production and trade-flows data for the Costa Rican economy comes from the Central Bank and the Ministry of Economy of Costa Rica. Sectoral foreign capital stocks in manufacturing have been obtained on the basis of foreign capital shares in overall capital income in each sector. Foreign capital stocks for agriculture and services were obtained from UNCTAD's *World Investment Directory 1994*. These were combined with estimates of aggregate capital stocks in those sectors to obtain sectoral domestic capital stocks. As no information on taxes paid by foreign companies is available, we assume that no income tax exemptions are given to them,[11], and that they pay the legal 20 percent rate on their profits.

[11]This is consistent with Costa Rica's FDI regime, though not with its free-duty zone legislation (see Section 2.2).

Table 9 presents the basic data used for the economy of Costa Rica. This is a semi-industrialised economy with a relatively large service sector. Manufacturing activities in Costa Rica—especially light industry—have traditionally enjoyed a high tariff protection *vis-à-vis* agriculture, and tended to rely more heavily on imports, particularly of intermediate and capital goods. Exports make up more than a fifth of output in the economy as a whole; they are especially important in the primary sector, where more than 42 percent of gross output is exported. However, manufacturing is by far the main contributor to overall export earnings, with a share of more than 40 percent.

The share of capital in value added in the Costa Rican economy has traditionally been high, especially in manufacturing, where it exceeds 60 per cent. Capital, however, is overwhelmingly owned by nationals in all sectors of the economy. Compared to some larger Latin American countries, for instance, foreign capital has not played a particularly important role in the economy of Costa Rica.[12] FDI in this country has tended to concentrate more in manufacturing. An unusual feature for an economy not particularly endowed with natural resources is the relatively high share of FDI that has gone to agriculture. The United States is by far the single most important foreign investor in Costa Rica, with American companies controlling

[12]Indicators on the importance of foreign capital in Latin American countries are usually scant but those existing are quite revealing: In Brazil, in 1990, more than 40 percent of overall profits in the economy were generated by foreign affiliates; while in Mexico, in 1986—when the Mexican foreign investment regime was still very restrictive—more than half of all assets were controlled by foreign affiliates (UNCTAD, 1994, Vol. 4, Table 9).

about a quarter of FDI in the manufacturing sector, and virtually all foreign capital in agriculture (UNCTAD, 1994, vol. 4).

Production data, including input-output flows, for the group of OECD countries comes from OECD (1995), and is based on data for Canada, Germany, Japan, the United Kingdom and the USA. Trade flows net of intra-regional trade have been computed from information from OECD's *Statistics of Foreign Trade by Commodity 1992* for the same countries. Sectoral foreign capital stocks are based on the share of foreign assets in aggregate assets in each sector for the same group of countries, excluding Canada (for which this information was not available). The data is based on information from UNCTAD (1994). These production, factor use and trade data have been scaled up to reflect the corresponding OECD aggregates.

Tariff rates refer to MNF tariffs corrected by the coverage of the Generalised System of Preferences (GSP) programme in each sector.[13] For completeness, Table 10 presents some base data for the group of OECD countries.

Regarding elasticities, the trade elasticity values used for Costa Rica are, for consistency, basically the same as those used for El Salvador in Chapter 1 (the differences reflect differences in sector aggregation). As indicated in Chapter 1, these values are based on estimates by Hinojosa *et al.* (1994). To take account of relative country size—at least in a qualitative sense—we use higher elasticity values for our

[13] We have used the proportion of items within each sector covered by the GSP programme in the United States.

Table 9. Selected Benchmark Data for Costa Rica

	QSH	M/Y	E/X	K/Q	K_m/K	$Tariff^*$
Primary sector	0.180	0.126	0.424	0.573	0.167	0.0004
Food. bev. and tob.	0.100	0.067	0.295	0.678	0.062	0.087
Textiles and apparel	0.017	0.495	0.468	0.547	0.096	0.139
Paper and printing	0.016	0.392	0.096	0.647	0.153	0.041
Chemical products	0.019	0.606	0.222	0.645	0.095	0.040
Non-met. mineral prod.	0.010	0.288	0.156	0.658	0.337	0.147
Metal products	0.005	0.836	0.472	0.712	0.422	0.053
Other manufacturing	0.034	0.582	0.275	0.686	0.111	0.069
Tradeable services	0.376	0.085	0.192	0.520	0.027	n.a.
Non-tradeables	0.244	0.000	0.000	0.275	0.000	n.a.
Overall	1.000	0.214	0.219	0.498	0.073	0.052

Column headings:

QSH: Share in GDP

M/Y: Share of imports in supply

E/X: Share of exports in output

K/Q: Share of capital income in value added

K_m/K: Share of foreign capital income in aggregate capital income

* Ratio of tariff revenue to imports. This column is quite different from those in Table 8 both because it corresponds to a different year (1991) and because takes into account exemptions and the existence of free trade within the CACM.

n.a. = not applicable

Table 10. Selected Benchmark Data for OECD Countries Using Tax Credits

	QSH	M/Y	E/X	K/Q	K_m/K	$Tariff$
Primary sector	0.034	0.119	0.015	0.683	0.005	0.035
Food. bev. and tob.	0.025	0.037	0.020	0.357	0.034	0.041
Textiles and apparel	0.011	0.171	0.025	0.226	0.020	0.086
Paper and printing	0.021	0.020	0.020	0.265	0.005	0.017
Chemical products	0.023	0.020	0.064	0.300	0.025	0.032
Non-met. mineral prod.	0.001	0.027	0.024	0.323	0.065	0.043
Metal products	0.023	0.026	0.036	0.295	0.005	0.028
Other manufacturing	0.112	0.046	0.077	0.206	0.005	0.031
Tradable services	0.265	0.009	0.017	0.379	0.009	n.a.
Non-tradeables	0.479	0.000	0.000	0.445	0.000	n.a.
Overall	1.000	0.023	0.023	0.393	0.073	n.a.

Column headings:

QSH: Share in GDP

M/Y: Share of imports in supply

E/X: Share of exports in output

K/Q: Share of capital income in value added

K_m/K: Share of foreign capital income in aggregate capital income

n.a. = not applicable

group of OECD countries.[14] As to input-substitution in value added, we again use a Cobb-Douglas specification. In the absence of empirical estimates, the elasticity of substitution between domestic and foreign capital, in turn, has been assumed to be 1.25 and 2.0 in Costa Rica and the group of OECD countries, respectively, in all sectors.[15] We carry out sensitivity analysis on the values for trade and capital substitution elasticities (our sensitivity analysis exercise for trade trade elasticities uses estimates based on Reinert and Roland-Holst). Finally, shift and share parameters are obtained through the same calibration procedure described in Chapter 1.

2 5 Simulation Results

We have used the model and data described above to quantify the welfare gains, or losses, to the economy of Costa Rica from completely eliminating import tariffs. We also compute the optimal tariff structure for this economy in the presence of taxation of foreign capital income. Our result discussion focuses on Costa Rica since we are concerned with the case of a *small* economy (we discuss briefly some simulation results for the group of OECD countries at the end of this section). Central case results for this country are presented in Table 11.

Table 11 presents the impact on capital flows of trade liberalisation as well as the optimal import-tariff structure when foreign capital is taxed and there are

[14] Again, given the empirical estimates by Reinert and Roland-Holst (1992) and Shiells and Reinert (1993) for the US, this places our elasticity values definitely on the high side.

[15] Wang and Pereira (1993) use a Cobb-Douglas specification for domestic and foreign capital, but do not provide any empirical support for it either.

Table 11. Costa Rica: Trade Liberalisation Effects and Optimal Tariff Structure

Central Case

I. *Liberalisation Effects*	
1. Welfare (EV change as a % of GDP)	
A. With no foreign capital taxation	0.23
B. With foreign capital taxation	-0.07
2. Capital Stock (% change in aggregate level)	-0.66
II. *Optimal Tariff Structure (tariff rate, %)*	
Primary sector	-5.01
Food. bev. and tob.	0.18
Textiles and apparel	-0.30
Paper and printing	-0.03
Chemical products	1.75
Non-met. mineral prod.	3.82
Metal products	3.97
Other manufacturing	6.24
Tradable services	n.a.
Non-tradeables	n.a.

n.a. = not applicable

foreign tax credits. It also compares the welfare effects of trade liberalisation when foreign capital is not taxed with those when it is taxed. With no taxation of foreign capital income, the optimal commercial policy consists effectively of free trade. Trade liberalisation causes an outflow of capital of 0.66 percent, which, in the absence of foreign capital taxation, does not hurt the economy and is in fact accompanied by a slight welfare improvement (the small size of this improvement is the result of relatively low tariffs—which, furthermore, generally do not exhibit a great deal of dispersion, as shown in Table 8). Geographically, the outflow of capital follows roughly the composition of FDI between OECD countries and the rest of the world. At a sectoral level, capital tends to leave especially those activities enjoying higher tariff protection. The intuition for capital leaving the country is provided by the Stolper-Samuelson theorem. Since in Costa Rica import-tariff protection is higher for manufacturing activities (Table 8), its elimination tends generally to contract these activities. Given that in this economy manufacturing goods tend to be intensive users of capital relative to others, its contraction reduces the demand for capital, making this factor's return fall.

With foreign capital being taxed, the outflow of capital produced by complete tariff elimination would cause welfare to fall by about 0.07 per cent. This results from lower income tax revenue and lower national income. The small size of the welfare decline suggests that the optimal tariff structure is not very different from free trade—and in fact this turns out to be the case (Table 11). Under the optimal tariff structure with foreign capital taxation, agricultural imports would be subsidised whereas those of manufacturing goods would be generally subject to a tariff. Optimal tariffs tend to be higher in those sectors using capital more intensively, and which have a larger FDI share (metal products and other manufacturing, especially).

The low level of the optimal subsidy and tariff is basically driven by the relatively modest role played by foreign capital in the Costa Rican economy (Table 8). Of some significance is also the fact that trade intervention distorts consumption patterns as well. Substitution elasticities also play a role, though this is not very important in absolute terms (Tables 12 and 13). Furthermore, the pattern of results across sectors remains basically unchanged as elasticity values are varied. In Table 12 we present sensitivity analysis results on trade elasticities. The simulation exercise has been performed using elasticity values based on Reinert and Roland-Holst (1992)—which, as suggested earlier, are generally smaller for manufacturing activities than our central case values (as in Chapter 1, we have left the elasticity for our primary sector unchanged and lower that for services by half).

Lower trade elasticities imply that trade liberalisation has a weaker impact on goods relative prices and thereby on relative factor returns. This leads to free trade causing a smaller outflow of capital, which, in turn, generates lower welfare losses when foreign capital is taxed (Table 12). However, the level of optimal tariffs is now higher. The intuition for this runs as follows: since the effect of tariff on relative factor returns is now weaker, a larger tariff is needed to generate a capital inflow (and

Table 12. Costa Rica: Sensitivity Analysis on Trade Elasticities*

I. *Liberalisation Effects*	
1. Welfare (EV change as a % of GDP)	
A. With no foreign capital taxation	0.18
B. With foreign capital taxation	-0.05
2. Capital Stock (% change in aggregate level)	-0.58
II. *Optimal Tariff Structure (tariff rate, %)*	
Primary sector	-5.08
Food. bev. and tob.	0.21
Textiles and apparel	-0.33
Paper and printing	-0.04
Chemical products	2.12
Non-met. mineral prod.	4.21
Metal products	5.54
Other manufacturing	7.02
Tradable services	n.a.
Non-tradeables	n.a.

* Trade elasticities are based now on Reinert and Roland-Holst (1992).
n.a. = not applicable

Table 13. Cota Rica: Sensitivity Analyses on Capital Elasticities*

I. *Liberalisation Effects*	
1. Welfare (EV change as a % of GDP)	
A. With no foreign capital taxation	0.25
B. With foreign capital taxation	-0.08
2. Capital Stock (% change in aggregate level)	-0.77
II. *Optimal Tariff Structure (tariff rate, %)*	
Primary sector	-4.21
Food. bev. and tob.	0.12
Textiles and apparel	-0.21
Paper and printing	-0.02
Chemical products	1.15
Non-met. mineral prod.	2.56
Metal products	3.21
Other manufacturing	4.02
Tradable services	n.a.
Non-tradeables	n.a.

* Capital substitution elasticities are now 2.0 in all sectors
n.a. = not applicable

tax revenue gain) of a given size. In addition, lower trade elasticities imply that the traditional resource misallocation cost of tariffs is smaller, and so the capital-inflow consideration in choosing tariffs (which push them upwards) becomes relatively more important.

With a higher degree of substitution between foreign and domestic capital (the corresponding elasticities are now equal to 2.0 for Costa Rica), the capital-outflow effect of trade liberalisation is also strengthened (Table 13)—which is consistent with the fact the return to capital has fallen. Accordingly, the negative welfare impact under foreign capital taxation is magnified. As to the new optimal tariff structure, this does not change much but the average level optimal tariffs decreases. The latter simply reflects the fact that, with a larger capital elasticity, a smaller change in the relative return to capital and—therefore a smaller tariff—is required to bring a capital inflow (and tax revenue) of a given size.

We have also computed the welfare gains for Costa Rica from directly subsidising capital (the first-best policy) instead of using import tariffs/subsidies, as discussed in Section 2.1. Results (for the central case specification) show that this would increase welfare by only 0.02 percent in comparison with the optimal tariff scenario. This modest gain is not surprising given that the optimal-tariff level across sectors is quite small and does not present a great deal of dispersion (Table 11).

Increasing the tax on foreign capital income to a level similar to the OECD average (approximately 38 percent, in 1991, for countries using the credit mechanism) would generate greater welfare gains (twice as much) than a switch to a direct subsidy. In a more disaggregated model, this number should be smaller, as our calculation does not take into consideration the fact that companies from countries with a tax rate lower than the OECD average will find themselves with non-refundable excess credits and might therefore prefer to locate in a different country. Despite this, a greater tax rate on foreign capital income might still be a superior option to the direct subsidy and seems to be more feasible as well. The current Costa Rican rate implies a revenue transfer to countries using the credit system—an outcome difficult to justify on economic grounds.

Finally, the group of OECD countries included also loses from trade liberalisation but for entirely different reasons. Given its huge size in relation to Costa Rica, its optimal tariff structure cannot be one of free trade. Simulation results (not reported here) show that this structure consists of positive and relatively large import-taxes for agriculture and manufacturing activities regardless of whether foreign capital is taxed or not. Taxation of foreign capital slightly increases the optimal tariff in agriculture and reduces it in the majority manufacturing activities. The intuition for this results is that the agricultural sector for the group of OECD countries included in the model is in fact capital-intensive relative to the bulk of manufacturing activities (and services).

2.6 Summary and Conclusions

In this Chapter we have used a calibrated general equilibrium model to quantify the welfare impact of trade liberalisation and compute the optimal tariff structure for Costa Rica once trade-policy-induced capital flows and foreign capital taxation are taken into account. Our main finding is that with foreign capital being taxed and the foreign-tax-credit system in force, the complete elimination of import tariffs would hurt Costa Rica. This to the extent that tariff removal will lead to an outflow of capital and a loss of tax revenue that more than offset the positive traditional reallocation effect of moving to free trade. Thus, the optimal tariff structure for the Costa Rican economy does not consist of zero-import tariffs but rather of a mixture of positive import tariffs and subsidies. The optimal tariff and subsidy level is, however, quite low, reflecting basically the fact that the role of foreign capital in this economy is relatively modest. A direct subsidy to foreign capital is a slightly superior option to import tariff, though probably not feasible and little effective in practice. There seems to be some room for a different, probably more effective option—increasing the tax on foreign capital income. For some reason, Costa Rica has not exploited this opportunity and foreign capital taxation is low in comparison with OECD standards, resulting in a transfer of revenue to capital exporting countries' governments.

Given the relatively small level of optimal tariffs/subsidies, and the fact that there seems to exist some costs associated with non-uniform-tariff structures (such as rent-seeking-related costs, for instance), our finding cannot be taken as providing a strong case against free trade in an economy such as the Costa Rican. Also, it must be bear in mind that the (static) nature of our model is unable to capture dynamic gains often associated with trade (Stokey, 1991; Young, 1991). At the same time, it should be noted that even if we restrict our analysis to the static cost and benefits of freer trade, trade liberalisation typically does not consist of a complete tariff elimination, but rather of a reduction in the level of protection and its dispersion. Therefore, even in the presence of foreign capital taxation, trade liberalisation, as usually practised, could still improve welfare for a small open economy—even in a static context. Our numerical simulations imply, however, that allowing for capital flows and their taxation might reduce the size of static gains from non-full, unilateral trade liberalisation.

It should also be noted that we have considered only one side of the relation between trade liberalisation and FDI. There are at least two aspects which might lead to a different relationship. First, there are other strands of trade liberalisation, such as reciprocal trade liberalisation—whether global or regional—, which might be complementary with FDI in countries with a relatively abundant labour supply. The various NAFTA models that tried to incorporate foreign capital effects for Mexico were formulated with the idea that such an agreement would increase FDI flows into the Mexican economy. Second, it is evident that not all FDI located in developing countries—or, in this case, in Costa Rica—is "tariff-jumping" investment. There are multinational companies which locate there with the idea of exporting back to their home countries. To the the extent that it is quite likely that unilateral trade liberalisation would be beneficial to these companies, freer trade would encourage this type of FDI inflows. The size of this type of FDI flows *vis-a-vis* those motivated by tariff-jumping considerations is therefore a crucial element. Lack of information has not allowed us to do this comparison for Costa Rica.

CHAPTER 3

LABOUR MARKET INSTITUTIONS AND DECOMPOSITION OF WAGE INEQUALITY OUTCOMES

A vast volume of literature has emerged on the explanation of the recent trend towards rising wage inequality documented for a number of developed countries—most notably the UK and the US.[1] The debate on the factors responsible for this phenomenon initially concentrated on the relative roles of trade and technology—and, to a lesser extent, other factors related to market forces (e.g. changes in factor supplies, immigration, and foreign direct investment).[2] More recently, a number of empirical studies have examined the contribution of changes in labour market institutions to observed wage inequality surges.[3] These studies suggest that institutional changes—defined basically as changes in the degree of labour market flexibility—have in fact played an important role in increased wage inequality (Card, 1996; Dinardo *et al.*, 1996; Dinardo and Lemieux, 1997; Grottschalk and Joyce, 1998; Machi and van Reenen, 1998).[4] The institutional factors this literature has paid

[1] There is extensive evidence documenting this rise in wage inequality. See, for example, Davis (1992); Kosters (1994); OECD (1997); and Grottschalk and Smeeding (1997).

[2] See the surveys by Bound and Johnson (1992); Burtless (1994); Deardorff and Hakura (1994); and Brenton (1998).

[3] On the analytical side, Davis (1998a,b) sets out a framework to examine the role of labour market institutions in wage dispersion and unemployment in a global context.

[4] Institutional forces have also been found to play an important part in the *level* of wage inequality across industrialised countries (e.g., Blau and Kahn, 1996).

attention to include the presence of trade unions and collective bargaining, and government policy towards the labour market (e.g. the erosion of real minimum wages, or reduced scope for minimum-wage legislation).[5]

In this Chapter we also examine the role of labour market institutions in wage inequality outcomes, but follow a different approach from that found in the empirical literature. Existing econometric-based studies try either to decompose observed changes in wage inequality into separate components due to trade, technological change and *changes* in labour market institutions (e.g. Machi and van Reenen, 1998), or test the relationship between changes in wage dispersion and changes in institutions (e.g. Card, 1996). Here, we are interested in comparing an economy's response to trade and technology shocks under *given*, alternative labour market institutional frameworks.

Our approach is similar to that followed in Davis (1998a,b) in an analytical setting, where the wage and employment effects of trade (Davis, 1998b) and technology (Davis, 1998a) shocks are separately analysed under alternative labour market arrangements. Here, we analyse an economy's response when these shocks take place at the same time, and focus on the relative contribution of each of them to the resulting wage inequality under alternative labour market institutions. Specifically, we

[5]Changes experienced by a number of industrialised economies in this area during the 1980s are documented in, e.g. Faber (1990); Ridell (1992); Gosling and Machin (1995); and Machin and van Reenen (1998).

examine how the presence of rigidities in the market for unskilled labour affects the decomposition of wage inequality outcomes into trade and technology components.

The incorporation of labour market rigidities into models trying to determine the effect of trade and technology on relative wage changes seems natural since the majority of OECD economies—especially in Europe— still exhibit varying degrees of labour market inflexibility (see, e.g. Machin and van Reenen, 1999). Furthermore, it is in a context of at least some labour market rigidity that trade and technology shocks have taken place.

We employ a version of the differentiated goods model first set out in de Melo and Robinson (1989). This is a two-factor, two-produced-goods model, incorporating imperfect substitution in preferences between domestic and imported goods. We modify this structure to consider institutional rigidities in the market for unskilled labour in the form of a fixed real minimum wage, which allows for unemployment of this factor.[6] The presence of this type of labour market rigidity makes our model similar in spirit to the ones specified in Brecher (1974), Corden and Findlay (1975), and—as suggested earlier—Davis (1998a,b). The model can be also considered as a generalisation of the two-factor, two-good Heckscher-Ohlin structure, reverting to this form as the substitution elasticity between domestic products and imports becomes sufficiently large.

[6] Matusz (1996) presents an analytical general equilibrium trade model where unemployment results from the presence of efficiency wages.

Abrego and Whalley (1999) have found differentiated-goods structures to be preferable to the pure Heckscher-Ohlin version for conducting multi-sector, general equilibrium-based empirical analysis of trade shocks. One of the reasons for this is that, as also discussed in Johnson (1966), under non-extreme conditions of factor use, the Heckscher-Ohlin structure generates a nearly-linear transformation frontier—which makes an economy move towards complete specialisation following even small changes in relative goods prices. This feature renders basically impossible the task of numerically computing the wage inequality impact of relative prices changes of the magnitude that have taken place in some industrialised economies in the last couple of decades.

We calibrate our model to UK 1990 data on production, consumption, trade and factor use as well as on international price and technology changes over the period 1976-90. We then simulate the impact of trade and technology shocks that occurred in the UK over this period, both in the presence and absence of labour market rigidities. To perform the decomposition exercises, we follow a methodology set out in Abrego and Whalley, and compute separate equilibria for trade, technology, and combined shocks.

Under fully flexible labour markets, increased wage inequality is basically the result of technological change, with trade playing only a minor role. The presence of rigidities in the market for unskilled labour significantly changes this decomposition, increasing the relative contribution of trade. For our central case parameter specification, this change in decomposition is only quantitative, as the dominant factor continues to be technological change. However, for some model parameterisations consistent with existing ranges of empirical estimates for key parameters, the change brought about by the introduction of labour market rigidities is also qualitative, as it turns trade into the dominant factor.

The Chapter is organised as follows. Section 3.1 briefly reviews the literature on trade, technology and wage inequality. Section 3.2 presents the model we use for our decomposition exercises. Section 3.3 describes the data used and our model calibration. Section 3.4 discusses results, and Section 3.5 draws some conclusions.

3.1 A Brief Review of the Literature*

The literature on trade and wages focuses on understanding the quantitative significance of trade in explaining the sharp increase in OECD wage inequality which has occurred during the 1980s. This increase in inequality has been documented for a number of OECD countries, most notably the US and the United Kingdom (e.g., Davis, 1992; Kosters, 1994; OECD, 1997; Gottschalk and Smeeding, 1997). The pattern has been observed across different types of workers according to their skills (low vs. high skill), education levels (college vs. non-college graduates), and experience. There has also been documentation of a rise in unemployment in some

* This Section draws partially on Abrego and Whalley (1999).

European countries without major increases in wage inequality (Kosters, 1994; OECD, 1997; Dewatripont et al., 1998)

A large volume of literature has emerged on the explanation of increased wage inequality, especially for the US case. Two major factors have been discussed as primarily responsible for this phenomenon: increased trade with low-wage developing countries, and technological change biased against unskilled labour. The great majority of research has concluded that skilled-biased technological change, rather than trade, is the main source of this increase in wage inequality.

This literature uses a variety of econometric methods. Early papers focused on how trade changes labour demand via the factor content of trade (e.g. Borjas et al., 1991; Murphy and Welch 1991, and Katz and Murphy , 1992). They typically ran regressions which linked labour demand (by type of labour) and trade flows, and then used actual trade flows to infer the changes in labour demand they imply. They then combined these labour demand changes with wage elasticity of labour demand estimates culled from the literature to infer what portion of actual wage changes are due to trade changes. This work generally came to the conclusion that the portion of actual wage change attributable to trade is small.

Conclusions based on factor content of trade calculations, were, however, criticised by Wood (1994), who argued that trade is a considerably more important factor than these analyses show. He argued that for many products, and especially those from developing countries, there is no comparable domestic product, and so factor substitution effects attributed to trade using conventional elasticities are understated. He also argued that technological response to trade will occur in expectation of future trade surges, and so some of what is attributed to technology in factor content analyses should in reality be attributed to trade.

Later papers in the area use a different approach, and relate relative product price changes to relative wage changes (e.g. Lawrence and Slaughter, 1993; Baldwin and Cain, 1997; Leamer, 1998; Haskel and Slaughter, 1999; Harrigan and Balaban, 1999). Many of these work with estimating equations derived from general equilibrium models of a Heckscher-Ohlin type. The majority of these studies conclude that skilled-biased technical change was the main source of increased wage inequality during the 1980s, with the role of trade being insignificant.

Other recent work regresses measures of factor shares on measures of outsourcing and other factors (Feenstra and Hanson, 1996; Anderton and Brenton, 1998; Autor et al., 1998) concluding that trade may be more important than in earlier analyses. Anderton and Brenton (1998), in particular, find that trade is more important when only trade with developing countries rather than with all countries is used as an explanatory variable.

Although it has been widely assumed for some time that increased wage inequality in OECD countries has been mainly the result of skill-biased technological change, there has been a lot discussion about the specific form taken by technological change. The prominence of the skill-biased hypothesis in the literature reflects the fact that, in spite of a rise in relative wages for skilled workers, shifts in the composition of employment towards skilled labour have been of an intra-industry type as opposed to inter-industry (Katz and Murphy, 1992; Berman, Bound and Griliches, 1994; Berman, Bound and Machin, 1998). However, this hypothesis has been challenged on theoretical grounds by both Leamer (1994 and 1998), and Haskel and Slaughter (1998). Appealing to the zero profit conditions of a two-factor, multiple-good Heckscher-Ohlin model, they argue that only sector-biased technological change can affect relative wages in a small open economy. Using the traditional two-good, two-factor version of Heckscher-Ohlin, Leamer (1994) argues that the factor bias of technological change is irrelevant for wage inequality and only sector bias matters. Leamer (1998) qualifies this result, demonstrating that factor bias is irrelevant only for small changes, and if technological change does not induce relative price changes. For discrete changes, Leamer shows that factor bias can matter through second-order effects involving changes in inputs and wages.

The sector-bias hypothesis has, in turn, been challenged by Krugman (2000) and Berman, Bound and Machin (1998). Krugman criticises Leamer (1994), arguing that global (affecting other countries at the same time) factor-biased technological change will affect relative wages in a small open economy, whereas the sector-biased variety will be irrelevant. He recognises that if technological change is local (i.e. it only takes place in the country in question), factor bias is irrelevant and only sector bias matters. Krugman shows this using a closed-economy model with Cobb-Douglas preferences and Leontief technology, but argues that the last two assumptions in particular are not crucial for his argument, which he suggests is valid for a large economy.

Trying to reconcile these opposite views, Haskel and Slaughter (1998) maintain that the relevant form of technological change is both skill and sector-biased, supporting their argument both analytically and empirically. On the analytical front, they specify a two-good, two-factor, two-country model with CES production technology, and show that in a small economy only sector-and-skill-biased technological change can affect relative wages. For the large-economy case, they find that the effect of both sector-biased and sector-neutral technological change is ambiguous. At an empirical level, Haskel and Slaughter test their sector-and-skill-biased hypothesis using manufacturing-sector data for 10 OECD countries, and find a strong correlation between such a type of technological change and changes in wage inequality. Berman, Bound and Machin (1997) empirically test the global skill-biased hypothesis by testing two of its implications. One is whether the intra-industry shifts towards skilled labour observed in the US have also occurred throughout the developed world; and the other is whether these shifts have been concentrated in the same industries in different countries. Using data for 10 OECD countries they find evidence consistent with these predictions, and conclude that global skill-biased technological change has been the principal cause of increased wage inequality in OECD countries.

A central feature of the emperical analyses in this literature is its use of reduced-form data in their estimations. There has been indeed very little work explicitly employing structural models. In the literature using econometric-modelling techniques, exceptions are Leamer (1998), and Harrigan and Balaban (1997), where structural forms are estimated. As to structural models using applied general equilibrium techniques, to the best of our knowledge, the only papers in which the role of trade and technology are examined within an AGE structure are Francois and Nelson (1998) and Abrego and Whalley (1999). Francois and Nelson compare the pure Heckscher-Ohlin structure with differentiated goods models as well as with a Heckscher-Ohlin version including intermediate goods. Their numerical simulation analysis focuses on the relative intensity of trade effects on wages (presence or absence of a magnification effect, and/or absolute losers) under different model structures. Abrego and Whalley explore the numerical properties of the conventional Heckscher-Ohlin structure *vis a vis* those of a differentiated goods model, and try to do decomposition analysis for both of them. They do not consider alternative labour market institutions and concentrate on the perfectly competive case only.

3.2 A Model for Decomposition Analysis

A large proportion of the literature trying to explain recent trends in wage inequality employs models based on the standard two-good, two-factor Heckscher-Ohlin structure. The conceptual suitability of this model for examining the effect of trade-related changes on relative wages has been widely discussed in this literature (e.g., Deardorff and Hakura, 1994; Leamer, 1994, 1998). As shown in Abrego and Whalley (1999), however, the standard Heckscher-Ohlin structure presents difficulties for doing empirical analysis trying to determine the effect of price changes on wage inequality within a multi-sector, general equilibrium setting. On the one hand, due to the near linearity of the transformation frontier associated with convenient functional forms (see also Johnson, 1966), even small changes in goods relative prices move the economy towards full specialisation.[7] This renders virtually impossible the simulation of the impact of observed price changes on wage dispersion.

On the other hand, the model can generate a considerable degree of ambiguity as to the relative importance of trade and technology in observed changes in wage inequality—there are multiple parameterisations consistent with a given wage dispersion outcome, with some of them allocating a dominant role to trade, and others to technology. In addition to these problems, and as suggested in the previous Section, the conventional Heckscher-Ohlin model has difficulties accommodating skill-biased technological change in the small open economy case—unless this is assumed to be global in nature.

Here, we use a differentiated-goods model, in which domestic goods and imports are assumed to be imperfect substitutes. This model removes the problems

[7] In the UK case, at least, a consequence of this is that changes in relative prices constituting only a small fraction of the actual changes are able to generate wage inequality effects stronger than those observed.

of specialisation associated with the standard Heckscher-Ohlin structure, largely because the heterogeneity between imports and domestic goods implies an imperfect pass-through of world price changes onto prices for domestically produced goods. Similarly, to the extent that it incorporates (partial) endogenous price determination, the differentiated goods structure used here is able to accommodate skill-biased technical change in a small economy. This is important for our case since we use a sigle-country model and cannot therefore consider global factor-biased technical change, but want to analyse the experience of a small open economy. However, as shown below, this differentiated goods can still generate a large degree of ambiguity in decomposition when labour market rigidities in the form of a real minimum wage are present.

The differentiated goods model we consider here is similar to the one set out in de Melo and Robinson (1989), discussed in Bhattarai *et al.* (1999), and used in Abrego and Whalley (1999). Unlike the pure Heckscher-Ohlin structure, in this model, imports and domestically produced goods are imperfect substitutes in consumption. The present structure also differs from trade models used in previous Chapters in that product differentiation is present only on the consumption side, i.e. there is no differentiation between domestically consumed goods and exports on the production side. The reason for this is that we want to remain as close as possible to the standard Heckscher-Ohlin structure used in most of the trade and wages literature, and for which analytical results establishing an unambiguous link between trade and relative wages are available.

In the structure we use here, imports are not produced domestically, and one of the domestically produced goods is not traded. Imports and exports are assumed to be traded at fixed world prices. The model remains a two-produced-goods, two-factor structure with two traded goods, but includes three goods on the consumption side. The structure generalises the Heckscher-Ohlin model since it asymptotically approaches it as the elasticity of substitution between domestically produced goods and imports becomes very large.

3.2.1 Preferences

Let us denote imports by M, exports by E, and goods produced only for domestic consumption by D. Preferences are defined over these three goods, with D and E being the two produced goods. Unlike in the pure Heckscher-Ohlin model, preferences are now relevant, and, in our small-country case, one price—the price of D—is endogenously determined.

Preferences are given by

$$V = V(E^d, C^d), \tag{3.1}$$

where E^d denotes domestic demand for the exportable good, and C^d is demand for a composite of imports and the domestic import substitute D^d, i.e.,

$$C^d \equiv H(M, D^d) \tag{3.2}$$

3.2.2 Production

We consider a small open, price-taking economy that produces two goods. One of these (D) is consumed domestically only, and the other (E) is both consumed domestically and exported. The varieties of E produced for exports and the internal market are assumed to be exactly the same. The production of each good requires the use of two factors—skilled labour, and unskilled labour:

$$Y_E = Y_E(U_E, S_E); \tag{3.3}$$

$$Y_D = Y_D(U_D, S_D), \tag{3.4}$$

where Y_i $(i{=}D{,}E)$ denotes output, U_i represents unskilled labour, and S_i is skilled labour. In the empirical implementation of the model, we take D as being intensive in the use of U.

Prices for exports and imports are fixed, and given by $\bar{P}_E, \bar{P}_M$, respectively. The price of the domestic good, P_D, is, however, endogenously determined. The per unit cost functions for the production of each good consistent with zero profits are

$$\bar{P}_E = G_E(W^U, W^S), \tag{3.5}$$

$$P_D = G_D(W^U, W^S), \tag{3.6}$$

where W^U and W^S are the wage rates of unskilled and skilled labour, respectively, and $G_i(i = D,E)$ represent unit cost functions.

3.2.3 Labour Markets

Unskilled and skilled labour are assumed to be available in fixed supply, which is given by $\bar{U}$ and $\bar{S}$, respectively. We model two types of labour market institutions. In the first one, perfectly competitive conditions exist, and labour markets clear In the second labour market type, we assume complete flexibility in the market for skilled labour, while the unskilled labour market is assumed to be subject to a fixed real wage. This could be the result of some form of bargaining between unskilled-workers trade unions and employers, but here we abstract from the specific reason for unskilled-wage rigidity.

Using Shephard's Lemma, the employment condition for unskilled labour is given by

$$Y_D \frac{\partial G_D}{\partial W^U} + Y_E \frac{\partial G_E}{\partial W^U} = \bar{U} - N, \tag{3.7}$$

where N represents unemployment of unskilled labour—which is endogenously determined, and different from zero in the presence of a real minimum wage. N is equal to zero under perfectly competitive conditions.

Flexibility in the skilled labour market implies that this factor will be fully employed. The market clearing condition for this factor is given by

$$Y_D \frac{\partial G_D}{\partial W^S} + Y_E \frac{\partial G_E}{\partial W^S} = \bar{S}, \tag{3.8}$$

3.2.4 Market Clearing for Goods

The representative household in this economy maximises the utility function (3.1) subject to the budget constraint

$$P_D D^d + \bar{P}_M M + \bar{P}_E E^d = W^U(\bar{U} - N) + W^S \bar{S}. \tag{3.9}$$

In equilibrium, the price of the domestically produced good, $P_D{}^*$, will be determined such that market clearing occurs in D, i.e.

$$Y_D = D^d. \tag{3.10}$$

No market clearing is required in either E or M. Walras law, which holds for demand functions generated from utility maximisation subject to a budget constraint, also implies that trade balance will hold, i.e., in equilibrium,

$$\bar{P}_M M = \bar{P}_E E, \tag{3.11}$$

where E represents exports.

3.2.5 Functional Forms

In the numerical implementation of the model, preferences for (non-exportable) domestic goods, imports, and exportables are represented through a two-level nested Cobb-Douglas/CES aggregation. Preferences for imports and (non-exportable) domestic goods are given by

$$C^d(M, D^d) \equiv \left[\delta M^{\frac{\sigma-1}{\sigma}} + (1-\delta)(D^d)^{\frac{\sigma-1}{\sigma}}\right]^{\frac{\sigma}{\sigma-1}}, \tag{3.12}$$

where δ denotes the share of imports in aggregate demand for importables, and σ is the elasticity of substitution between imports and domestic (non-exportable) goods.

Preferences for exportables and importables are modelled via a Cobb-Douglas function

$$V(E^d, C^d) \equiv (E^d)^{\theta}(C^d)^{1-\theta}, \tag{3.13}$$

where θ represents the share of exportables.

Goods are produced using a constant return to scale, CES technology, with constant elasticity of substitution between S and U:

$$Y_i = \gamma_i \left[\beta_i U_i^{-\rho_i} + (1-\beta_i) S_i^{-\rho_i}\right]^{-\frac{1}{\rho_i}} \quad i = D, E, \tag{3.14}$$

where γ_i denotes units of measurement, β_i is a share parameter, and ρ_i determines the elasticity of substitution, η_i, between U_i and S_i, with $\eta_i \equiv \frac{1}{1+\rho_i}$. As indicated earlier, our model parameterisation implies $\beta_D > \beta_E$, i.e. the import substitute, D, is unskilled-intensive.

Profit maximisation subject to (3.14) implies

$$W_U = \frac{1}{\gamma_i^{\rho_i}} P_i \beta_i \left(\frac{Y_i}{U_i}\right)^{1+\rho_i} \qquad i = D, E \tag{3.15}$$

$$W_S = \frac{1}{\gamma_i^{\rho_i}} P_i (1 - \beta_i) \left(\frac{Y_i}{S_i}\right)^{1+\rho_i} \qquad i = D, E \tag{3.16}$$

where $P_E \equiv \bar{P}_E$.

Modelling of Trade and Technology Shocks

We model the trade shock as a decline in the price of imports ($\bar{P}_M$), rather than as a change in the volume of trade, which is endogenously determined. This is consistent with the Heckscher-Ohlin-Samuelson analytical framework, which relates changes in relative factor prices to changes in relative goods prices (see, e.g. Deardorff and Hakura, 1994; Leamer 1994, 1998). In line with the findings in the bulk of the empirical, econometric-based literature, we assume that unskilled labour saving technological change occurs, and take this as being pervasive, rather than sector-specific.[8] This differ from Abrego and Whalley (1999), where technical change is assumed to be Hicks-neutral, and sector-biased (which can be accommodated by the Heckscher-Ohlin structure used there). We model skill-biased technological change as a uniform reduction in the share of unskilled labour (β_i) in the two sectors.

[8]The hypothesis of sector and skill-biased technological change has been little explored in the literature, with Haskel and Slaughter (1998) seemingly being the only authors examining it. As indicated in the previous Section, they find empirical support for it.

3.3 Data and Parameter Calibration

This section describes the data used for the parameterisation of our model and the implementation of trade-and technology-related decomposition exercises. We have calibrated the model to a 1990 data set on UK production, consumption, trade, and factor use. Data on production, consumption and trade flows come from the UK input-output table for 1990. The data on trade covers all UK trade partners, and have been adjusted for model consistency, i.e. to ensure that trade is balanced in the base case equilibrium. Wage and employment data by sector and skill category have been obtained from *Employment Gazette* and *New Earnings Survey.* All these data are aggregated into the two-good, skilled (exportable good) and unskilled intensive (domestic good) classification. The parameters used for model implementation are presented in Table 14.

The definition of 'unskilled' and 'skilled' workers we utilise goes beyond the manual and non-manual classification frequently used in the literature (e.g. Haskel and Slaughter, 1999; Abrego and Whalley, 1999). We have followed a UK Office for National Statistics Office classification, according to which each skill category includes both manual and non-manual workers, depending on the specific type of job performed by workers. This information is available for the manufacturing sector only, and so we assume that the other sectors of the economy use skilled and unskilled labour in the same proportion. The production sectors included in our domestic, unskilled-intensive sector are those that for the 1990 input-output table level of disaggregation were net importers of goods or services, plus non-traded sectors (public administration, utilities and construction). Our exportable, skilled-intensive sector is then made up of the remaining sectors. This aggregation produces a ratio of factor use of unskilled to skilled labour of 0.85 for the unskilled-intensive sector, and 0.52 for the skilled-intensive sector, in our 1990 base case.

Table 14. Central Case Parameters for UK Decomposition Model

	Goods			
	Domestic	Exportable	Imported	Composite
Share Parameters				
Production				
Unskilled labour	0.46	0.34	n.a.	n.a.
Skilled labour	0.54	0.66	n.a.	n.a.
Consumption				
Top level	n.a.	0.34	n.a.	0.66
Bottom nest	0.80	n.a.	0.20	n.a.
Elasticities				
Production	2.50	2.50	n.a.	n.a.
Consumption				
Top level	n.a.	1.0	n.a.	1.0
Bottom nest	1.25	n.a.	1.25	n.a.

n.a. = not applicable

The values for the elasticities of substitution in production and consumption that we use are within the ranges of empirical estimates reported in Hamermesh (1993) for the former, and Reinert and Roland-Holst (1992) for the latter. These ranges imply values in the neighbourhood of unity for the substitution elasticity between domestic goods and imports, and between 1.5 and 6.0 for production-side elasticities. The central case values we have chosen for consumption and production are 1.25 and 2.5, respectively. We carry out systematic sensitivity analyses over the literature-based ranges for both sets of elasticity values.

The data on relative price changes for goods used in our trade shock modelling are based on Neven and Wyplosz (1996). They disaggregate import price changes for manufacturing both by sector (which they also disaggregate according to different factor-skill intensities) and origin of imports (between developed and developing countries), and cover the period 1976-90. This source, together with information on the composition of UK imports by country of origin for 1990, gives a decline in the relative import price of the unskilled-labour intensive good of 7.9% over the period.

The size of technological change, which as indicated earlier we model as a decline in the share of unskilled labour for both sectors in the production function, β_i, is obtained as follows. Machin and van Reenen (1998) have found that, for the UK, the relative contribution of technological change to the decline in the employment share of non-production workers in manufacturing during 1973-89 was 22%. Combining this estimate with information from the UK Office for National Statistics on the fall in the employment share of unskilled labour in manufacturing over the period 1976-90, we find that unskilled-labour-saving technological change reduced this share by about 2.5%. We use this number as an estimate of the technology shock in our simulations.

3.4 Simulation Results

The effects of the trade and technology shocks are simulated under the two labour market scenarios described in Section 3.2—fully flexible labour markets, and market for unskilled labour subject to fixed real wage. To carry out decomposition exercises for each model variant, we first remove the trade shock only and compute a model solution; we next restore the trade shock, remove the technology shock and solve the model again; finally, we remove simultaneously both shocks to get a new model solution yielding the effect of the two factors.

Table 15. UK Wage Inequality and Unemployment Decomposition: Central Case

	Model	
	Flexible Wage	Fixed Wage
Fall in W^U/W^S (%)	4.23	1.17
Trade contribution (%)	1.92	40.45
Technology contribution (%)	98.08	59.55
Unemployment of U (%)	0.00	7.30
Trade contribution (%)	0.00	35.04
Technology contribution (%)	0.00	64.96

3.4.1 Central Case Results

Our labour market central case results are reported in Table 15. These results show technology as the main factor behind increased wage inequality—regardless

Table 16. UK Decomposition Model: Central Case Sectoral Effects

	Flexible-Wage Model	
	Trade	Technology
Output change (%)		
Exportable	0.38	0.56
Domestic	-0.29	-0.44
Consumption change (%)		
Exportable	-0.01	0.58
Domestic	-0.29	0.94
Imports	10.48	0.51
	Fixed-Wage Model	
	Trade	Technology
Output change (%)		
Exportable	0.36	-1.60
Domestic	-0.31	-2.23
Consumption change (%)		
Exportable	-0.02	-1.63
Domestic	-0.31	-2.23
Imports	10.47	-1.51

of the institutional arrangement in the labour market. The reason for this is that, due to the imperfect substitutability between domestic goods and imports, the trade shock tends to be accommodated by changes in the level of imports, rather than production; the technology shock, in contrast, tends to be accommodate more by changes in production (Table 16). This pattern is also reflected in the decomposition of the unemployment outcome in Table 15—which, incidentally, is very similar to that of the wage inequality outcome for the fixed-wage case.

However, taking account of the existence of rigidities in the market for unskilled labour significantly changes the decomposition of the wage inequality outcome, rising the contribution of the trade shock. The intuition for this result has to do with how the effects of each shock are spread throughout the economy. The trade shock effect is basically driven by a change in the scale of output—the relative price change leads to a contraction of the unskilled-intensive sector, which reduces demand for unskilled labour and thereby the relative price of this factor. There is also a substitution effect going on here, but this is of second order—the fact that unskilled labour becomes cheaper increases its demand and partially dampens the initial decline in its relative price—and is dominated by the scale effect regardless under both labour market institutional arrangements. The contraction of the unskilled-intensive sector is, however, more acute in the presence of wage bargaining, which seems natural since a relatively higher wage rate for unskilled labour will affect more using more intensively.

The technology-shock effect, in turn, is fundamentally derived from a substitution effect. In this case, the change in technology makes unskilled labour less productive (by reducing its marginal product), leading to substitution away from it and to a decline in its relative price. This favours the unskilled-intensive sector, giving rise to a second-order scale effect whereby the initial relative-wage change is partially reversed. When wage bargaining is present, the technology shock will tend to reduce output in both sectors. This differs from the flexible wage case, where only the unskilled-intensive sector contracts. Thus, the second-order, scale effect is stronger under wage bargaining, and the technology shock causes a smaller decline in W^U/W^S. This, together with the fact that the unskilled intensive sector contracts more in the presence of bargaining following a trade shock, makes this factor more important in the wage inequality outcome when trade unions are present.

Note that, independently of the labour market specification used, the earnings inequality effect from trade and technology shocks is quite small, and certainly smaller than the observed change in wage inequality over the period.[9] This suggest that other factors have also played a significant role in this phenomenon.

3.4.2 Sensitivity Analysis

We have performed sensitivity analyses on the values for the elasticities of substitution in consumption and production. We have varied elasticity parameters over a range roughly consistent with available literature estimates. The ranges we have experimented with are 1.05 to 2 for the consumption-side elasticity, and 1.5 to 6 for the the elasticity of substitution between skilled and unskilled labour.

Table 17 summarises our sensitivity analysis results. These results confirm that elasticity parameters are crucial in determining the wage inequality outcome, not only in terms of its magnitude but also in terms of decomposition into trade and technology components. We should highlight two points emerging from our results. First, for some parameter values, the dominant force behind the resulting earnings

[9]Unskilled workers' relative earnings fell by approximately 15% in the UK over the period 1976-90 (Author's calculations based on information from the Office for National Statistics)

inequality outcome switches from technology to trade. This makes decomposition results quite ambiguous. Furthermore, the parameter changes that are able to reverse the role of trade/technology from dominant to minor factor are not really extreme. For example, reducing the production-side elasticities from 2.5 to 2.0, while keeping consumption parameters at their central-case levels, dramatically alters the decomposition.

Table 17. Ranges for Trade Contribution to UK Wage Inequality

		Parameter Range	
	central case	σ = 1.05 - 2.0	η = 2.0 - 6.0
Fall in W^U/W^S (%)			
Flexible wage model	4.23	4.17 - 4.45	3.93 - 4.57
Minimum wage model	1.17	1.16 - 1.20	0.98 - 1.42
Trade contribution (%)			
Flexible wage model	1.92	0.39 - 7.37	3.37 - 0.75
Minimum wage model	40.45	37.13 - 50.37	95.91- 13.71

The degree of ambiguity resulting in the minimum wage case is even more dramatic than that reported in Abrego and Whalley (1999) for the standard Heckscher-Ohlin model under flexible labour markets.[10] With fully flexible wages, the decomposition is so skewed in favour of technology (Table 15) that we were not able to find

[10]The constraints there are, however, more stringent than here since ambiguity is defined as different parameterisations producing *the same* wage inequality outcome (with qualitatively different decompositions).

model parameterisations—consistent with literature-based estimates—able to reverse the dominant factor and generate some degree of ambiguity.

Second, the sign of the technological change effect can vary depending on the values used for the production-side elasticities. Values close to the lower limit of Hamermesh's range (different from those in Table 17) yield that technological change actually favours unskilled workers.[11]. As discussed above, there is a substitution effect and a scale effect associated with the technology shock. The latter implies indeed an expansion of the unskilled-intensive sector, which naturally favours unskilled labour. Here, with factor-substitution possibilities being relatively low and additionally constrained by the fixed real wage, the scale effect outweighs the substitution effect, resulting in a higher relative wage for unskilled workers.

3.5 Summary and Conclusions

This Chapter has used a calibrated general equilibrium model to examine the role of labour market institutions in decomposition results of wage inequality outcomes into trade and technology components. Our main finding is that, compared to fully flexible labour markets, the presence of rigidities in the market for unskilled labour significantly alters this decomposition, rising the contribution of trade. For our central-case parameter specification, the change in decomposition results, though of

[11] We could have included these results in Table 17, but chose not to so in order to make result presentation there clearer. In this case, the increase in wage inequality is all due to trade.

sizeable magnitude, is only quantitative, as it still leaves technology as the dominant factor. Sensitivity analyses on consumption and production-side elasticities show, however, that, for some parameterisations still consistent with empirical estimates for these parameters, the increase in the contribution of trade trade with a real minimum wage is large enough to switch the role of trade from minor to dominant in the wage inequality outcome.

These results have at least two implications. First, institutional arrangements in the labour market have an important bearing in the outcome of wage inequality decompositions. Given the fact that a number of industrialised economies with recent wage inequality surges still present at least some degree of labour market inflexibility, this feature should probably be incorporated in models trying to decompose relative wage changes for them. Second, giving the amplitude of the range of empirical estimates on some key parameters—such as substitution elasticities in production—decomposition results are quite ambiguous when labour market rigidities are present. Abrego and Whalley (1999) how that, under fully flexible labour markets, this phenomenon occurs in standard Heckscher-Ohlin models but is unlikely to show up in a differentiated goods model. The fact that it is also present in a more general model lends additional support to the claim that models in which the underlying structure of the economy is explicitly specified are probably better suited for conducting meaningful decomposition of wage inequality outcomes. By its own nature, their reduced-form counterparts are indeed unable to discriminate between alternative economy structures or paramterisations.

Finally, our finding that—regardless of the degree of labour market flexibility and model parameterisation—trade and technology account for only a fraction of the observed change in earnings inequality in the UK suggest that other factors should probably be brought into the picture as well. These factors might include, for example, changes in factor supplies and changes—if not in the level—in the sectoral patterns of foreign direct investment.

CHAPTER 4

TRADE AND ENVIRONMENT: BARGAINING OUTCOMES FROM LINKED NEGOTIATIONS

Since the early 1990s trade and environment has been a high profile issue, with environmental groups arguing that restrictions are needed on certain types of trade (species, tropical lumber, pollution intensive manufactures) to safeguard the environment, and less developed countries (LDCs) opposing what they see as a new threat of trade restrictions against their exports. Where countries fail to institute policies which internalize global or cross-border environmental externalities, environmental groups argue that appropriate trade restrictions can improve resource allocation. Trade liberalisation advocates, on the other hand, see trade measures as very much second-best environmental policy, and worry over environmental legitimization of new trade restrictions by protectionist interests.

This Chapter discusses possible LDCs participation in possible future linked trade and environment negotiations in the World Trade Organization (WTO), which we suggest would largely break down on North-South lines. The South we see as the custodian of yet to be used environmental assets (forests) and the North as having a high existence value on these assets due to higher income. Whether or not environmental justifications for the use of trade restricting policies should be part of any future (post Uruguay Round) trade negotiations is now a central issue. Developed countries (DCs), responding to pressures from their own non-government environmental organizations, have supported their inclusion, while LDCs have appeared more reluctant to engage in a linked negotiation; they instead seek direct compensation for implementing growth slowing environment protecting policies.

In this Chapter, we argue that global (and also cross-border) environmental externalities provide LDCs with strategic leverage over the use of trade restrictions by DCs against their own exports. Although GATT/WTO tariff barriers in OECD countries are now low, sectoral barriers in textiles, apparel, footwear, steel and other areas are still significant, as are voluntary export restraints, regulatory restrictions in services, and the use of anti-dumping and countervailing-duty measures. Linking environmental and trade negotiations thus gives developing countries opportunities to restrain adverse trade policy in DCs, with environmental concessions being available to bargain for lower trade barriers to their exports. Linkage expands the bargaining set, offering more opportunity to exchange concessions, which can result in more trade and lowered barriers. Seemingly, linked trade and environment negotiations should be embraced by both the developing and developed world as expanding the choice set for bargaining, leaving the question remaining as to why LDCs are opposed.

The literature on linkage between international trade and environmental quality has primarily focused on two related questions: whether international trade contributes to lowered environmental quality (e.g., Anderson, 1992a; Anderson, 1992b;

Dean, 1992; Rauscher, 1992); and whether trade liberalisation is desirable, both in terms of global efficiency and individual-country interest, when environmental emissions are not internalized (e.g., Dean, 1992; Pearce, 1992). The policy debate on trade and environment has also often been interpreted as reflecting concerns over these forms of linkage. In both the academic and the policy debate there seems to be a presumption that linkage between trade and environmental policies is weak and that trade policies are ineffective instruments of environmental protection—a conjecture confirmed by model-based estimates of trade-environment linkage (Perroni and Wigle, 1994). As Blackhurst and Subramanian (1992) have pointed out, there are also strategic reasons for linking trade and environmental policies in multilateral negotiations. The complementarity between trade and environmental policies, which stems from the asymmetric structure and distribution of the gains and losses across high and low income countries associated with each of these two policy dimensions, can also make global cooperation easier to sustain when pursued through linked negotiations.

This strategic linkage between trade and environmental policies does not seem to have been directly addressed in the literature. Barrett (1994) and Ulph (1996a, 1996b), among others, have studied the interaction between trade and environmental policies theoretically, but define the strategic element from the standpoint of the market structure in which firms operate. Copeland and Taylor (1995) examine environmental policy games between open economies; they mention the possibility of a linkage between North-South trade and environmental policies, but do not explore it in detail. Other paper mention possible strategic trade and environment linkages within a North-South dimension but indeed focus on different issues include Barret (1994), Chichilnisky (1994), and Sandler (1993).

The papers that are most closely related to the analysis we present here are Cesar and Zeeuw (1994), Folmer *et al.*, (1993) Spagnolo (1996), Carraro and Siniscalco (1994), Ludema and Wooton (1994), and Nordhaus and Yang (1996).[1] The first two papers build a general framework linking environmental cooperation with cooperation in some other, non-specified area. Cesar and Zeeuw, in particular, show that cooperation in both areas is sustainable provided that the two games roughly offset each other Spagnolo and Carraro and Siniscalco's papers models linked international negotiations within a repeated game framework. In these papers, however, the policy games examined are fully independent of each other, which is not the case for trade and environmental policies. Ludema and Wooton use a partial equilibrium model to examine a non-cooperative policy game between two countries in the presence of a cross-border externality, but do not explore the possibility of environmental policy cooperation, although they point out a linkage between trade and environment could be implicitly present in some free trade agreements involving countries of different size. Nordhaus and Yang use a multi-region dynamic general-equilibrium model to compute non-cooperative Nash equilibria in environmental policies as well as cooper-

[1]Schulz and Barbier (1997) have independently developed an analytical model of trade and environment very similar to the one we use here. The policy games discussed in their model are, however, more limited in scope than the ones we deal with here. We became aware of this paper only after the first versions of the present one had been completed.

ative equilibria where countries adopt globally efficient policies to reduce emissions. In their model, however, bargaining solutions are not examined and no interaction between trade and environment is considered.

Here, we explore this negotiation linkage using a two-region (North-South) numerical simulation model of world trade and environment, benchmarked to 1990 data and projected over a 100-year time horizon. We compute non-cooperative Nash equilibria (disagreement outcomes for bargaining), and bargaining outcomes (Nash bargaining) for trade negotiations only and joint negotiations over trade and the environment. The trade side of the model is a conventional heterogeneous products (Armington) model, in which trade elasticities play a key role. The environmental structure of the model involves environmental assets in the South which are depleted more rapidly when used in trade-related production activities, and whose existence value enters North's preferences considerably more strongly than is the case for Southern preferences. The calibration of the model involves some strong assumptions and adjustments of data for model admissibility, but generates a specification with sharply asymmetric North-South preference weightings on environmental asset depletion.

The central case results we generate show that, relative to free trade, the South (as the smaller region) loses in a trade war. A trade-only negotiation helps both the North and South in lowering trade barriers, but leaves large barriers in the North. A joint trade and environment negotiation allows the North to generate welfare gains from Southern environmental management and the South to lower

Northern trade barriers. The main theme is that LDCs should embrace a trade and environment negotiation as it provides them with more leverage over trade. However, in a negotiation with side payments the South does considerably better than in a constrained negotiation, suggesting that a trade-environmental policy negotiation may be an inferior option; that is, a negotiation of cash compensation is better for them.

In our concluding section, we also note that trade rule constrained bargaining—in which existing trade rules (such as MFN) are taken to imply restrictions on the bargaining set—may yield a different picture. If we consider trade and environment linkage as a proposal under which MFN trade rules would also be relaxed where environmental effects are at issue, and if an initial weakening of MFN could lead to further system-wide weakening in other areas, then LDCs' concerns over a trade and environment negotiation may be more firmly based. In such cases, gains from expanded bargaining could be more than offset by losses from the weakening of prior agreed restraints on trade policy.

The Chapter is structured as follows. The next Section describes the structure of the model, while Section 4.2 discusses the data and methodology used for calibration. Section 4.3 describes our experiments and presents our findings. Section 4.4 concludes.

4.1 A Two-Region Trade and Environment Model

We consider a world consisting of two regions, which we refer to as 'North' (N) and 'South' (S). Focusing on a two-region structure avoids the numerical complexities associated with computation of non-cooperative equilibria in higher dimensions, and allows us to focus on two-player cooperative solution concepts. Computational limitations in working with non-cooperative and cooperative game-theoretic solutions concepts, rather than more traditional competitive equilibria, thus severely restrict dimensionality in the numerical analysis.

We consider an environmental asset, E, which is entirely owned by the South, and can be viewed as a stock reflecting available tropical habitat. Each region produces two goods, a tradable good X, a non-tradeable good Y. Region S uses two factors in production, value added V, and the natural resource asset. Production in region N only uses value added. We again use an Armington structure in consumption, and assume that each region views tradable produced domestically and abroad as imperfect substitutes, and consumes both domestic and imported traded goods, along with own region non-tradeables. The environment (available habitat) is depleted by its use in production, and enters the utility function of each region. Depletion occurs more heavily from use in production of the traded good. The endowment of value added is constant in each region, and equal to G^i ($i = N, S$).

4.1.1 Production

The structure of production in the model is set out in Figure 1. CES functions are used, in which value added and the environmental asset can be transformed into an environment-using input at the lower level of nesting. At the higher level of nesting,

the environment-using input and value added are transformed into tradable and non-tradeable output. We use substitution elasticities of zero at the lower level, and of unity at the higher level. Value added used in the two levels of nest can be transformed at a constant marginal rate of transformation, which, for simplicity, we assume to be equal to unity. The rationale for using this construction is that it implies a non-zero cost for the environment-using input even when pollution taxes are zero; this, in turn, prevents infinite substitution away from other inputs. The main difference between the tradable and non-tradeable goods sectors lies in the share parameters on the environment-using input.

4.1.2 Prices and Environmental Taxes

Net-of-tax prices for value added and the environment-using input are denoted as p^i $(i = N, S)$ and are the same within each region. Each unit of environment-using input employed in production in region S reduces global environmental quality

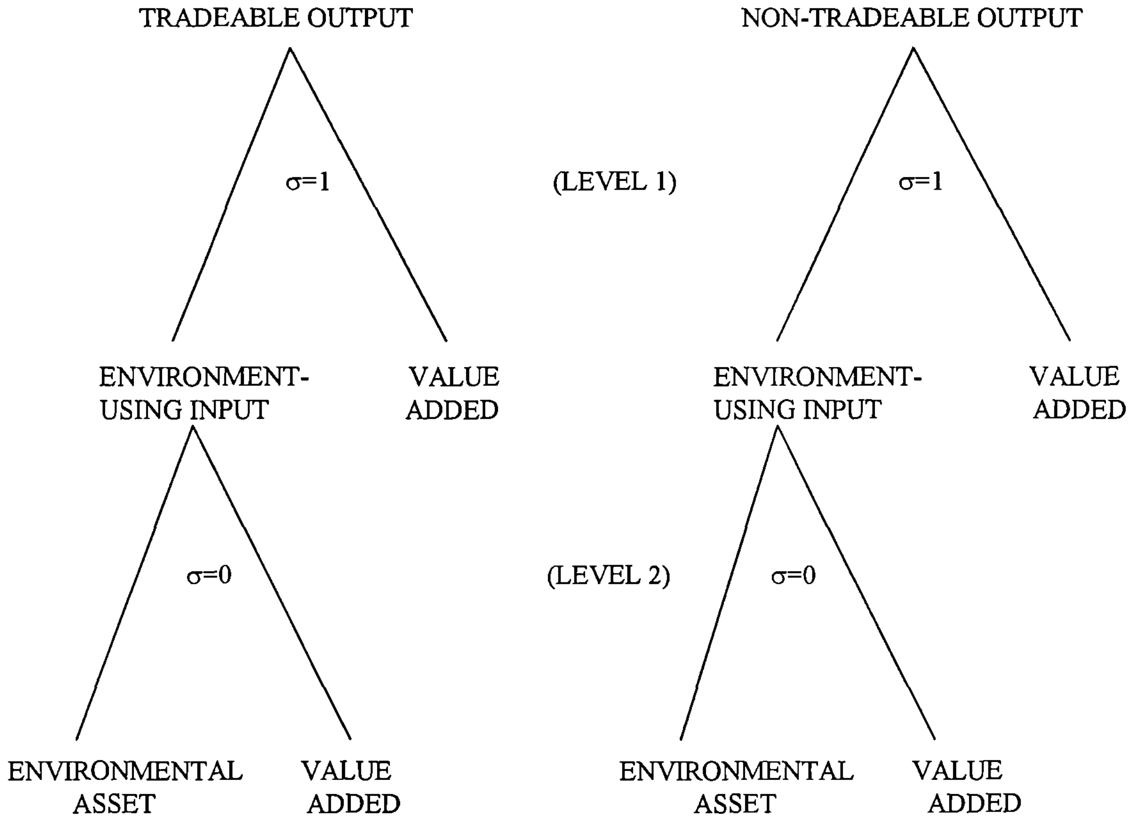

Figure 1. CES Production Structure in the Model (South Region)

by an amount ϵ. We consider taxes on the use of the environmental asset at rate τ^S, and hence the gross-of-tax price of the environment-using input in the South is

$$p_E^S = p^S + \epsilon\tau^S. \tag{4.1}$$

Value added and the environment-using input are both used in the production of tradable and non-tradable through unitary substitution elasticity, constant-returns-to-scale technologies. Thus, domestic prices of domestically produced goods are equal to unit costs:

$$p_j^N = c_j^N(p^N); \qquad p_j^S = c_j^S(p^S, p_E^S); \qquad j = X, Y. \tag{4.2}$$

For given output levels L_j^i ($i = N, S,\ j = X, Y$) we can write aggregate domestic demands for the environment-using input (using Shephard's Lemma) as

$$D_E^S = \sum_j L_j^S \frac{\partial c_j^S}{\partial p_E^S}, \qquad j = X, Y. \tag{4.3}$$

4.1.3 Environmental Quality

Environmental quality enters the preferences of both the North and the South, but with a substantially higher share parameter in the North, reflecting the differential existence value placed on environmental assets by region. The quantity of environmental assets entering preferences as existence value equals the initial stock of assets less that amount used up in production (through deforestation, for instance). The period used for the model is a number of years or decades, during which significant depletion can occur depending upon the policy regime. For given demands for the environment-using input, environmental quality is then given as

$$Q = \bar{Q} - \epsilon(D_E^S), \tag{4.4}$$

where $\bar{Q}$ denotes the initial endowment of the environmental asset (before use in production).

4.1.4 Trade and Demand

Each region levies ad valorem import tariffs at rates t^i, where superscripts refer to the importing region. The gross-of-tariff price of imported tradable is thus

$$q^N = (1 + t^N)p_X^S; \qquad q^S = (1 + t^S)p_X^N. \tag{4.5}$$

Given preferences, a level of environmental quality Q, commodity prices p_j^i, q^i, and incomes I^i, utility maximization yields uncompensated demands for domestic goods, D_j^i, and uncompensated import demands, M^i. The marginal valuation for environmental quality in each country v^i, is also a function of the same variables.

Expanded income in each region is written as the value of resource endowments, plus tariff revenue, plus revenues from environmental levies, plus the (shadow) value of environmental quality (note that the latter is a function of income itself, which makes the definition of I^i implicit):[2]

[2]This is added to income since environmental quality is purchased at its shadow price, but this price is not actually paid between countries, i.e. the North makes no actual payment to the South for the existence value of environmental quality they enjoy.

$$I^N = p^N G^N + t^N p_X^S M^N + \upsilon^N Q; \tag{4.6}$$

$$I^S = p^S G^S + t^S p_X^N M^S + \tau^S \epsilon D_E^S + \upsilon^S Q. \tag{4.7}$$

4.1.5 Market Equilibrium

Market clearing for competitive equilibrium in which use of the environmental asset is only charged through environmental levies requires the following:

$$L_X^N = D_X^N + M^S; \qquad L_X^S = D_X^S + M^N; \tag{4.8}$$

$$L_Y^i = D_Y^i, \qquad i = N, S; \tag{4.9}$$

$$D_E^i + \sum_j L_j^i \frac{\partial c_j^i}{\partial p^i} = G^i, \qquad i = N, S; \qquad j = X, Y; \tag{4.10}$$

where $D_E^N = 0$.

4.1.6 Choice of Functional Form

In the numerical implementation of the model, unit cost functions for tradable and non-tradeables production are a Constant-Elasticity-of-Substitution (CES) aggregation of the environment-using input and value added prices in the South region:

$$c_j^S(p^S, p_E^S) \equiv \left[(1-\alpha_j^S)(p^S)^{1-\beta^S} + \alpha_j^S (p_E^S)^{1-\beta^S}\right]^{\frac{1}{1-\beta^S}}, \qquad j = X, Y; \tag{4.11}$$

where the βs are the elasticities of substitution between the environment-using input and value added, and the αs are share parameters. Note that, since the environment-using input is not utilized by the North, the corresponding cost function is simply $c_j^N = p^N,\ j = X, Y.$

Preferences for domestic goods and imports in each region are represented by a two-level nested Cobb-Douglas/CES aggregation of the form

$$H^i(D_Y^i, D_X^i, M_A^i, M_B^i) \equiv (D_Y^i)^{\theta^i}\left[\delta^i(D_X^i)^{\frac{\sigma^i-1}{\sigma^i}} + (1-\delta^i)(M^i)^{\frac{\sigma^i-1}{\sigma^i}}\right]^{\frac{(1-\theta^i)\sigma^i}{\sigma^i-1}}, \quad i = N, S; \tag{4.12}$$

where θ^i is a share parameter for non-tradeables demand; δ^i refers to the share of domestic goods in total tradable demand; σ^i is the elasticity of substitution between same-region tradable and tradable produced in the other region.

Preferences for consumption and environmental quality are represented by a Cobb-Douglas utility function:[3]

$$U^i(Q, H^i) \equiv Q^{\eta^i}(H^i)^{1-\eta^i}, \qquad i = N, S; \tag{4.13}$$

where η^i is the Cobb-Douglas share parameter on environmental quality.

4.1.7 Policy Games in the Model

The model incorporates trade policy parameters in the form of tariffs, and environmental policy parameters in the form of environmental charges. A traditional

[3]For this specification, the marginal valuation for environmental quality is proportional to (non-expanded) income.

tariff game can be analysed (as in Johnson, 1953-4) in which regions play strategically against one another in tariffs. With the North being large and the South small, the presumption is that the North will gain from such a retaliatory game while the South will gain little, or more likely lose. There is also an environmental game that can be analysed in terms of environmental charges associated with the use of the environmental asset. Since the South owns the environmental asset and the North places a high existence value on it, the South can use a policy instrument jointly with trade policy in a linked trade and environment game which can result in lower Northern trade protection.[4]

In using the model, therefore, we go beyond conventional numerical simulation work which mainly focuses on Walrasian competitive equilibria, by computing non-cooperative equilibria and bargaining outcomes. To do this, we iterate over calculations of optimal policy responses by individual regions, subject to a full set of general equilibrium constraints (as set out above) until convergence to a Nash equilibrium is achieved. We are able to do this separately for the tariff game and for the linked trade and environment game. We also compute cooperative bargaining solutions associated with these games, adopting Nash's (1950) bargaining solution. This is the most widely used cooperative solution concept in the literature, although

[4]Throughout our analysis we maintain the assumption that countries in each bloc are able to coordinate policies among themselves in an inter-bloc non-cooperative equilibrium. Even though the necessary environmental institutional arrangements are not currently in place for such intra-bloc coordination to take place, they could well emerge in the future as has been the case in the trade area. In UNCTAD, for instance, the G77 emerged as the common developing country demand for special and differential treatment in GATT gained momentum in the 1970s.

others, such as Kalai-Smorodinsky (1975), could alternatively be used. In computing bargaining solutions, we take the non-cooperative Nash equilibrium solution utilities as representing the disagreement point, simulate the utilities possibilities frontier under cooperation, and apply the Nash criterion to the product of the differences in region utilities along the frontier and disagreement utilities.

In our central case, with trade or trade and environment games, no side payments are considered, and thus the resulting outcomes remain second-best allocations. Typically in such equilibria there will be less than full internalisation of the environmental externality. We also compute bargaining with side payments. This realizes a full Pareto optimal allocation, and allows us to assess how far towards Pareto optimality a joint trade and environment policy-based negotiation could move.[5] Note that side payments should not be interpreted as implying lack of negotiation linkage: if there were no environmental agreement, zero tariffs would not be optimal even with side payments. Thus, the side payments we compute here represent net compensation for environmental restraint by the South *in conjunction with* trade policy cooperation.

[5]Alternatively, one could view cooperation as reflecting a subgame perfect equilibrium of an infinitely repeated game, supported by the threat of future punishment in response to unilateral deviations from a coordinated strategy (trigger strategies). In such a formulation, it would be possible to explore whether a linked trade-environmental policy game makes cooperation in both areas easier to sustain in comparison with a scenario where the trade and environment dimensions of strategic interaction are examined in isolation from each other.

4.2 Data and Model Parameterisation

We have calibrated the model to a 1990 base case projected forward over a period of 100 years. The economies of the North and the South are both assumed to lie on a growth path on which value added, production and consumption grow at a constant rate, reflecting average growth rates over the period 1985-93. Data for this period implies rates of growth of 2.5% and 4% for the North and South respectively. We assume a discount rate of 5%. The production and consumption (and hence trade) data we use are based on information taken from World Bank (1992), World Bank (1995), and IMF (1995). Production activities are disaggregated into two parts: traded and non-traded production.[6] This implies a very high degree of aggregation, but, as indicated earlier, limitations associated with the computation of non-cooperative and cooperative equilibria severely restricts numerical analysis dimensionality. Furthermore, given the highly conjectural nature of some of the environment data we use, moving to a more detailed sectoral disaggregation would not significantly improve the reliability of numerical estimates obtained from the model.

In representing the regions, we include countries for the South which account for a significant portion of key global environmental assets, such as tropical forest and biological diversity. Table 18 identifies these countries and illustrates their importance

[6]The non-traded goods sector contains all distribution, transportation, construction, utilities, and government services. This corresponds roughly to 68% and 47% of GDP for the North and South respectively.

Table 18. Countries in the 'S' Region in the Model and Their Tropical Forest Cover

	Hectares 1990 (Thousands)	% of world tropical forests
Angola	24,074	1.37
Bolivia	49,317	2.81
Brazil	561,107	31.95
Cameroon	20,350	1.16
Central African Republic	30,562	1.74
Colombia	54,064	3.08
Congo	19,865	1.13
Gabon	18,235	1.04
Guyana	18,416	1.05
India	51,729	2.95
Indonesia	109,549	6.24
Malaysia	17,583	1.00
Mexico	48,586	2.77
Mozambique	17,329	0.99
Myanmar	28,856	1.64
Papua New Guinea	36,000	2.05
Peru	67,906	3.87
Tanzania	33,555	1.91
Sudan	42,976	2.45
Venezuela	45,690	2.60
Zaire	113,275	6.45
Zambia	32,301	1.84
TOTAL 'S' REGION	1,441,325	82.07
WORLD	1,756,299	100.00

Source: World Resources Institute (1994) in the ownership of the tropical rain forest asset. The countries included in the South region jointly control more than 80% of tropical forest and provide habitat for an unknown but presumed considerable proportion of species.[7] The North we take to be represented by OECD countries—who jointly reflect the environmental concern over depletion of environmental assets and would be the lead players in any eventual trade and environment negotiation in the WTO—and the rest of the world.

Table 19 reports the base year 1990 data on production by region and the corresponding 1990-2090 discounted data. Table 20 gives share, elasticity and other parameters. In calibrating the model, we select a value of 2 for Armington substitution elasticities, a choice which is consistent with most model-based studies (e.g., Perroni and Wigle, 1994); we subsequently vary this value for sensitivity analysis.

Parameters for the environmental portion of the model, are obtained as follows. The environment-using input coefficients by region have been computed from input-output data for selected OECD countries.[8] We make the strong assumption that LDCs use the environment-using input in the two sectors in the same ratio as they are used in OECD countries. We consider the following sectors as providing environment-using inputs: agriculture, forestry and fishing, mining and quarrying; petroleum and coal products; electricity, gas and water; and construction. The initial

[7]As is well-known, tropical ecosystems have a higher and more diverse number of species in a given area than temperate ecosystems. It is estimated that between 40% and 90% of all species live in tropical region habitats (World Resources Institute, 1994).

[8]The countries are Germany, United Kingdom and United States. The input-output data has been taken from OECD (1995).

Table 19. Production Data Used in Trade and Environment Model

	North	South
1990 GDP (Billion US dollars)	20,942	1,387
Discounted 1990-2090 GDP (Billion US dollars)	800,551	92,954

Table 20. Parameters for Trade and Environment Model

	North	South
Goods submodel		
Calibrated share parameters		
Imports in tradable demand	0.037	0.246
Non-tradeables in aggregate demand	0.681	0.473
Intra-regional trade in total trade	0.941	0.046
Substitution elasticities		
Armington trade elasticities (σ)	2.0	2.0
Tradeables-non-tradeables substitution in consumption	1.0	1.0
Environment-using input-value added substitution	n.a	1.0
Environment submodel		
Overall environmental damage*	n.a	10
Damage coefficients		
Tradable	n.a	0.22
Non-tradeables	n.a	0.06
Elasticity of marginal valuation with respect to income	1.25	1.25

n.a: not applicable

* As a % of North's GDP

(1990) endowment of the environmental assets in the South, relative to which depletion occurs, is set to be half of the North's GDP.[9] The value of base-case environmental damage, in terms of depletion of the endowment of the South's environmental asset, as valued by the North, is set to be equal to 10% of income in discounted value terms. This is admittedly highly conjectural, but could be rationalized as follows. The annual average depletion rate of tropical forests during the period 1981-90 was 0.6% (World Resources Institute, 1994). Assuming that this depletion rate remains constant throughout a 100-year period and assuming a quadratic damage function, the estimate of physical damage for our period of analysis would amount to approximately a 60% depletion of Southern environmental assets.

To impute a valuation for this damage, we can take Kramer and Mercer's (1997) estimate for the US of willingness to pay (WTP) to avoid the destruction of a certain area of tropical rain forest. We assume that this WTP changes with income growth (assumed to be 2.5% a year) throughout our period, and use an income elasticity of 1.25 (consistent with estimates obtained by Kramer and Mercer), to obtain an estimate for the stream of environmental damages for the 100-year period. Using a 5% discount rate, the present value of this stream is just above 10% of the North's GDP. These calculations are sensitive to parameter assumptions and in particular to the assumed damage function; at the same time, there exist other

[9] Although this assumption is largely arbitrary, it has only second-order implications for the behaviour of the model; specifically, it only affects the *elasticity* of the marginal valuation of environmental quality, not its level (i.e., the model's behaviour for marginal policy changes is unaffected); nevertheless, we perform sensitivity analysis on this parameter.

important aspects of environmental damage (such as loss of biodiversity) which are omitted from the calculation.

By choice of units we are able to set the marginal existence value of the North (v^N) equal to unity. The South's existence value of the environmental asset is calculated on the basis of the difference of per capita income between the two regions and using again an elasticity of marginal valuation with respect to income of 1.25 (again, consistently with Kramer and Mercer's findings). This gives an estimate of approximately 0.04 (relative to the North) for v^S.

We stress the fact that the calibration of the environmental side of the model relies on very strong assumptions on some key parameters. This is especially the case with the initial value for the environmental asset and the shape of the damage function, which crucially affects the elasticity of marginal valuation with respect to damage and the share of the environmental asset in preferences. Although we carry out sensitivity analyses on some key parameters—including the size of both the environmental asset and damage—we emphasize that our data constraints necessarily give our calculations a highly conjectural and illustrative nature—at least from a quantitative standpoint.

4.3 Simulations and Results

We have used our parameterised model to analyse the implications for LDCs of a linked trade and environment negotiation. We employ this structure to first compute non-cooperative Nash equilibria of a tariff game (the disagreement point). Because of their relatively small size, LDCs are at disadvantage relative to the North in this non-cooperative equilibrium. A bargained trade outcome improves the developing country situation a little relative to the disagreement point, but significant trade barriers remain against LDCs. In contrast, a linked trade and environment bargained outcome, where bargaining involves both trade and environmental policies, helps LDCs since they can use their leverage in environmental policy (given the relatively high existence value in the North) to help reduce Northern trade barriers against them.

These features emerge strongly from our central case set of model results summarized in Table 21.[10] Here we have taken the central case model specification summarized above and computed non-cooperative Nash equilibria in tariffs, bargained outcomes in trade (tariffs), and joint bargained outcomes covering both trade and environment policies. Trade elasticities are critical parameters in determining outcomes, and in this specification we have used values of 2 for both North and South. As is well known, as these values approach unity, in a symmetric case both regions optimal tariffs would become large, and values significantly in excess of unity need to be used to avoid numerical problems. Because the asymmetries in size in our model can lead

[10]In our tables, we adopt the zero tariffs and taxes scenario as a benchmark, to which all other simulation results are compared. The idea is that such a scenario reflects the state of affairs at the beginning of the 1990s, when significant trade cooperation had been achieved but tensions over global environmental problems were relatively new. One could argue that a scenario featuring optimal taxes from the South's point of view would provide a more natural benchmark; however, since non-cooperative taxes are close to zero on our simulations, the difference between the two scenarios is negligible.

Table 21. Trade and Environment Bargaining: Central Case Results

	Scenario		
	Non-cooperative equilibrium	Bargaining over trade	Bargaining over trade and environment
Tariff rates (%)			
North	500.00	253.63	0.0
South	101.03	0.0	47.68
Environmental internalisation rate (%)*			
North	0.0	0.0	0.0
South	0.41	0.41	54.10
Hicksian equivalent variation (% of GDP)			
A. With respect to disagreement point			
North	0.0	0.57	6.53
South	0.0	2.54	6.87
B. With respect to zero taxes and tariffs			
North	0.27	0.84	6.79
South	-8.89	-6.35	-2.02

* Ratio of emission tax to marginal emission damage

to large tariffs and associated numerical problems, we use an upper bound of 500% for tariffs in both regions in computing model solutions.[11] However, this is not of great significance since, well before tariffs reach such a high level, trade between the two regions has virtually ceased.

In the central case non-cooperative equilibrium (first column of Table 21) the South's internalisation rate is close to zero, consistent with most of the utility loss from lowered environmental quality being borne by the North. The North's trade barriers reach the upper bound of 500%, while the South's non-cooperative tariff rate is around 100%. This difference in non-cooperative tariff levels reflects both differences in country size and the fact that under zero environmental internalisation in the South, the North employs tariffs as a second-best environmental policy instrument.[12] The South's loss from a trade war is close to 9% of GDP, whereas the North gains a little relative to a free-trade scenario.

Bargaining over trade policies in the absence of side payments (column two of Table 21) leads to an elimination of tariffs in the South and lowers tariffs in the North to around 250%. This generates substantial gains in the South (2.54% of GDP), which are significantly smaller than the almost 9.0% loss experienced by the South under tariff retaliation.[13]

[11] We also rule out negative tariffs, which given our model structure, would never be used as an optimal response.

[12] This also contributes to the high level of tariffs, although the finding of high non-cooperative tariffs is, more fundamentally, a feature of Armington models featuring constant substitution elasticities.

[13] Although we allow the non-cooperative level of internalisation to adjust endogenously, it remains effectively unchanged (to the second decimal digit).

In contrast, combining trade and environmental policies in a joint negotiation makes it possible to sustain a level of internalisation in excess of 50%, and leads to the total elimination of tariffs in the North. Some trade barriers remain in the South, as a "concession" by the North in exchange for the higher internalisation rate. In this outcome the South's gains in relation to a non-cooperative outcome are considerable—almost 7% of GDP, and a linked trade and environment negotiation is an attractive proposition to them.

As pointed out earlier, we can alternatively think of cooperation as reflecting tacit collusion in an infinitely repeated game,[14] where players maintain a cooperative stance if the gains from unilateral defection are less than the discounted gains from cooperation. By computing pay-offs for the various players under cooperation, non-cooperation, and for unilateral deviations from cooperation, we could characterize the maximum discount rate for which the threat of future punishment is effective as an inducement to cooperate. To explore how linkage of trade and environment dimensions affects the viability of cooperation, we could compare the maximum discount values obtained for scenarios where dimensions of strategic interaction are considered in isolation and where they are examined jointly. Given the regional asymmetries in trade and environmental costs and benefits, without side payments it would never be possible to sustain any form of cooperation in this model that is consistent with

[14]For an application of this approach to trade cooperation, see, for example, Bagwell and Staiger (1993).

Table 22. Trade and Environment Bargaining with and without Side Payments

Hicksian equivalent variations (% of GDP)

	Scenario	
	Central case	Bargaining with side payments
A. Relative to the disagreement point		
North	6.53	6.62
South	6.87	14.00
B. Relative to zero taxes and tariffs		
North	6.79	6.89
South	-2.02	5.11

Note: with side payments, tariff rates are equal to zero, and the environmental internalisation rate is equal to 100%

Pareto optimality, either in environmental policies or in trade policies, independently of whether they are combined.

With explicit bargaining and lump-sum side payments (Table 22), on the other hand, it is possible to achieve a first-best outcome with zero tariffs and 100% internalisation. Introducing side payments overwhelmingly benefits the South, whose gains more than double as a result. Compared to a situation with no intervention, with cash transfers the South ends up with welfare gains which are high and not that different from those of the North, even though Southern preferences for environmental quality are much weaker than Northern ones. Thus, compared to a negotiation involving cash compensation for environmental restraint, the South gains far less from a linked trade and environment negotiation. A linked trade and environment negotiation with no side payments may be preferred to a trade-only negotiation, but may still be the wrong negotiation so far as the South is concerned. In reality, side payments are not often used; and without side payments it could be difficult to achieve free trade even abstracting from environmental concerns. Thus, one might interpret our results as showing that linkage can induce freer trade by providing an imperfect substitute for income transfers.

We have performed sensitivity analysis of our central case results to the Armington elasticities, the size of damage, and the North's existence value. This shows that varying key parameters have mainly quantitative effects, leaving most of our results qualitatively unaltered. Sensitivity analysis to the Armington elasticity values suggests that an increase in trade elasticities to a value of 3 (Table 23), which makes trade retaliation less damaging for the South, weakens opportunities for negotiation linkage. As a result, the maximum level of internalisation that can be achieved through linkage (not reported) is reduced. Results in Table 23 also show that, when linkage is weakened through higher trade elasticities, a linked negotiation can make the South worse off in comparison with a trade policy-only bargained outcome—a finding not inconsistent with the comparative statics properties of Nash bargaining solutions: a change which makes the utilities possibilities frontier more "skewed" in favour of one region, can benefit both parties, but it can conceivably also result in a lower level of utility for the other party. Intuitively, if there is more to be gained by one party from moving policies in the direction it favours, the affected party will become a "more concerned" negotiator. On the other hand, a reduction in trade elas-

Table 23. Trade and Environment Bargaining: Sensitivity Analyses on Trade Elasticities

Hicksian equivalent variations relative to zero taxes and tariffs (% of GDP)

	Scenario		
	$\sigma = 2$ (Central case)	$\sigma = 3$	$\sigma = 1.25$
A. Non-cooperative equilibrium			
North	0.27	0.24	0.11
South	-8.89	-6.13	-11.98
B. Bargaining over tariffs			
North	0.84	0.50	1.76
South	-6.35	-0.72	-10.14
C. Bargaining over tariffs and env. policies			
North	6.79	6.17	7.18
South	-2.02	-1.78	-4.94

Table 24. Trade and Environment Bargaining: Sensitivity Analyses on Damage and Existence Value

Hicksian equivalent variations relative to zero taxes and tariffs (% of GDP)

	Scenario			
Damage*	10	7.5	12.5	10
North's existence value	1 (Central case)	1	1	0.5
A. Non-cooperative equilibrium				
North	0.27	0.05	0.59	-0.02
South	-8.89	-4.61	-8.87	-4.88
B. Bargaining over tariffs				
North	0.84	0.46	1.22	0.44
South	-6.35	-3.72	-7.61	-3.75
C. Bargaining over tariffs and env. policies				
North	6.79	4.43	8.41	2.84
South	-2.02	-2.72	-1.85	-2.85

* As a % of North's GDP

ticities (third column of Table 23) strengthens the potential for environment-trade policy negotiation linkages, and makes it possible to achieve a level of internalisation close to 100% even in the absence of side payments.

Table 24 reports sensitivity analyses to model parameters affecting the size of damage and Northern existence value. When we decrease the level of damage (second column of Table 24), the non-co-operative level of tariffs (not shown) in the North is reduced. This is because the presence of environmental externalities in tradeables production in the South generates an additional incentive for the North to curtail trade, beyond the standard terms-of-trade large-country motive. In other words, the presence of externalities induces the North to use trade policy as a substitute for environmental policy. As externalities are reduced, so is the North's optimal tariff. Negotiation linkage, however, remains strong. For higher levels of damage (third column of Table 24), negotiation linkages become stronger as the North increases its optimal tariff if the South does nothing to improve environmental quality. On the other hand, a lower marginal valuation of damage by the North (last column of Table 8) has effects qualitatively similar to those of reducing the assumed level of damage, with negotiation linkages remaining important, especially for the North.

4.4 Concluding Remarks

This Chapter has addressed the issue of whether LDCs should participate in linked trade and environment negotiations in the WTO over the next few decades. We have developed a small dimensional global simulation model capturing both North-South trade, and Southern use of environmental assets in trade-related production when there is a high Northern existence value on such assets. The model has been calibrated to data over a projected 100-year period from 1990 to 2090, in which Southern countries are identified as those accounting for 80% of tropical assets (forest, species). We have computed various model solutions for alternative scenarios, principally non-cooperative Nash equilibria for tariff games which serve as threat points for cooperative bargaining (Nash) solutions, and similar solutions for linked trade (tariffs) and environmental (taxes) policy games.

In our central case analysis, linking trade and environmental policies in a joint negotiation expands the bargaining set and offers Southern LDCs an opportunity to exert discipline over Northern trade measures by making environmental concessions. The South thus benefits from a linked negotiation compared to a stand alone trade negotiation. However, in a negotiation with side payments, the South gains considerably more, suggesting that LDCs should negotiate over cash for environmental restraint rather than indirectly on trade and environmental policy instruments. Sensitivity analysis suggests that as trade elasticities increase, and optimal stand alone tariffs fall, the benefits of linkage fall to the point that Southern countries benefit from being shielded from a trade and environment negotiation. Indeed, we report cases where linked negotiations can be detrimental to the South, but this is crucially dependent on the (axiomatic) bargaining solution concept adopted and is not true in our central case.

While model results are suggestive, our model parameterisation is heroic, and there are missing features, reflecting developing country concerns over trade and environment linkage, which are not captured here. Trade and environment linkage could become the precedent for further wider linkage in trade negotiations, should developing countries agree to participate (trade and labour standard, for instance). Agreeing to the use of trade measures on environmental grounds would weaken the MFN principle in GATT/WTO, so central to developing country interests in the trading system. There is also ambiguity as to whether a cohesive Southern coalition can really be formed to participate in such a negotiation. Furthermore, cooperation in the GATT/WTO may not reflect a bargained agreement (which in the absence of a supranational authority would effectively not be enforceable) but rather a non-cooperative equilibrium supported by implicit triggered retaliation threats, which the agreement only serves to ratify ex post. Under this interpretation, introducing an environmental dimension alongside trade negotiations may inject instability into the system, especially if policies are not observable (Riezman, 1991), and make retaliatory episodes more likely.

CHAPTER 5

ADAPTATION, INTERNALISATION AND ENVIRONMENTAL EXTERNALITIES

The literature on externalities begins with Pigou's (1924) identification of the difference between marginal social and private benefits (or costs) and the need to correct for this with a tax or subsidy. It continues with Coase's (1960) seminal paper which identifies the importance of property rights in designing internalisation instruments. This literature argues that the difference between alternative property rights lies mainly in income distribution effects, and that prior bargaining (Coasian deals) between the parties can (wholly or partially) internalize externalities before any other policy instrument is used. Policy instruments designed in ignorance of such bargaining can overcorrect for an externality.

This Chapter adds to this discussion by arguing that adaptation (or behavioural response) to the damage associated with externalities is a pervasive phenomenon that can also affect internalisation instrument design. Examples of this type of adaptation include individuals spending more time indoors when ultraviolet radiation increases as damage to the ozone layer occurs; relocating upstream when fishing stocks are adversely affected by pollution; moving between locations due to localised emissions; or switching travel times in order to avoid traffic congestion. We argue that these behavioural responses need to be accounted for in any policy intervention designed to internalize externalities. Ignoring them will typically produce instruments which overcorrect for the externality.

In the case of traffic congestion, the externality widely thought to need correction is that the average and marginal (or private and social) cost of driving differ, with the latter needing to be taken into account when making transit decisions. With a labour-leisure choice underlying decisions of workers who travel, we argue that the presence of damage (avoided by not working) also creates a wedge between the marginal value product of labour and the marginal value of leisure, as individuals adapt to the damage and modify their labour supply behaviour. Internalising congestion externalities through a tax on transit which reduces the number of travellers increases the wedge between the marginal product of labour and the marginal value of time if there is diminishing marginal productivity of labour in the workplace. In this case, neglecting the adaptation to damage overestimates (potentially sharply, as we show later by numerical simulations) the true welfare gains from internalisation.

The issue has not been paid much attention to in the literature. In the widely used environmental texts, such as Baumol and Oates (1988), and Pearce and Turner (1990) we find no discussion of this adaptation issue. Classical papers in transport economics, including Walters (1961), Johnson (1964), and Else (1981), and recent texts such as Button (1993a), Button (1993b), begin from the proposition that appropriate internalisation of congestion externalities involves a transit tax reflecting the difference between average and marginal cost, and neglects the adaptive behavioural responses we highlight here.[1] Some of the literature on environmental valuation comes much closer to the point we make here (e.g. Freeman, 1993; Smith, 1997). In a different context, Coase (1960) and Turvey(1963) has also made a similar point. However, the welfare and policy instrument design implications we highlight here are not discussed in detail in such work.

The point has wide application and potentially sharply changes the evaluation of appropriate environmental policies.[2] We use a hierarchy of numerical models of instrument design responding to congestion externalities in developing our theme,[3] and appeal to OECD data in calibrating and parameterising them. In our first model the structure is kept simple, with one produced good, work-related transit, and damage in the form of congestion (time and traffic-related health effects). In this model

[1]Other literature examines the effects of congestion externalities on residential land use, emphasizing the distortion in land markets created by them (e.g. Arnott and MacKinnon, 1978; Henderson, 1975; Solow, 1973). Sullivan (1983a, 1983b), in particular, extends previous land-use models by including a labour demand sector and considering not only residential land but also industrial and transportation land, showing that unpriced congestion externalities distort housing, land and labour markets, which, in turn, generate inefficiencies in commodity markets. None of this literature, however, considers the adaptation effects on instrument design we stress here.

[2]Recent econometric literature explores unintended consequences of environmental policy, but does not make the link to the design of internalisation measures that we make here. Kahn (1998), for instance, estimates the relationship between environmental quality improvement and household migration in California.

[3]In the models we present in this Chapter, the cost of adaptation behaviour is not modelled explicitly or is assumed away. However, following the 'envelope theorem', if households have fully optimised, marginal damage cost calculations can ignore adaptation behaviour. The implication is that in settings where adpation costs have to be modelled separately, adaptation responses would not matter. Thus, the point we make here would not apply to adaptation behaviour in general. We are grateful to Alistair Ulph for pointing this out to us.

we consider labour-leisure responses as the vehicle for adaptation, with individuals assumed to avoid damage by not working. We then consider a model with regional labour mobility and region-specific congestion damage, where adaptation occurs in the form of induced migration responses.

We consider various embellishments on this regional structure. One includes local housing markets, with regional house prices adjusting to migration induced by localized damage and acting to damp migration. Here, changes in house prices reflect the adaptation response to region-specific damage. Another is region-specific production-related damage in the form of utility loss for residents of the affected region. Here, again, migration is the adaptation response, but two instruments are needed to internalize the externality—a sector-specific production tax and a region-specific labour subsidy.

The issue of allowing for adaptation responses in instrument design remains the same through all these cases. Internalisation instruments designed as though adaptation is not present differ significantly from those which take adaptation responses to damage into account. Typically, gains from internalisation are substantially smaller than those in comparable models which ignore adaptation responses, as are externality correcting taxes or subsidies. In the language of the literature on the Coase theorem, the issue is not only whether partial internalisation of externalities has occurred through Coasian deals, and so a simple Pigouvian tax overcorrects for them; it is also whether any adaptive response to the externalities has also taken place.

5.1 Internalising Congestion Externalities in the Presence of Labour Market Adaptation Responses

We first consider a simple model of congestion externalities in which labour supply decisions adapt to the time loss in traffic in various ways. One is by modifying the amount of labour supplied to the market; another is by relocating from cities to rural areas. We build on literature which estimates the social costs of traffic-related external effects in cities. These include excess time use in traffic, noise, elevated accident rates, and the impact of sulphides, nitric oxides, and particulate matter on human health, material damage and plant life. Khisty and Kaftanski (1986) some years ago produced an estimate that the added social costs in the US were in the order of 38 cents (at 1982 prices) per extra vehicle mile; perhaps 20 times the then price of gasoline.[4] A more recent OECD (1994) report puts congestion-related additional time use (relative to free flowing traffic) at 2-3% of GDP for OECD economies, noise costs at 0.3%, accident costs at 1.5-2%, and local pollution at 0.4%; in total 4-6% of GDP. For the UK, Newbery (1995) reports an estimate (for 1993) of congestion costs from additional time use as equivalent to 3% of GDP.[5]

[4]Khisty and Kaftanski (1986) also produced component estimates for extra travel time as (in cents): air pollution (2), noise pollution (4), excess fuel consumption (11), additional accidents (13), and others effects (11).

[5]Small (1992) and Miller (1989) find cost of travel time figures for the US of 50% and 60% of the hourly wage, respectively. More recently, Calfee and Winston (1998) have estimated the value

These are large orders of magnitude, with seemingly significant gains achievable from internalisation. Our point of departure is that with localized external effects individuals can adapt to the damage they suffer if they travel to work. One simple way is to reduce time supplied to the market, but other more subtle responses occur, such as changing the time at which transit occurs. Because these effects are present in the pre-intervention equilibrium, they affect the perceived welfare gain from internalising the externality. A Pigouvian tax seeking to correct for the difference between average and marginal damage which misses these adaptation responses typically overestimates the gain.

5.1.1 Labour-Leisure Response

We make our argument by first examining a simple case of congestion externalities in the presence of a labour-leisure choice. We consider a short run, in which additions to road capacity to deal with congestion are taken as infeasible.[6] The damage function from congestion we consider is, for now, defined over the number of workers in transit in urban areas, ruling out more sophisticated mechanisms through

of transit time for the US based on a willingness to pay (WTP) survey, and find an average WTP per hour of 19% of the gross hourly wage, considerably smaller than other studies, though—unlike OECD (1994)—it reflects time loss only.

[6]Significant increases in capacity or infrastructure within (as against between) urban areas are thus assumed away. This can be due to political opposition to new roads by existing residents, unwieldy legal process for compensation, or other considerations.

which existing urban residents can jointly reduce damage by, say, staggering transit times to work.[7]

We consider the starting point for gains occurring from internalisation to be one where Coasian bargaining has not already occurred. Motorists are thus not jointly bargaining to mitigate congestion damage.

Given these assumptions, we consider a fixed number of workers, $\bar{L}$, each of whom has identical homothetic preferences. Each worker has a fixed endowment of time, which we take to be unity. Workers decide on how much of their time to devote to market activity (which requires transit, and hence congestion), and how much to devote to leisure, which, for simplicity, we assume to be free of congestion. We denote aggregate time devoted to production by all workers as L, L being measured net of transit time. Market production is given by a decreasing returns to scale production function:

$$Y = L^{\alpha}; \qquad \alpha < 1 \tag{5.1}$$

where Y denotes output. The parameter α is strictly less than one, and defines the elasticity of output with respect to the labour input. The average product of labour (Y/L) exceeds the marginal product $(\alpha Y/L)$.[8] With the formulation used here rents also accrue to an unspecified non-labour, fixed factor. We assume that these rents

[7]In reality, such mechanisms are clearly important, but we ignore them for now both to simplify the analysis and to keep the focus on our main point.

[8]Equation (5.1) can be reformulated as constant returns to scale by adding a fixed factor with a Cobb-Douglas share (1-α).

accrue to households (implicitly through ownership of the fixed factor) in lump-.sum form.

We assume a damage function from congestion which is increasing in the market-supplied labour input, L

$$D = \lambda L^{\gamma}; \quad \gamma > 1 \tag{5.2}$$

where D represents total damage (here denominated in units of labour), $D/\bar{L}$ is the damage per market participant, λ and γ are parameters of the damage function. $\gamma > 1$ implies that marginal exceeds average damage.

We assume households have a utility function defined over goods (Y) and leisure (E) consumed:

$$U = U(Y, E) \tag{5.3}$$

where

$$E = 1 - L/\bar{L} - D/\bar{L} \tag{5.4}$$

The equation for E reflects an endowment of time per household of unity, market labour supply per household of $L/\bar{L}$, and damage per worker (in time units) of $D/\bar{L}$.

Households maximize utility subject to a cash budget constraint

$$P_Y Y = W \frac{L}{\bar{L}} \tag{5.5}$$

where P_Y is the price of the good, Y, and W is the market wage.

The externality that congestion creates in this case is that individual workers respond to the private (or average) cost each of them faces in transit, not to the social (or marginal) cost. From (5.2), marginal damage exceeds average damage, and there are gains to be had from internalisation. However, because of adaptation responses to damage, a wedge also exists in the with-damage equilibrium between the marginal value product of labour in goods production—which equals the wage rate—and the marginal value of time in leisure consumption (marginal utility of leisure). Through adaptation individuals can mitigate damage by not working, and hence equate the market wage per unit of labour supplied to the market net of damage per unit of labour supplied to the marginal utility of leisure. Thus, with adaptation, individual choose labour supply such that

$$\frac{U_E}{U_Y} = \frac{W[1 - (D/L)]}{P_Y}, \tag{5.6}$$

where U_E is the marginal utility of leisure, U_Y the marginal utility from goods consumption and P_Y is the price of Y.

In this case, internalisation instruments can reduce damage, but they also alter the adaptation to the damage. A transit tax reduces output, and hence damage, but in doing so it also further increases the marginal product of labour in goods production. The distortion between the marginal product of labour in goods production and the marginal value of time in leisure consumption is intensified by internalisation, and the gain from internalisation is reduced.

In contrast, if adaptation responses are not present, individuals equate the market wage to the marginal utility of leisure. Consequently, labour supply is chosen such that

$$\frac{U_E}{U_Y} = \frac{W}{P_Y} \tag{5.7}$$

Damage still occurs, and affects market output through (5.2) and (5.4), but no internalising adaptation occurs. An optimal internalising transit tax based on (5.7) would typically be larger than one based on (5.6),[9] and so would be the perceived welfare gains from internalisation. These effects occur simply because adaptation responses to damage have already partially internalize the externality.

We illustrate these impacts of adaptation by calibrating the simple model set out above to a 1995 UK data set on production, consumption, and congestion-related damage and performing general equilibrium numerical simulations. We compute optimal internalisation tax rates, and the gains from instituting them, both in the presence and the absence of adaptation responses. The calibration is based on UK GDP in 1995 in the region of 700 billion pounds (1 trillion US dollars). Assuming a work force of 25 million, this gives an annual income per member of the work force

[9] In the absence of adaptation, the internalisation tax is given by the difference between marginal damage (MD) and avergage damage (AD). With adaptation, the full internalisation tax rate is obtained as follows. If individuals are assumed to respond to AD, rather than MD, the internalization tax involved would be such that

$$(W - AD)(1 - t) = (W - MD)$$

where t is the tax rate. This implies

$$t = \frac{MD - AD}{W - AD},$$

which is smaller than the tax with no adaptation.

of around 40,000 US dollars. We use the labour share in the value of market production implied by 1995 UK national account data (0.68), and take the leisure share in expanded income (market income + leisure) to be 3/7.

For calibration on the environmental side, the OECD (1994) report we refer to earlier cites two different estimates of economy-wide congestion-related costs; one based on total time lost, equivalent to 8.5% of GDP, and the other 2-3% of GDP based on time lost compared with free-flowing traffic. Combining the first estimate with accident costs (1.5-2% of GDP), noise costs (0.3% of GDP) and local pollution costs (0.9% of GDP) yields a total congestion-related damage figure of 11-12% of GDP. Based on this figure, and trying to capture total rather than only congestion-related damage, we take total base-case damage for the UK as being 10% of GDP.

Using these data, we are able to calibrate share parameters for goods and leisure consumption for Cobb-Douglas preferences. Assuming a damage function elasticity, γ (which we set equal to 1.5), we can then determine the other parameter, λ, of the damage function. Part A of Table 25 summarises both the data used in and the parameters generated by these procedures.

Our simulation results (both in the presence and absence of adaptation responses) are reported in Table 25. With adaptation responses, we show a transit tax of 7.2% as being needed to achieve full internalisation, and an associated welfare gain of 0.08% of GDP. This is an extremely small number compared to the damage in the base case, but in the absence of adaptation responses it increases sharply.

Table 25. Internalising Congestion Damage in a Model with Labour-Leisure Choice

A. Specification of Base Case	
UK GDP (billion pounds)	700
Congestion-related damage (billion pounds)	70
Labour share in market production	0.68
Leisure share in expanded income (market income + leisure)	3/7
Share of goods in preferences (β_G)	0.56
Damage function elasticity (γ)	1.5
B. Internalisation Impacts with Adaptation Responses (%)	
Optimal tax rate on market labour supply	7.2
Internalisation gain (EV as % of GDP)	0.08
Change in labour supplied to the market	-3.3
C. Internalisation Impacts with No Adaptation Responses (%)	
Optimal tax rate on market labour supply	21.0
Internalisation gain (EV as % of GDP)	0.71
Change in labour supplied to the market	- 9.5

Table 26. Sensitivity of Internalisation Impacts in Table 25
to Key Model Parameters

	γ=1.1	γ=2.0	β_G=0.8
A. With Adaptation Responses(%)			
Optimal tax rate on market labour supply	1.5	14.0	7.3
Internalisation gain (EV as % of GDP)	0.003	0.29	0.004
Change in labour supplied to the market	-0.72	-5.7	-1.6
B. With No Adaptation Responses(%)			
Optimal tax rate on market labour supply	16.0	26.1	21.5
Internalisation gain (EV as % of GDP)	0.42	1.1	0.36
Change in labour supplied to the market	-7.6	-11.3	-5.0

Gains from internalisation calculated as though there were no adaptation response are nearly nine times larger, at 0.71% of GDP, and the optimal internalisation tax rate is 21%. Market labor supply responses differ by a factor of nearly three across those cases. Including or excluding adaptation responses to damage makes a large difference to the design of appropriate instruments to internalise externalities.

Sensitivity analyses on the results from Table 25 using variations on key model parameters are reported in Table 26, again for cases with and without adaptation responses. These results suggest that the large differences between cases with and without adaptation responses prevail. Increasing the elasticity of the damage function (γ) increases the gains from internalisation since both average and marginal damage increase. Variations occur in impact also under changed preference parameters, but the theme of the importance of adaptation assumptions still prevails.

5.1.2 Interregional Labour Locational Response

A further way in which adaptation responses to congestion damage can occur is where damage is localized and locational choice is present. To show how this further element of adaptation response can affect instrument design, we build on the literature on interregional labour mobility associated with Flatters, Henderson and Mieszkowski (1974), Boadway and Flatters (1982), and Myers (1990), amongst others, and add region-specific environmental considerations to the model above. Flatters, Henderson and Mieszkowski show how local public goods financed by taxes on residents can generate inefficient migration, since wage differences across regions can be supported by differences in individual benefits less taxes. In our structure, we assume damage is region-specific, and that migrants respond by comparing the wage premium they can receive if they remain in the affected region to the cost to them of the damage they incur. Adaptation to damage in this case generates migration.

We consider an economy with two regions, labeled as U (for urban) and R (for rural). Environmental effects occur in only one of the two regions, and affect interregional labour migration. For now, we assume these are from congestion-related effects within the U region, affecting only the region's residents.[10] We also assume that labour is interregionally mobile.

We assume again that the economy has a fixed endowment of labour, $\bar{L}$, which can move costlessly between the two regions, and that each region has a decreasing returns to scale production function

$$Y^j = (L^j)^{\alpha^j}, \quad j = U, R \tag{5.8}$$

where Y^j denote output, and L^j market supplied labour in region j. The terms α^j are, as above, strictly less than one, and define the elasticity of output with respect to the labour input in region j, with the average product of labour exceeding its marginal product. Rents again accrue to households (implicitly through ownership of

[10]Thus, by working in the rural region workers avoid the commuting congestion of working in cities; or, alternatively, all residents of urban areas bear congestion costs by living there, even if they work elsewhere.

fixed factors) from unspecified non-labour, region-specific fixed factors, in ways that do not influence locational choice.

In this case, we assume a damage function which is increasing in the number of residents in cities (L^U):

$$D^U = \lambda(L^U)^\gamma, \quad \gamma > 1 \tag{5.9}$$

where D^U represents total damage in cities (here again denominated in units of labour). D^U/L^U is the damage per urban resident, and λ and γ are parameters of the damage function. D^R equals zero.

As the single good is homogeneous across regions, it has the same price in both regions, and in equilibrium there is market clearing in both the good and in the labour markets. Consumers in each region maximize utility subject to their budget constraint and producers maximize profits. Because of interregional labour mobility, equilibrium involves an equal-utility condition across regions. With identical preferences for all consumers, interregional differences in wage rates are offset by the value of damage for those locating in region U.

If adaptation behavioural responses are explicitly recognized, this yields the equilibrium condition:

$$W^U\left(1 - \frac{D^U}{L^U}\right) = W^R \tag{5.10}$$

If no adaptation responses enter, the equilibrium condition is

$$W^U = W^R \tag{5.11}$$

We consider the internalisation instrument in this case to be a tax on inward migration into the congested region (with the revenues distributed equally to residents of all regions). In this case, a trade imbalance for regions is financed by tax revenues received by the other region, and in such cases consumption in region j, C^j , will not necessarily equal regional output, Y^j .

Efficiency conditions in the labour market in this case require that the marginal damage inflicted on by a migrant, rather than the average damage per resident, should affect migration decisions. Thus, in this model, we have different market equilibrium and efficiency conditions for the labour market. In the case where adaptation responses are present, the labour market equilibrium condition implies that

$$W^U(1-\lambda(L^U)^{\gamma-1}) = W^R, \tag{5.12}$$

while efficiency requires that

$$W^U(1-\lambda\gamma(L^U)^{\gamma-1}) = W^R. \tag{5.13}$$

These conditions imply that the marginal product of labour between the two regions diverges. Any move towards internalisation through a tax on migrating labour will once again affect adaptation responses to damage.

In Table 27 we provide a parameterisation for this model generated through calibration. We again take the UK case, and use it as an example of an OECD country with region-specific congestion. We first calibrate the model to a base case, and then

Table 27. Internalising Congestion Externalities with Interregional Labour Mobility

A. Base Case Calibration	
UK GDP (billion pounds)	700
Share of labour in cities	0.6
Region-specific congestion-related damage in the base case (billion pounds)	70
Share of labour in national income	0.68
Damage function elasticity	1.5
B. Internalisation Recognizing Adaptation (%)	
Optimal tax rate on urban labour	3.7
Gain from internalisation (EV as % of GDP)	0.03
Change in urban labour	-3.4
C. Internalisation with No Adaptation (%)	
Optimal tax rate on urban labour	30.7
Gain from internalisation (EV as % of GDP)	2.2
Change in urban labour	-30.3

compute a counterfactual in which tax policies are used to internalize the congestion externality, examining cases with and without adaptation responses. We use the same production, labour force and congestion-related cost data as in the previous section, but assume in addition that labour residing in congested regions reflects employment in manufacturing (approximately 16% of total employment in 1995), plus one half of employment in services. In combination, this is approximately 60% of the work force. We again use a labour share in total value of production of 0.68, set γ equal to 1.5, and calibrate the values of λ.

Results in part B of Table 27 show even larger discrepancies in the welfare gains from internalisation in the presence and absence of adaptation responses. Gains from internalisation if adaptation responses are recognized are only 0.03% of GDP, but 2.2% of GDP if their presence is ignored. Optimal tax rates with adaptation are 3.7%, but 30.7% in their absence, and the changes in labour migration across regions differ by a factor of almost 10. Incorporating adaptation responses makes an even larger impact than in our first model, both in terms of the setting of tax rates and in the perceived welfare gains.

Table 28 presents sensitivity analysis results on the elasticity of the damage function (γ) as well as on the assumed size of damage in the base case. Results again show that welfare gains from internalisation are sensitive to model parameter values used, and particularly to the elasticity parameter used in the damage function; but that the sharp differences across cases with and without adaptation responses persist. These sensitivity analyses also show that the internalisation tax rate and the welfare gain are inversely related to the size of damage to which the model is calibrated.[11]

5.2 House Prices and Migration

We next consider an extension to the regional migration model presented above, in which region-specific house prices now enter the picture.[12] This extension yields results in which adaptation effects now occur through housing markets. In this

[11]The reason for this is that the internalisation tax rises the divergence between urban and rural value marginal product of labour, offseting the reduction in damage and interregional wage rate wedge induced by the tax.

[12]Indeed, in some literature it is common to use indirect measures of location-specific damage as the change in land (or house) prices. See, for instance, some of the studies in Barde and Pearce (1991) and Navrud (1992).

Table 28. Sensitivity Analyses for Model with Interregional Labour Mobility

A. Alternative Parameter Configurations for Sensitivity Cases

	α^U	γ	Value of damage (% of GDP)	Share of labour in cities
Case 1	0.68	2.0	10	0.6
Case 2	0.68	1.5	15	0.6
Case 3	0.68	1.5	5	0.6
Case 4	0.68	1.5	10	0.75
Case 5	0.68	1.5	10	0.5

B. Internalisation Impacts with Adaptation (%)

	Welfare gain*	Optimal tax on L^U	Change in L^U
Case 1	0.25	12.1	-9.1
Case 2	0.0007	0.7	-0.5
Case 3	0.041	3.6	-4.8
Case 4	0.027	4.1	-2.5
Case 5	0.019	3.1	-3.2

C. Internalisation Impacts without Adaptation(%)

	Welfare gain*	Optimal tax on L^U	Change in L^U
Case 1	3.0	33.4	-31.9
Case 2	4.2	43.1	-38.9
Case 3	0.67	16.6	-18.3
Case 4	1.3	26.6	-18.4
Case 5	2.9	34.5	-38.9

* Hicksian EV as a % of GDP.

model there are fixed endowments of houses in each of the regions; migration into one region out of the other drives up house prices in the receiving region and drives prices down in the labour donating region. The effects of region-specific externalities on labour flows are therefore damped by adaptive house price effects, since these affect the migration decision via changes in relative real wage rates across regions. In these cases, potentially large redistribution under internalisation can also occur in favour of those owning homes in the non-congested region prior to any intervention to achieve internalisation.

More formally, we assume that in each region there is a pre-existing stock of houses, $\bar{H}^U$, $\bar{H}^R$. Houses are infinitely divisible—a larger proportion of the population in a region implies that each individual (or household) lives in a smaller house. Houses across regions are perfect substitutes in preferences, even though the separate fixed housing stocks imply different prices of houses in each region in the presence of region-specific external effects.

Household preferences are written as

$$U = U(C^j, H^j); \quad j = U, R \tag{5.14}$$

where C^j is the per person consumption of goods in region j, and H^j is the per person consumption of housing in region j. We again use Cobb-Douglas functional forms for (12) in which β_G and β_H denote share parameters on goods and housing.

Given the common goods price, P_C, and the two region specific house prices, P_{H^U} and P_{H^R}, we can construct region specific true cost of living indices from (5.14) using the expenditure functions

$$\pi^j = g^j(P_C, P_{H^j}); \qquad j = U, R \tag{5.15}$$

These price indices appear in the migration condition (5.10) and (5.11) in the presence and absence of adaptation responses in the form

$$\frac{W^U}{\pi^U}\left(1 - \frac{D^U}{L^U}\right) = \frac{W^R}{\pi^R} \tag{5.16}$$

and

$$\frac{W^U}{\pi^U} = \frac{W^R}{\pi^R} \tag{5.17}$$

and house prices influence migration decisions through the π^j variables in both the with and without adaptation response cases.

Equilibrium prices for the good, rural and urban housing (in terms of the numeraire, labour) are given by P^*_{Hj}, P^*_C, such that

$$H^j = \bar{H}^j$$

$$\sum_j C^j = \sum_j Y^j \tag{5.18}$$

$$\bar{L} = \sum_j L^j + D^U,$$

We again parameterise this model specification (with housing) using the UK as a case representative of an OECD economy. In our base case, by choice of units the price of housing is unity in both urban and rural areas. We assume (through the choice of $\bar{H}^U$ and $\bar{H}^R$) that 50% of housing (by value) is in urban areas in the base case, and we specify a housing share in preferences of 0.20. We later carry out sensitivity analyses on these parameter values.

Tables 29 and 30 report model results on the impact of internalisation taxes in the presence of house price changes, with and without adaptation responses. Table 31 compares them with the corresponding no house price cases. Results in Table 29 once again show that incorporating adaptation responses sharply reduces optimal tax rates. The presence of adaptive house price responses also substantially reduces the welfare gains from internalisation and migration out of the urban areas. This is the result of house prices falling in the cities and rising in rural areas as transit time is taxed and people move out of the cities. This movement in house prices causes migration towards the countryside to be smaller as internalisation occurs. House price effects also induce a distributional impact against those residing in the cities before internalisation.

Sensitivity analyses (Table 30) show that the large differences in cases with and without adaptive responses prevail across various model parameterisations Increasing the damage function elasticity magnifies these results, while reducing the labour output elasticity in the urban area yields changes in the opposite direction. As in the model with no house prices, increasing the size of the damage in the base case reduces the gain from internalisation. Results in Table 31 examine various cases

Table 29. Internalisation with Regional House Price Effects

A. Specification of base case	
UK GDP (billion pounds)	700
Share of labour in cities	0.6
Congestion-related damage (billion pounds)	70
Share of labour in national income	0.68
Share of national housing value terms in urban area	0.50
Share of housing in preferences	0.20
B. Internalisation with Adaptation Responses (%)	
Optimal tax rate on urban labour	2.7
Gains from internalisation*	0.01
Change in labour in cities	-1.3
C. Internalisation without Adaptation Responses (%)	
Optimal tax rate on urban labour	25.5
Gain from internalisation*	1.0
Change in labour in cities	-14.1

* Hicksian EV as a % of GDP.

Table 30. Sensitivity Analyses for Model with Regional House Price Effects

A. Alternative Parameter Configurations

	α^U	γ	β_G	Value of damage (% of GDP)	Share of labour in cities
Case 1	0.68	2.0	0.8	10	0.6
Case 2	0.68	1.5	0.7	10	0.6
Case 3	0.68	1.5	0.8	15	0.6
Case 4	0.68	1.5	0.8	10	0.75

B. Internalisation Impacts with Adaptation (%)

	Welfare gain*	Change in P_H^U	Change in P_H^R
Case 1	0.10	-5.4	10.1
Case 2	0.007	-1.3	2.4
Case 3	0.0003	-0.3	0.5
Case 4	0.007	-0.9	3.2

C. Internalisation Impacts without Adaptation (%)

	Welfare gain*	Change in P_H^U	Change in P_H^R
Case 1	1.5	-20.8	37.5
Case 2	0.73	-13.9	24.0
Case 3	2.0	-24.7	44.3
Case 4	0.41	-7.9	26.4

* Hicksian gains as a % of GDP.

Table 31. Comparing Results of Internalisation with and without House Price Effects

(%)

	Model variant	Welfare gain*	Tax on L^U (%)	Change in L^U (%)
Central case	NHPE	0.03	3.7	-3.4
Central case	HPE	0.01	2.7	-1.3
$\gamma = 2$	NHPE	0.25	12.1	-9.1
$\gamma = 2$	HPE	0.10	8.7	-3.7
Damage Value (% GDP) = 15	NHPE	0.0007	0.7	-0.5
Damage Value (% GDP) = 15	HPE	0.0003	0.4	-0.2
Share of labour in cities = 0.75	NHPE	0.027	4.1	-2.5
Share of labour in cities = 0.75	HPE	0.007	2.7	-0.5

HPE : House price effect
NHPE : No house price effect
* EV as % of GDP

where adaptation responses are present and shows smaller welfare gains from internalisation compared to no-house-price models since a lower of people moves into R as house prices there rise while in U fall.

5.3 Adaptation to Production-based Externalities

Besides labour supply, locational choice, and house prices, several other adaptation responses to environmental damage occur. In this final section to the Chapter one more is analysed—adaptation to region-specific production-related damage, rather than congestion-based damage. In this case, two goods (a clean and a dirty good) enter the analysis, with damage reflecting the production of the dirty good in cities. Adaptation-based migration now results from utility-based damage, rather than a time loss. Importantly in these cases, two interventions (a production and a labour market tax or subsidy) are needed to restore efficiency; a simple Pigouvian production tax will not suffice to fully internalize the externality. The need of using two policy instruments in similar situations seems to have first been raised by Coase (1960), although without exploring in detail welfare implications.

We again consider an economy with two regions—which, as before, we label urban (U) and rural (R)—and a fixed endowment of labour, $\bar{L}$. Labour can again costlessly move between regions. We consider two goods, clean (C) and dirty (D), each of which can be produced in each region with a decreasing returns to scale technology

$$Y_i^j = (L_i^j)^{\alpha_i^j}; \quad \alpha_i^j < 1; \quad j = U, R; \quad i = C, D \tag{5.19}$$

where Y_i^j denote outputs and L_i^j denote labour inputs. The α_i^j terms are again strictly less than one, and are equal to the elasticity of output with respect to labour inputs for each good in each region. The average product of labour again exceeds the marginal product of labour in all industries. Goods are traded and homogeneous across regions, and have the same price (P_i) in both regions.

We consider a case where damage is caused by the production of the dirty good in the urban region, and only impacts residents of cities. We assume that damage takes the form of emissions which lower environmental quality in U. We model environmental quality supply and demand as in the previous Chapter. Thus, we assume an exogenous initial endowment of environmental quality and a fixed coefficient damage function:

$$D^U = \theta Y_D^U \tag{5.20}$$

where D^U defines the damage in the cities (in units of reduced environmental quality), θ is the damage per unit of production of the dirty good, and Y_D^U is the production of the dirty good in the cities. D^R equals zero. Note that given the public good nature of environmental quality, average and total damage in U are the same.

Effective environmental quality in each region, Q^j, is then given by

$$Q^j = \bar{Q} - D^j; \quad j = U, R \tag{5.21}$$

where $\bar{Q}$ is environmental quality before damage occurs.

We assume identical preferences for all consumers, with preferences defined over consumption of goods, C_i^j, and environmental quality in each region. Thus,

$$U^j = U^j(C_i^j, Q^j); \quad i = C, D; \quad j = R, U \tag{5.22}$$

Households maximize utility subject to their budget constraint

$$\sum_i P_i C_i^j + \mu^j Q^j = I^j \tag{5.23}$$

where μ^j represents the shadow price (or marginal valuation) of environmental quality, and I^j is expanded income. Trade between regions can again be generated by internalisation policy interventions, such as a Pigouvian production tax on the dirty industry in the cities. Hence C_i^j will not necessarily equal Y_i^j.

In equilibrium, consumers in each region maximize utility subject to their budget constraint, but because of interregional labour mobility, equilibrium now involves an equal-utility condition across regions as well as market clearing in goods and labour. Thus with identical goods prices and preferences across regions, differences in wage rates are offset by the value of production-related damage for those residing in region U.

In the special case where we write (5.22) in separable form as the utility function per urban resident, i.e.

$$U = U(C_i^j) + V(D^j) \tag{5.24}$$

we assume that the same damage $V(D^j)$ accrues to all residents of cities, but again, given that Q is a public good, the value of average and total damage are the same.

Migration equilibrium in the presence of adaptation responses requires

$$W^U - \frac{V(D^j)}{MUI} = W^R \tag{5.25}$$

where W^U and W^R are urban and rural wage rates, and MUI is the marginal utility of income.

In the presence of uninternalised damage, (5.25) will not satisfy the conditions required for Pareto optimality. For efficiency, the wage rate differential (the difference in the value marginal product of labour across regions) should equal the value of damage in the region caused by the re-location of one extra migrant rather than the value of damage suffered by each city resident. Since the marginal product of labour in each region is falling, and as damage is a fixed coefficient multiple of output, marginal damage will be below average damage. This can be seen also by comparing the expression for average damage per urban resident implied by (5.20) with that for marginal damage, which is given by

$$\frac{\partial D^U}{\partial L^U} = \alpha_D^U \theta \frac{Y_D^U}{L_D^U}, \tag{5.26}$$

with $\alpha_D^U < 1$.

An implication of this structure is that, in this case, a physical externality creates a second external effect as migrants respond to average, not marginal damage. As a result, to achieve internalisation more than one instrument is needed (i.e. more than a Pigouvian, or production, tax on dirty output in U). An additional instrument, a region-specific labour subsidy or an interregional transfer, is needed.

We have used a structure incorporating these additional features to once again analyse the impacts of internalisation in the presence and absence of adaptation responses. In the numerical implementation we employ UK production and labour force data as in the model from the last section, but we now disaggregate this by industry (clean and dirty). We take the dirty industry to consist of manufacturing and transport activities, which jointly account for approximately 25% of UK GDP. We assume that production of dirty goods (and services) takes place in urban areas only, and that approximately two thirds of clean output is generated in the cities. A substitution elasticity in preferences of 1.5 is used for goods consumption in each region, and goods share parameters are determined through calibration.

We take the value of local environmental damage to be 1% of GDP—roughly consistent with estimates from OECD (1994).[13] Given this estimate, and assuming Cobb-Douglas preferences for goods and environmental quality, and an elasticity of marginal valuation of environmental quality with respect to damage of 0.5 (the value used in Perroni and Wigle, 1994), we can simultaneously calibrate the model to an initial endowment of environmental quality ($\bar{Q}$) and a share parameter on environ-

[13]This estimate corresponds to the sum of the costs of noise and local pollution (in terms of health, and material and vegetation damage) for the UK in OECD (1994).

mental quality in preferences. In the process, we choose units such that the marginal valuation of environmental quality is unity in both regions.[14]

Table 32 (Part A) presents and summarizes the parameters and data we use in a production-based damage model. The results show smaller differences between the adaptation and no-adaptation response cases. Note that a the use of only a tax on dirty output yields only part of the gains achievable through internalisation. To achieve full gains, a subsidy on urban labour must be employed (Table 32, Part B). As indicated earlier, this is because workers make decisions on migration on the basis of average rather than marginal (smaller) damage, which causes too many people to leave the cities if only a production tax is used.[15] We note that the use of a subsidy induces an increase in the production tax as well. This is because the subsidy, in making urban labour cheaper, causes dirty industry output to increase and further deteriorates environmental quality; the tax increase corrects for this effect.

5.4 Conclusion

In this Chapter we have argued that adaptive responses by agents can significantly affect the design of policies aiming to internalise environmental externalities. These effects occur where households or firms directly modify their behaviour in re-

[14]Here, we depart from the previous Chapter both in the calibration of the environment-side parameters and the modelling of marginal valuation of environmental quality.

[15]When only a production tax is used, the number of residents in the urban area falls by 1.3%; whereas when a subsidy is also introduced, the number of city residents rises by 0.9% (compared to the non-intervention scenario).

Table 32. Internalisation Effects in a Model with Production-Based Damage

A. Specification of Base Case

UK GDP (billion pounds)	700
Share of labour in cities	0.6
Share of labour in national income	0.68
Labour output elasticity	
Urban	0.68
Rural	0.68
Preferences elasticity	1.5
CES shares	
Clean.Rural	0.5
Clean.Urban	0.5
Share of goods in preferences	
Rural	0.93
Urban	0.97
Damage (billion pounds)	7.0

B. Impacts of Internalisation Taxes (%)

	With Adaptation	Without Adaptation
Welfare gain* from instituting both an optimal production tax and a labour subsidy in cities	0.019	0.022
Welfare gain* from instituting only optimal production tax	0.007	0.021
Optimal production tax rate on Y_D^U when no labour subsidy is used	2.1	3.6
Optimal production tax when subsidy to L_i^U is used	4.25	4.18
Optimal subsidy rate on L_i^U	2.4	0.65

* Hicksian EV as a % of GDP.

sponse to environmental damage. Examples include modifying labour supply due to time lost in traffic, moving between locations due to localised emissions, working indoors because of ultraviolet radiation from damage to the ozone layer. We mainly focus on adaptation to congestion-based damage in cities (time loss, noise, accidents, health effects) to illustrate our argument.

We use models calibrated to UK and OECD studies data, as well as to estimates on the division of the labour force between urban and rural areas. We develop a hierarchy of ever more complex models in which house-price effects (which dampen mobility) and production externality effects are taken into consideration and generate various adaptation responses. In all cases, adaptation responses to damage occur and affect pre-internalisation equilibrium outcomes and partially internalize the costs of damage. Both gains from internalisation and tax rates needed to restore Pareto optimality are considerably smaller than in models which do not take adaptation into account. Our conclusion is that adaptation responses to damage are important for environmental policy design, and not taking them into consideration can seriously mislead analyses of the consequences of internalising environmental externalities.

CHAPTER 6

SUMMARY AND CONCLUSIONS

This thesis has used general equilibrium numerical simulation techniques to examine trade and environmental issues. It has tried to go beyond the traditional confines of applied general equilibrium modelling by adding features such as international capital mobility and cooperative and non-coperative solution concepts. It has also tried to go beyond traditional counterfactual experiment analysis and used models to decompose observed changes derived from various sources into portions attributable to each source.

On the trade side, we have analysed the effects of trade liberalisation in small open economies both in the presence and absence of foreign direct investment flows and their taxation. Using data both for Costa Rica and El Salvador, we have found that, in the absence of FDI flows, the welfare gains from trade liberalisation are quite small, but positive. Using Costa Rican data in a model where such capital movements are present and foreign capital is taxed in accordance with foreign tax credit system rules, welfare gains might become even negative. In fact, complete tariff elimination will, in this case, reduce welfare in a small open economy.

We have also use a trade model to decompose the relative wage change that occurred in the UK during 1976-90 into trade and technology-related constituents parts. We have compared decomposition results for different institutional arrangements in the market for unskilled labour, and found that the way in which labour markets are modelled makes a substantial different to the decomposition. Specifically, when labour markets are fully flexible, technology is by far the principal factor responsible for increased wage inequality; whereas, when the unskilled labour market is inflexible due to the presence of a real minimum wage, trade can become the main force.

As to the environment side, we have analysed the issue of the incentives for developing country participation in possible future trade and environment linked negotiations within the World Trade Organization. We have computed non-cooperative and cooperative (bargaining) solutions with and without side payments of cash, using a North-South model incorporating trade and environmental assets. Our main finding has been that developing countries would benefit from a linked trade and environment negotiation with their developed counterparts, compared with a trade negotiation only. In a negotiation with side payments, however, developing countries do considerably better, suggesting that they should negotiate over cash for improved environmental management rather than over trade and environmental instruments.

Using a hierarchy of models, we have also examined the importance of adaptation responses to environmental externalities. We have considered models with labour-leisure choice and regional labour mobility, which we have calibrated to UK data and used to compute the optimal level of various internalisation instruments—

both in the presence and absence of adaptation responses to environmental damage. Our main finding has been that adaptation responses make a considerable difference to both the optimal level of internalisation instruments and the welfare gains from instituting these, driving both of them downwards in comparison with the case where adaptation responses are absent. Our conclusion is that not taking into account adaptation responses to environmental damage can seriously mislead analyses of the consequences of internalising environmental externalities.

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