Exchange Rate Regimes, International Linkages, and the Macroeconomic Performance of the New Member States

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Abstract

Research assessing the benefits and costs of joining a monetary union has used different tools to examine the macroeconomic costs of the loss of monetary sovereignty and the microeconomic gains from greater international integration. This paper takes an initial step toward integrating these two aspects in a unified framework, using a monetary macroeconomic model underpinned by a microeconomic theory of international trade based on the theory of comparative advantage. Within this framework we focus on the long-run benefits through greater trade integration. The long-run rise in trade, output and welfare are found to be substantial and almost certainly larger than the short-run macroeconomic costs. However, the fact that these benefits accumulate slowly over time may create a conflict between short-term pain and long-term gain.

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1 Introduction

The recent accession of the Czech Republic, Hungary, Poland, Slovakia, Slovenia, and the Baltic States into the EU represents the latest chapter in these countries' rapid economic transformation from centrally planned economies in the 1980s, through a wrenching transition to a market economy after the fall of the Berlin wall, to becoming fully fledged "emerging markets". For these accession countries, EU membership involves a commitment to enter EMU, hence the final stage of this process will be joining a large and wealthy currency union.[1]

Just as has been true for its earlier members, euro adoption will simultaneously provide the benefits of rapid economic integration (including dramatic improvements in production technologies, reductions in trade barriers, and greater financial integration) with the other members of EMU, at the cost of a loss of monetary autonomy. While these costs and benefits have been examined in several studies, such assessments have been complicated by fact that the benefits are primarily microeconomic and long-term in nature while the costs are usually measured in terms of changes in macroeconomic variability. Existing analysis has often focused on only one side of the coin—such as work on the correlation of shocks across countries as a way to analyze the potential losses from a common monetary policy and thereby assess whether countries form an "optimum currency area". Even when a more comprehensive approach examining both the microeconomic and macroeconomic effects of EMU membership is used, these two aspects are generally analyzed using separate methodologies and models, making any overall assessment quite subjective.

This paper provides a first step in bringing this analysis together in a single framework, thereby providing a more holistic view of the benefits and costs of recent EU entrants adopting the euro. More specifically, we present a theoretically consistent model that combines a microeconomic approach to trade with the real and nominal rigidities typically

[1] Many of the issues associated with joining EMU are addressed in Schadler and others (forthcoming).

used to assess the macroeconomic effects of different monetary regimes. The focus on the current exercise is assessing both the static and dynamic benefits of the fall in transportation costs and higher level of trade integration from entering EMU, with nominal and real rigidities playing an important role in defining the dynamics of this process. Recent analysis suggests large increases in trade associated with entry into a currency union, presumably because of the associated institutional changes such as more harmonized legal and regulatory regimes. Accordingly, we focus the paper on quantifying the benefits to trade, output, and economic welfare from lower costs of trading goods across countries.

Looking to the future, the model could be used to analyze the major microeconomic benefits of EMU membership—greater trade and financial integration with the rest of the currency union—and the major macroeconomic cost—the loss of monetary autonomy—in one overarching analytical framework. As the model is derived from strong theoretical foundations, these costs and benefits can in theory be measured using a single, consistent measure, namely the welfare of a representative individual in the economy. While at this point computational and other limitations constrain the analysis of macroeconomic policies and financial integration, these are temporary constraints, while the way forward in terms of using the model to combine the main micro- and macro-economic issues associated with entry into EMU is clear.

By incorporating a microeconomic model of trade based on the theory of comparative advantage, this paper represents a further extension of the "new-open-economy macro" approach pioneered by Obstfeld and Rogoff (1996, 2000), in which policy issues are analyzed in the context of models with strong theoretical underpinnings—see Smets and Wouters (2002a, 2002b), Huang and Liu (2004), Laxton and Pesenti (2002, 2003) for other examples. While it needs to be recognized that the theoretical framework involved in this type of analysis implies some limitations (for example, in its current form, the model cannot analyze some of the real-world issues faced by recent EU entrants, such as the fiscal pressures implied from complying with the Maastricht criteria and other EU standards), in our view these limitations are dominated by the benefits that can be obtained from analyzing the most important medium- to long-term effects of EMU in an integrated framework.

The rest of the paper is organized as follows. To motivate our analytical approach, Section 2 presents some stylized facts about the Czech Republic and the existing euro area. Section 3 presents the analytical framework, which extends the work of Naknoi (2004) by adding a range of real world elements that allow the model to produce more plausible dynamics. Section 4 discusses the base-case calibration of the model, and Section 5 discusses long-run comparative statics and dynamic simulation results concerning the trade-related benefits of EMU. Section 6 provides some policy conclusions.

2 Some Basic Facts About The Czech Republic

This section presents some basic facts about the Czech Republic, one of the transition countries that has emerged from the collapse of the Soviet block (Figures 1 to 3).[2] They are based on Eurostat quarterly data that start in 1995, about 5 years after the collapse, as earlier data are not considered to be reliable.

Trends in the volume of trade flows of the Czech Republic are striking. Figure 1 reports real export-to-GDP ratios and import-to-GDP ratios for both the Czech Republic and the euro area. Over the last decade, both the export and the import ratios in the Czech Republic have increased by around 50 percentage points.[3] Their strong correlation reflects the intensive use of imported intermediate inputs in the production of traded goods, and their strong growth has coincided with high levels of investment in sectors that produce such goods. This

[2] While the focus is on data for the Czech Republic, many of the arguments are also applicable to other transition countries—see Laxton and Pesenti (2002) for a review of similar trends in other transition countries such as Hungary and Poland.

[3] These ratios are based on constant-dollar trade flows relative to constant-dollar GDP. The absolute magnitude and upward trend in the ratios based on nominal data are smaller, as the relative price of exports and imports has declined over time. It is important to note that the estimates for the euro area in Figure 1 include intra-area trade which accounts for a significant fraction of the estimates of exports and imports reported in the Eurostat database.

development is partly related to structural reforms that over time have reduced restrictions on trade in goods and capital. On the other hand, risk factors in capital markets have limited the magnitude of trade and current account deficits in emerging-market economies—see Lipschitz, Lane, and Mourmouras (2002). Some evidence to support this can be seen in Figures 1 and 3, which include measures of the trade balance and proxy measures for the real interest rate. The real interest rate has usually been higher in accession countries than in the euro area. There is an exception of a period in 2000 and 2001, when the Czech National Bank did not respond to an increase in imported energy prices that was neutralized by the appreciating exchange rate and downward pressure on inflation coming from measured slack in the economy—see Čapek and others (2003).

Figure 2 also shows the investment share and the consumption share. The investment share has been approximately 15 percentage points higher in the Czech Republic than in the euro area. This high level of investment in the Czech Republic is generally ascribed to the process of building the capital stock up to levels observed in western countries. The implication is that the investment share will remain high as long as there are higher rates of return in accession countries, but then should start to fall at some point as this gap is narrowed.[4] It is interesting to note that the boom in investment has been accompanied by a boost to consumption as a ratio to GDP. This ratio, which was below the level in the euro-area aggregate a decade ago, has closed the entire gap and has recently risen above the ratio in the euro area,[5] plausibly reflecting wealth creation due to buoyant growth opportunities.

There have been important changes in the inflation process in the Czech Republic that are a result of changes in the underlying monetary policy regime. The Czech Republic evolved from a conventional peg (1990-1995) to a crawling peg in 1996, which then quickly evolved

[4] As far as we know, there are no reliable data on the capital stock that could be used to analyze this contention. It remains to be seen how long this process will continue before the investment share declines to more sustainable levels.

[5] The rise in nominal consumption expenditures as a share of nominal GDP has been less. The larger increase in the real consumption share reflects the increase in purchasing power of consumers.

into an explicit inflation-targeting regime (1997).[6] Inflation has declined from double-digit rates and for the last few years has been low and relatively stable compared to earlier periods. This is reflected in the level of short-term nominal interest rates, which have declined to levels seen in the euro area. That said, Figure 3 indicates that the current real interest rate spread is not out of line with historical values.

Finally, Figure 4 compares the CPI-based real exchange rate for the Czech Republic (measured so a rise is an appreciation) with estimates of aggregate labor productivity, expressed as a ratio of the level of labor productivity in the Euro area.[7] There has been a clear positive association between productivity catch-up and the real exchange rate. To many observers, this provides clear evidence in support of the Balassa-Samuleson hypothesis (BSH), according to which strong productivity growth in the traded-goods sector results in higher real wages in both the tradables and nontradables sectors, a trend increase in the price of nontradables relative to tradables, and an upward trend appreciation in CPI-based real exchange rates.[8]

Halpern and Wyplosz (2001) provide econometric evidence in support of a Balassa-Samuelson effect in Eastern European countries. Their analysis is supported by proxy measures indicating that aggregate productivity gains have been predominantly concentrated in the tradables sector and that there is a strong positive correlation between relative productivity levels and the relative price of nontradables. While this suggests that the BSH may be able to account for some of the upward trend in the real exchange rate, it leaves substantial room for other explanations, as the trend real appreciation in the real exchange rate has been much stronger than would be implied by the catch-up in productivity levels.[9]

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[6] See Čapek and others (2002) on the history of monetary policy in the Czech Republic.

[7] The real exchange rate is defined relative to a euro area aggregate. Throughout this paper we will follow a convention that an increase represents a real depreciation from the perspective of a transition country. The measure in Figure 4 has been inverted to make it easier to compare its trend with relative productivity levels.

[8] The original contributions are Balassa (1964) and Samuelson (1964).

[9] For examnple, Lipshitz, Lane and Mourmouras (2002) suggest that the real exchange rate may have been very low at the start of the transition because of insufficient market penetration and product reputation in Western markets.

More importantly, the analytical 2-sector nontradables-tradables framework, which is the basis for the BSH, cannot easily explain the strong trends in trade flows that have been observed in transition countries like the Czech Republic.

These data pose some interesting challenges to researchers that seek to build the appropriate analytical frameworks. For example, what extensions are needed to a standard macroeconomic framework consisting of fixed tradable and nontradable sectors to help us understand the rapid expansion of trade volumes? What factors were at work that could explain the high levels of investment and rise in the consumption ratio over the last decade? The paper presents some critical insights that we believe help to shed some light on these trends. It builds on a theoretical framework developed by Naknoi (2004), by adding a range of real-world elements. Some of these are quickly becoming standard in the modern theory-based macroeconomic models that are being rapidly developed to support policy analysis in central banks and the IMF, but there are also a number of intuitively appealing novel features associated with the interaction of trade and macroeconomic dynamics.

3 The Model

3.1 General Description

Figure 5 contains a detailed breakdown of the economy's production structure. The model is complex - but for a very good reason. A simple one or two sector model is simply not capable of generating the most prominent feature of the data we presented in Section 2, the dramatic increase in exports (and imports) to GDP ratios. We therefore specify a model with features that naturally give rise to such a phenomenon in response to the types of shocks recently observed in transition economies, namely rapid improvements in technology and reductions in costs of trading.

The model economy consists of two countries, a small country referred to as Home (representing accession countries) and a much larger one referred to as Foreign (representing the euro area). Households face a relatively standard set of constraints. We include habit persistence in consumption and time-to-build capital lags in investment, which help produce the lagged and hump-shaped responses of real variables to real and monetary shocks found in macroeconomic data (see also Laxton and Pesenti, 2003). These are complemented by some similar but theoretically more novel real rigidities on the economy's supply side. Indeed, the three key innovations of the paper are related to firms.

First, the model reflects the complex, multi-stage nature of both production and trading in modern industrial economies. There are two stages in the production process at which value is added - intermediate goods D (with goods varieties $y(z)$) and final goods Ω. Countries produce, import and export intermediate goods, use them to make final goods, and can re-export the resulting products. Such transactions that break up the value chain tend to be particularly high between countries at different levels of development, such as the accession countries and the euro area. Consumption goods C are also finalized in a third stage of production, reflecting the fact that while most firms have a direct relationship with their major suppliers, consumers do not. In addition, goods at each level of production are assumed to be sold to their ultimate users via a distribution sector that is subject to mark-ups and nominal rigidities.[10] The main advantage of this assumption is that it separates the sources of nominal and real rigidities, thereby simplifying the analytic issues involved in imposing both rigidities at the same level of production. That said, it is also an intuitive description of the real world.

Second, trade in intermediate goods is based on a Dornbusch-Fischer-Samuelson comparative advantage theory of trade in which, in principle, all goods can be produced by both countries, but where actual tradedness is determined endogenously by the interaction between the costs of trading and relative productivity levels between the potential producers of any given good in the two countries (Figures 6 and 7).[11] If the price advantage for the more

[10] The real transactions costs of changing prices described in Zbaracki and others (2004) for multi-product firms, due to management time and customer costs, appear to describe such a sector well.

[11] In principle, there is no difficulty in extending endogenous tradability to finished goods trade, although it would add further complexity to an already large model. We decided to dispense with this feature because

efficient producer at prevailing marginal factor costs and productivity differentials exceeds the costs of trading, the good is made in only one country and traded with the other. If not, then the good is produced in both countries and no trade occurs. As a result, lower trade costs and better technologies can then lead to much more rapid increases in trade than in standard models where the status of a good as traded or nontraded is exogenous.[12]

Third, the model is able to reproduce the gradual response of trade to movements in the real exchange rate by introducing a range of real rigidities. In addition to habit persistence in consumption and time-to-build capital lags for investment, we add a "time-to-build markets" constraint on trade. This captures the significant efforts in terms of time and resources that are typically necessary for companies to develop new supplier relationships, especially if those suppliers are in foreign countries. There is therefore both a time lag between an order decision and actual delivery, and a cost of changing the size of deliveries.[13] The implication is that swings in the real exchange rate do not immediately lead to large shifts in spending between domestic and foreign inputs. In our model such swings would, absent adjustment costs, be especially large, because the endogeneity of intermediates trade requires the assumption that the varieties that are traded have a very high elasticity of substitution. With adjustment costs the short run elasticity of trade with respect to the real exchange rate is much more moderate, while the long-run elasticity remains very high. This is indeed a well-known feature of the data, see Ruhl (2003).

We continue with a short overview of the production process. This is described in much more detail in the following subsections. In the first stage of production, **intermediate goods varieties** $y(z)$, $z \in [0, 1]$, are produced in each country using capital K, labor L and fixed

the main trade expansion in the accession countries did indeed take place in the intermediate goods sector.

[12] Bergin and Glick (2003) use a two-period small open economy model where firms take world prices as given. The source of heterogeneity is product-specific transport costs, whereas this paper emphasizes product-specific levels of productivity. To the best of our knowlege, this is the first infinite horizon DSGE model of endogenous tradability with nominal inertia.

[13] The difference between time-to-build capital and time-to-build markets is essentially the rate of depreciation. Capital depreciates slowly over time, while supplier relationships need to be renewed each period, or in other words they "depreciate" fully each period.

factors G. In equilibrium there will be three sub-baskets over varieties in each country, one over varieties only produced in Home, partly for Home consumption and partly for export (H goods: sub-baskets D_H and D_H^*), another over varieties only produced in Foreign, partly for Foreign consumption and partly for import by Home (F goods: sub-baskets D_F and D_F^*), and another over nontraded varieties in each country (N goods: sub-baskets D_N and D_N^*). The division of the unit interval between these goods will be endogenous to the two countries' comparative advantage pattern and to the size of trade barriers. It is at this level that this is a model of endogenous tradability. At the next stage the sub-baskets of varieties are traded, and domestically and foreign produced varieties are combined and assembled into final, homogenous **intermediates** D. Intermediates producers face adjustment costs and a time-to-build markets problem when varying the shares of D_H, D_N and D_F components in final intermediates D. The homogenous intermediate good D is then sold to a domestic **distribution** sector, which in turn supplies it to producers of final output. We assume that final output producers require all varieties of distribution sector goods, giving distributors market power, and that pricing at this level is subject to nominal rigidities. **Final output** Ω is produced by combining intermediates D with further labor, capital and fixed factors. The cascading of rigidities continues at the level of Ω, which is again assumed to be sold to a **distribution** sector that sets prices subject to nominal rigidities. This output is available for sale either in Home or in Foreign, and as consumption goods (C^H and C^F) or as investment goods (J^H and J^F). Sales that cross borders (C^F, C^{H^*}, J^F and J^{H^*}) are subject to the same cost of trading that affects trade in intermediates further up the production chain. Sales of **investment goods** go directly to households, who face the time-to-build capital cum adjustment cost technology described above. Sales of **consumption goods** however go to a producer of final consumption goods C that combines domestic and foreign goods subject to another time-to-build markets technology that makes it both costly and time-consuming to substitute between domestic and foreign inputs. Finally, consumption goods are once more subject to nominal rigidities through a further **distribution** sector.

Many open economy models include a Balassa-Samuelson effect, created by the presence of goods that are nontraded and have a low elasticity of substitution with traded goods (haircuts being the oft-cited example). However, in this model traded and nontraded goods are endogenously determined, and all goods are relatively substitutable. Interestingly, such a micro-founded model of trade does not yield a large long-run appreciation of the exchange rate. This suggests that the observed appreciation is not closely connected with the benefits from closer trade integration, but from other aspects of economic convergence. Obvious possibilities are financial integration and the existence of a domestic factors of production which cannot easily be substituted by foreign trade. These issues are the subject of our current work.

This completes our general description of the production structure. In the following subsections we describe the optimization problem of each level of production in detail, starting at the lowest level and building up to final consumption and investment goods. As there are multiple interacting sectors, we use a symmetric notation to facilitate exposition. In particular, elasticities of substitution are always denoted by θ sub-indexed for the respective sector, and input share parameters in CES production (or utility) functions by ξ sub-indexed for the sector. Nominal producer prices (or marginal costs) are denoted by super- or sub-scripted M, and nominal user prices by super- or sub-scripted P (with lower case m and p for the respective relative prices). For flexible price goods, producer and user prices are the same, while for sectors with distribution sectors and nominal rigidities the user price is the sticky price charged by the distributor. Foreign variables are identified by a superscript asterisk and the two countries are allowed to be of different size, with the population of the home country being α and that of the foreign country $(1 - \alpha)$. We concentrate on analyzing the economic decisions for Home agents, as the corresponding decisions for Foreign agents are mirror images.

3.2 Households

Each individual household i maximizes lifetime utility which has three arguments, consumption C^i (which exhibits habit persistence), leisure $(1-L^i)$ (where L^i is labor effort and 1 is the time endowment), and real money balances $n^i = N^i/P^c$ (where P^c is the consumption based price index). Denoting the intertemporal elasticity of substitution by σ, we have:

$$Max \quad E_0 \sum_{t=0}^{\infty} \beta^t \left\{ \frac{o_t \left(C_t^i - \nu C_{t-1}^i\right)^{1-\frac{1}{\sigma}} - 1}{1-\frac{1}{\sigma}} + \psi \frac{(1-L_t^i)^{1-\frac{1}{\sigma}}}{1-\frac{1}{\sigma}} + \psi_n \frac{(n_t^i)^{1-\epsilon}}{1-\epsilon} \right\} , \quad (1)$$

where E_t is the expectation conditional on information available at time t, and o_t is a preference or demand shock. Households' capital accumulation decision involves separate decisions for domestically and foreign produced capital stocks K^{H^i} and K^{F^i}. This is because these are imperfect substitutes in firms' production functions,[14] the aggregate capital stock being given by a CES aggregator with share parameters ξ_k and elasticity of substitution θ_k:

$$K_t^i = \left[\xi_k \left(K_t^{H^i}\right)^{\frac{\theta_k - 1}{\theta_k}} + (1-\xi_k) \left(K_t^{F^i}\right)^{\frac{\theta_k - 1}{\theta_k}} \right]^{\frac{\theta_k}{\theta_k - 1}} . \quad (2)$$

Capital accumulation follows time-to-build technologies, with a six-period lag between the investment decision I_t^i and the point at which the investment decision leads to an addition to the productive capital stock:

$$\begin{aligned} K_{t+1}^{H^i} &= (1-\Delta) K_t^{H^i} + I_{t-5}^{H^i} , \\ K_{t+1}^{F^i} &= (1-\Delta) K_t^{F^i} + I_{t-5}^{F^i} . \end{aligned} \quad (3)$$

Furthermore, changes in the level of investment spending are subject to a quadratic adjustment cost paid out of household income (see the budget constraint below). Each investment decision represents a commitment to a spending plan over six periods, starting in the period of the decision and ending one period before capital becomes productive.

[14] We are thinking for example of domestic buildings combined with imported machinery.

The shares of the investment project that have to be disbursed in each period are given by $\omega_j,\ j = 0, ..., 5$, with $\Sigma_{j=0}^{5}\omega_j = 1$. Actual investment spending J_t^i is therefore given by

$$\begin{aligned} J_t^{H^i} &= \omega_0 I_t^{H^i} + \omega_1 I_{t-1}^{H^i} + \omega_2 I_{t-2}^{H^i} + \omega_3 I_{t-3}^{H^i} + \omega_4 I_{t-4}^{H^i} + \omega_5 I_{t-5}^{H^i} \ , \\ J_t^{F^i} &= \omega_0 I_t^{F^i} + \omega_1 I_{t-1}^{F^i} + \omega_2 I_{t-2}^{F^i} + \omega_3 I_{t-3}^{F^i} + \omega_4 I_{t-4}^{F^i} + \omega_5 I_{t-5}^{F^i} \ . \end{aligned} \tag{4}$$

In what follows we choose as our numeraire the price P_t of intermediate goods D_t, and lower case price and return variables p and r are in terms of this numeraire. The nominal exchange rate is S_t, and the real exchange rate for intermediates is $s_t = (S_t P_t^*)/P_t$. Households can hold two types of financial assets (apart from money), risk-free bonds issued in Home and denominated in Home currency $\tilde{F}_t^i$ yielding a nominal gross return of i_t, and risk-free bonds issued in Foreign and denominated in Foreign currency F_t^i yielding a nominal gross return of i_t^*, with the corresponding real variables given by $\tilde{f}_t^i = \tilde{F}_t^i/P_t$ and $f_t^i = (S_t F_t^i)/P_t$. The gross rate of currency depreciation is denoted by ε_t, and π_t^* and π_t are the gross foreign and domestic inflation rates for the numeraire good. Furthermore, households own three types of real assets, Home and Foreign produced capital K^{H^i} and K^{F^i}, and fixed factors (such as land) G_t^i. Households' income therefore consists of real wages $w_t L_t^i$, real returns on capital $r_t^{K^H} K_t^{H^i} + r_t^{K^F} K_t^{F^i}$, on fixed factors $r_t^g G_t^i$, on risk-free international bonds $f_{t-1}^i \frac{i_{t-1}^* \varepsilon_t}{\pi_t}$ and on risk-free domestic bonds $\tilde{f}_{t-1}^i \frac{i_{t-1}}{\pi_t}$, in addition to lump-sum government redistributions T_t^i/P_t and profit redistributions Π_t^i/P_t. We assume that agents do not have access to a complete set of internationally tradable state-contingent money claims. It is well-known that this makes net foreign assets nonstationary in linearized versions of the model economy. We therefore impose a small quadratic adjustment cost on deviations from a steady state level of private sector bond holdings (with the latter for simplicity set equal to zero), specifically $\frac{\phi^f}{2}\left(\alpha(f_t + \tilde{f}_t)\right)^2$. Households' expenditure consists of consumption spending $p_t^c C_t^i$ and investment spending $p_t^H J_t^{H^i}$ and $p_t^F J_t^{F^i}$, where p_t^H and p_t^F are the user prices of Home and Foreign produced final goods. Households also face a quadratic cost of adjusting their nominal wage as suggested by Rotemberg (1982), and as extended to costs of adjusting the rate of change of the wage by, among many others, Laxton and Pesenti (2003). Furthermore, following Ireland (2001), the adjustment cost is related to changes in household i's wage inflation relative to the past observed aggregate wage inflation rate. Specifically, the real wage adjustment cost is given by $\frac{\phi^w}{2}\left(\pi_t^{w^i}-\pi_{t-1}^w\right)^2$, where $\pi_t^{w^i}=W_t^i/W_{t-1}^i$ is the (gross) household specific rate of wage inflation and π_t^w is the aggregate rate of wage inflation. This and all other adjustment costs are assumed to be redistributed back to households as lump-sum payments. The period t budget constraint, whose multiplier is denoted by λ_t, is therefore:

$$
\begin{aligned}
f_t^i+\tilde{f}_t^i+(N_t^i/P_t) \quad = \quad & f_{t-1}^i\frac{i_{t-1}^*\varepsilon_t}{\pi_t}+\tilde{f}_t^i\frac{i_{t-1}}{\pi_t}+(N_{t-1}^i/P_t) \\
& +p_t^g(G_t^i-G_{t+1}^i)+(\Pi_t^i/P_t)+(T_t^i/P_t) \\
& +w_tL_t^i+r_t^{K^H}K_t^{H^i}+r_t^{K^F}K_t^{F^i}+r_t^gG_t^i \\
& -p_t^cC_t^i-p_t^HJ_t^{H^i}-p_t^FJ_t^{F^i} \\
& -\frac{\phi^f}{2}\left(\alpha\left(f_t+\tilde{f}_t\right)\right)^2-\frac{\phi^w}{2}\left(\pi_t^{w^i}-\pi_{t-1}^w\right)^2 \\
& -\frac{\phi^I}{2}p_t^H\frac{\left(I_t^{H^i}-I_{t-1}^{H^i}\right)^2}{I_{t-1}^{H^i}}-\frac{\phi^I}{2}p_t^F\frac{\left(I_t^{F^i}-I_{t-1}^{F^i}\right)^2}{I_{t-1}^{F^i}} \quad .
\end{aligned} \tag{5}
$$

We assume symmetry by fixing initial holdings of bonds, money, capital and fixed factors to be identical for all households. This implies that each household has the same present discounted value of income, and that all households' marginal conditions are identical, including a synchronization of wage setting behavior. We can therefore drop the index i in the following derivations.[15]

Households maximize (1) subject to (2), (3), (4), (5), and the demand for their labor. The first-order conditions for consumption, bonds and fixed factors are given by[16]

$$
o_t\left(C_t-\nu C_{t-1}\right)^{-\frac{1}{\sigma}}-\beta\nu\mathcal{E}_to_{t+1}\left(C_{t+1}-\nu C_t\right)^{-\frac{1}{\sigma}}=\lambda_tp_t^c \ , \tag{6}
$$

[15] A market for domestic state-contingent money claims is therefore redundant.

[16] Note that the first-order conditon for money is redundant unless money supply is assumed to follow an exogenous rule, a case that is not considered in this paper.

$$(1+\alpha^2\phi^f f_t) = \beta\mathcal{E}_t\left[\frac{\lambda_{t+1}}{\lambda_t}\frac{i_t^*\varepsilon_{t+1}}{\pi_{t+1}}\right] \quad , \tag{7}$$

$$(1+\alpha^2\phi^f f_t) = \beta\mathcal{E}_t\left[\frac{\lambda_{t+1}}{\lambda_t}\frac{i_t}{\pi_{t+1}}\right] \quad , \tag{8}$$

$$1 = \beta\mathcal{E}_t\left[\frac{\lambda_{t+1}}{\lambda_t}\frac{p_{t+1}^g + r_{t+1}^g}{p_t^g}\right] \quad . \tag{9}$$

Equivalent conditions can be derived for Foreign. Note also that (7) and (8) imply the interest parity condition

$$i_t = i_t^*\left(E_t\varepsilon_{t+1} + \frac{Cov_t\left[\left(\frac{\lambda_t}{\lambda_{t+1}}\frac{1}{\pi_{t+1}}\right), \varepsilon_{t+1}\right]}{E_t\left(\frac{\lambda_t}{\lambda_{t+1}}\frac{1}{\pi_{t+1}}\right)}\right) \quad . \tag{10}$$

The optimality conditions for investment and capital ($j = H, F$) are:

$$\begin{aligned}
&\omega_0\lambda_t p_t^j + \beta\omega_1\lambda_{t+1}p_{t+1}^j + \beta^2\omega_2\lambda_{t+2}p_{t+2}^j + \beta^3\omega_3\lambda_{t+3}p_{t+3}^j + \beta^4\omega_4\lambda_{t+4}p_{t+4}^j + \beta^5\omega_5\lambda_{t+5}p_{t+5}^j \\
&+\lambda_t p_t^j\phi^I\left(\frac{I_t^j - I_{t-1}^j}{I_{t-1}^j}\right) = \beta^5\lambda_{t+5}p_{t+5}^j q_{t+5}^j \\
&\beta\lambda_{t+1}p_{t+1}^j\phi^I\left[\left(\frac{I_{t+1}^j - I_t^j}{I_t^j}\right) + \frac{1}{2}\left(\frac{I_{t+1}^j - I_t^j}{I_t^j}\right)^2\right] \quad ,
\end{aligned} \tag{11}$$

$$q_t^j\lambda_t p_t^j = \mathcal{E}_t\left\{\beta\lambda_{t+1}\left[r_{t+1}^{K^j} + p_{t+1}^j q_{t+1}^j(1-\Delta)\right]\right\} \quad . \tag{12}$$

Cost minimization for the aggregate capital stock K_t requires the following conditions:

$$K_t^H = \xi_K K_t\left(\frac{r_t^k}{r_t^{K^H}}\right)^{\theta_k} \quad , \tag{13}$$

$$K_t^F = (1-\xi_K)K_t\left(\frac{r_t^k}{r_t^{K^F}}\right)^{\theta_k} \quad , \tag{14}$$

where

$$r_t^k = \left[\xi_K\left(r_t^{K^H}\right)^{1-\theta_k} + (1-\xi_K)\left(r_t^{K^F}\right)^{1-\theta_k}\right]^{\frac{1}{1-\theta_k}} \quad . \tag{15}$$

We finally consider an individual household's labor supply decision. Firms are assumed to demand labor in terms of an aggregate L_t which is a CES aggregate of all labor varieties supplied by households, with elasticity of substitution θ_w. In choosing its demands for all households' labor varieties, each firm therefore has to solve the following cost minimization problem:

$$\underset{L_t^i, i\in[0,1]}{Min} \int_0^1 W_t^i L_t^i di \;\; s.t. \; L_t = \left(\int_0^1 {L_t^i}^{\frac{\theta_w - 1}{\theta_w}} di \right)^{\frac{\theta_w}{\theta_w - 1}} . \tag{16}$$

This gives rise to the set of labor demands

$$L_t^i = \left(\frac{W_t^i}{W_t} \right)^{-\theta_w} L_t \ , \tag{17}$$

where the aggregate wage is given by

$$W_t = \left(\int_0^1 \left(W_t^i \right)^{1-\theta_w} di \right)^{\frac{1}{1-\theta_w}} . \tag{18}$$

Households maximize their utility from leisure subject to this demand (17) and subject to the wage inflation adjustment cost in the budget constraint (5). The optimal wage decision is given by

$$\lambda_t w_t L_t(\theta_w - 1) + \lambda_t \phi^w (\pi_t^w - \pi_{t-1}^w)\pi_t^w - \beta E_t \left[\lambda_{t+1} \phi^w (\pi_{t+1}^w - \pi_t^w) \pi_{t+1}^w \right] = \theta_w \psi L_t (1 - L_t)^{-\frac{1}{\sigma}} . \tag{19}$$

3.3 Intermediates

3.3.1 Varieties (z) of Intermediates

For each variety z there is a continuum of producers who are perfectly competitive price takers in both their input and output markets. They have the following production functions in labor, capital and fixed factors:

$$y_t(z) = a(z) x_t \left[(\xi_v)^{\frac{1}{\theta_v}} \left(l_t(z)^\gamma k_t(z)^{1-\gamma} \right)^{\frac{\theta_v - 1}{\theta_v}} + (1 - \xi_v)^{\frac{1}{\theta_v}} \left(g_t(z) \right)^{\frac{\theta_v - 1}{\theta_v}} \right]^{\frac{\theta_v}{\theta_v - 1}} = x_t a(z) v_t(z) \ . \tag{20}$$

The first two elements of the production function are sector specific productivity levels $a(z)$ and aggregate productivity levels x_t. Aggregate productivity or supply shocks are given by

$$\log(x_t) = \rho^x \log(x_{t-1}) + (1-\rho^x)\log(\bar{x}) + u_t^x \ , \tag{21}$$

$$\log(x_t^*) = \rho^{x^*} \log(x_{t-1}^*) + (1-\rho^{x^*})\log(\bar{x}^*) + u_t^{x^*} \ . \tag{22}$$

The sector specific productivity terms determine the pattern of comparative advantage between countries, a crucial ingredient in making tradedness of intermediate goods endogenous. For each producer, optimality requires that the price of its variety equal marginal cost, where marginal cost is equal to the ratio of marginal factor cost m_t^v (the cost of $v_t(z)$), derived below from the producer's cost minimization problem, and productivity:

$$p_t(z) = \frac{m_t^v}{x_t a(z)} \ . \tag{23}$$

When a good is produced in the Foreign country and shipped to the Home country or vice versa there are iceberg-type proportional trading costs τ_t that are identical across goods.[17] Therefore, in the absence of relative productivity differences, there would be no trade as each country would produce the entire range of consumption goods at home. But as soon as there are sufficiently strong comparative advantage patterns in productivity the effect of trading costs can be overcome, leading to trade. For a given pattern of comparative advantage, lower trade costs lead to more trade, or to a smaller range of nontraded goods. We denote the relative aggregate productivity by $\chi_t = x_t/x_t^*$, and the relative variety-specific productivity between Home and Foreign by $A(z) = a(z)/a^*(z)$. The shape of the function $\chi_t A(z)$, which we will refer to as the comparative advantage schedule, is of crucial importance for our results. This is of course an empirical question, but at this point we are not aware of any evidence to give us guidance. On the grounds of plausibility, we would prefer a negative exponential schedule, with a narrow range of goods over which

[17] Unlike adjustment costs, transport costs are not redistributed back to agents in a lump-sum fashion. They represent an actual loss in transit.

Home has a strong comparative (and possibly an absolute) advantage. For this paper we chose instead a negatively sloped kinked linear schedule, which approximates a negative exponential schedule. More importantly, it has an analytical advantage because the solution of the model requires analytical integration of the comparative advantage schedule over sub-intervals. In the absence of empirical evidence, the best we can (and will) do is to explore the sensitivity of our results to different parameterizations of this schedule.

We assume that $a^*(z) = 1$ for all z and that the z are ranked from the highest to the lowest relative productivity for Home ($A'(z) < 0$), so that the Home country has a comparative advantage for low end z's and the foreign country for high end z's. We also assume that the comparative advantage schedule is linear and continuous, with a kink at $z = kink$, with $A(z) = \tilde{T} - \tilde{U}z$ for $z \in [0, kink]$, $A(z) = \tilde{V} - \tilde{W}z$ for $z \in [kink, 1]$, and $A(z = kink) = x$, the average home productivity level (see Figure 6). In our base case $kink = \alpha$ (the country's size), $x^* = 1$ and $x = 0.5$, meaning for a good where $a(z) = 1$, the producer in the Home country is half as productive as his counterpart in the Foreign country. The intercept at $z = 0$ is set to $x * \tilde{T} = 1.25$, i.e. the maximum relative productivity for the Home country is 125 percent of Foreign productivity. The intercept at $z = 1$ is set to $x * (1/\tilde{T}) = 0.2$.

Figure 6, which shows $A(z)$ as the solid line at the center of the shaded area, illustrates the determination of the world trade pattern. This pattern depends on the relative prices of Foreign and Home produced goods. A Home firm will produce a given variety only if its price $P_t(z)$ does not exceed the price $(S_t P_t^*(z))/(1 - \tau)$ that an importer of the same variety is able to charge given his marginal cost and trade costs. Given the declining relative productivity pattern in Home there will therefore be a maximum level of z above which Home will rely entirely on imports instead of producing at home. We denote this time-varying level by z_t^h. Equally, there is a minimum z, denoted z_t^l, below which Foreign will rely on imports from Home. We can combine these two conditions on prices with the marginal cost conditions for Home and Foreign producers (23). These include m_t^v and $m_t^{v^*}$, the marginal factor costs (labor, capital and fixed factors), which are equalized across all varieties in each country. We have

$$\frac{m_t^v}{m_t^{v^*} s_t} \leqq \frac{x_t a(z_t)}{x_t^*} \frac{1}{(1-\tau)} \text{ for } z_t \in [0, z_t^h], \tag{24}$$

with equality at $z_t = z_t^h$, and

$$\frac{m_t^v}{m_t^{v^*} s_t} \geqq \frac{x_t a(z_t)}{x_t^*} (1-\tau_t) \text{ for } z_t \in [z_t^l, 1], \tag{25}$$

with equality at $z_t = z_t^l$. The first expression says that a Home producer's marginal cost $(m_t^v/(x_t a(z)))$ has to be below its Foreign competitor's marginal cost $((m_t^v s_t)/x_t^*)$ to be competitive, but allowing for the fact that a potential Foreign competitor's cost also includes the trading cost hurdle. The second condition expresses the same requirement for the Foreign producer, whose comparative advantage schedule is given by $x_t^*/(x_t a(z))$. In Figure 6, the condition (24) for domestic production to be viable is represented by the upper boundary of the shaded region and the condition (25) for foreign production to be viable by the lower boundary. The solid horizontal line is the relative factor cost, whose intersection with the boundaries of the shaded region determine z_t^l and z_t^h. We define $\delta_t = z_t^h - z_t^l$. The resulting trade pattern is illustrated in Figure 7.

The parametric form of the $A(z)$ schedule is rich enough to allow for the analysis of a variety of different technology shocks. For example, an increase in $\tilde{T}$ or an increase in $kink$ represents a positive productivity shock biased towards a country's export goods, while an increase in x represents a positive productivity shock to all goods. As we will show, the welfare and trade effects of a reduction in trading costs depend crucially on the shape of $A(z)$. For a flat schedule, parameterized as a low $\tilde{T}$, the expansion in trade is very large, but the gains from the extra trade are quite limited because the foreign country does not enjoy a strong productivity advantage. For a steep schedule, while trade may expand by much less, the welfare effects in terms of increased consumption and leisure will generally be higher.

It remains to determine marginal factor cost from the producer's cost minimization problem. Let $u_t(z) = l_t(z)^\gamma k_t(z)^{1-\gamma}$, and define $L_{t,H} = \int_0^{z_t^l} l_t(z)dz$, $L_{t,N} = \int_{z_t^h}^{z_t^h} l_t(z)dz$, and similarly for $K_{t,H}$, $K_{t,N}$, $U_{t,H}$, $U_{t,N}$, $G_{t,H}$, and $G_{t,N}$. Also:[18]

$$Y_{t,H} = \int_0^{z_t^l} \frac{P_t(z)}{P_t} y_{t,H}(z) dz \quad , \quad Y_{t,N} = \int_{z_t^l}^{z_t^h} \frac{P_t(z)}{P_t} y_{t,N}(z) dz \quad .$$

Then cost minimization implies the following set of conditions for Home (and an equivalent set of conditions for Foreign):

$$m_t^u = \frac{(w_t)^\gamma \left(r_t^k\right)^{1-\gamma}}{\gamma^\gamma (1-\gamma)^{(1-\gamma)}} \quad , \tag{26}$$

$$m_t^v = \left[\xi_v \left(m_t^u\right)^{1-\theta_v} + (1-\xi_v)\left(r_t^g\right)^{1-\theta_v}\right]^{\frac{1}{1-\theta_v}} \quad , \tag{27}$$

$$w_t L_{t,j} = \gamma m_t^u U_{t,j} \quad , \quad j = H, N. \tag{28}$$

$$r_t^k K_{t,j} = (1-\gamma) m_t^u U_{t,j} \quad , \quad j = H, N. \tag{29}$$

$$G_{t,j} = U_{t,j} \frac{1-\xi_v}{\xi_v} \left(\frac{m_t^u}{r_t^g}\right)^{\theta_v} \quad , \quad j = H, N. \tag{30}$$

$$\left[1 + \frac{1-\xi_v}{\xi_v} \left(\frac{m_t^u}{r_t^g}\right)^{\theta_v - 1}\right] m_t^u U_{t,j} = Y_{t,j} \quad , \quad j = H, N. \tag{31}$$

3.3.2 Finished Intermediates

The producer of finished intermediates $D_t^{\mathrm{Pr}od}$ is a price-taker in both his input and his output markets, with his (flexible) output price given by M_t^D. He uses inputs of export goods $D_{t,H}$,[19] nontraded goods $D_{t,N}$ and import goods $D_{t,F}$, with the following CES production

[18] This definition of sectoral real outputs in terms of the overall intermediates price level is a useful analytical "trick" to facilitate aggregation, see below.

[19] These are goods in the varieties range $z \in [0, z_t^l)$ that are both exported and used at home.

function:

$$D_t^{\Pr od} = \left[\int_0^1 y_t(z)^{\frac{\theta_d-1}{\theta_d}} dz\right]^{\frac{\theta_d}{\theta_d-1}} \tag{32}$$
$$= \left[\left(z_t^l\right)^{\frac{1}{\theta_d}} \left(D_{t,H}\right)^{\frac{\theta_d-1}{\theta_d}} + \left(\delta_t\right)^{\frac{1}{\theta_d}} \left(D_{t,N}\right)^{\frac{\theta_d-1}{\theta_d}} + \left(1-z_t^h\right)^{\frac{1}{\theta_d}} \left(D_{t,F}\right)^{\frac{\theta_d-1}{\theta_d}}\right]^{\frac{\theta_d}{\theta_d-1}} .$$

The sub-baskets of intermediate goods are given by

$$D_{t,H} = \left[\left(\frac{1}{z_t^l}\right)^{\frac{1}{\theta_d}} \int_0^{z_t^l} \left(y_t^h(z)\right)^{\frac{\theta_d-1}{\theta_d}} dz\right]^{\frac{\theta_d}{\theta_d-1}} , \tag{33}$$
$$D_{t,N} = \left[\left(\frac{1}{\delta_t}\right)^{\frac{1}{\theta_d}} \int_{z_t^l}^{z_t^h} \left(y_t^n(z)\right)^{\frac{\theta_d-1}{\theta_d}} dz\right]^{\frac{\theta_d}{\theta_d-1}} ,$$
$$D_{t,F} = \left[\left(\frac{1}{1-z_t^h}\right)^{\frac{1}{\theta_d}} \int_{z_t^h}^{1} \left(y_t^f(z)\right)^{\frac{\theta_d-1}{\theta_d}} dz\right]^{\frac{\theta_d}{\theta_d-1}} ,$$

where the price sub-indices for each of these baskets can be shown to be

$$P_{t,H} = \left[\frac{1}{z_t^l} \int_0^{z_t^l} P_t(z)^{1-\theta_d} dz\right]^{\frac{1}{1-\theta_d}} , \tag{34}$$
$$P_{t,N} = \left[\frac{1}{\delta_t} \int_{z_t^l}^{z_t^h} P_t(z)^{1-\theta_d} dz\right]^{\frac{1}{1-\theta_d}} ,$$
$$P_{t,F} = \left[\frac{1}{1-z_t^h} \int_{z_t^h}^{1} P_t(z)^{1-\theta_d} dz\right]^{\frac{1}{1-\theta_d}} .$$

Using our results on the pricing of individual varieties, and dividing through by the numeraire price level, we can rewrite these price indices in terms of aggregate variables as

$$p_{t,H} = \frac{m_t^v}{x_t a_{t,H}} , \tag{35}$$
$$p_{t,N} = \frac{m_t^v}{x_t a_{t,N}} ,$$
$$p_{t,F} = p_{t,F}^* \frac{s_t}{1-\tau_t} ,$$

and similarly for Foreign. Here we have used definitions of sectoral productivities derived through analytical integration over the appropriate sub-intervals of goods varieties. Assuming[20] that $kink = \alpha$, and that $z_t^l < \alpha < z_t^h$, these are given by

$$a_{t,H} = \left[\frac{\tilde{T}^{\theta_d} - \left(\tilde{T} - \tilde{U} z_t^l \right)^{\theta_d}}{\theta_d \tilde{U} z_t^l} \right]^{\frac{1}{\theta_d - 1}} , \tag{36}$$

$$a_{t,N} = \left[\frac{\left(\tilde{T} - \tilde{U} z_t^l \right)^{\theta_d} - \left(\tilde{T} - \tilde{U} \alpha \right)^{\theta_d}}{\theta_d \tilde{U} \delta_t} + \frac{1 - \left(\tilde{V} - \tilde{W} z_t^h \right)^{\theta_d}}{\theta_d \tilde{W} \delta_t} \right]^{\frac{1}{\theta_d - 1}} .$$

Producers of the finished intermediate good $D_t^{\Pr od}$ face a cost of adjusting the individual sub-components $D_{t,H}$, $D_{t,N}$ and $D_{t,F}$. In the present version of the model this cost is simply a quadratic adjustment cost, but future versions will also include delivery time-lags. Let the nominal discount factor be $I_t^{DF} = 1$ for $t = 0$ and $I_t^{DF} = \Pi_{j=0}^{t-1}(1/i_j)$ for $t \geqq 1$. Then producers solve the following problem:

$$Max\ E_0 \sum_{t=0}^{\infty} I_t^{DF} \left\{ M_t^D \left[\left(z_t^l \right)^{\frac{1}{\theta_d}} \left(D_{t,H} \right)^{\frac{\theta_d - 1}{\theta_d}} + \left(\delta_t \right)^{\frac{1}{\theta_d}} \left(D_{t,N} \right)^{\frac{\theta_d - 1}{\theta_d}} \right. \right. \tag{37}$$

$$\left. \left. + (1 - z_t^h)^{\frac{1}{\theta_d}} \left(D_{t,F} \right)^{\frac{\theta_d - 1}{\theta_d}} \right]^{\frac{\theta_d}{\theta_d - 1}} - \sum_{j=H,N,F} P_{t,j} \left[D_{t,j} + \frac{\phi^d}{2} \frac{\left(D_{t,j} - D_{t-1,j} \right)^2}{D_{t-1,j}} \right] \right\} .$$

The solution to this problem for $D_{t,H}$ is

$$m_t^D \left(z_t^l \right)^{\frac{1}{\theta_d}} \left(\frac{D_t^{\Pr od}}{D_{t,H}} \right)^{\frac{1}{\theta_d}} = p_{t,H} \left(1 + \phi_H^d \left(\frac{D_{t,H} - D_{t-1,H}}{D_{t-1,H}} \right) \right) \tag{38}$$

$$- \frac{\pi_{t+1}}{i_t} p_{t+1,H} \left(\frac{\phi_H^d}{2} \left(\frac{D_{t+1,H} - D_{t,H}}{D_{t,H}} \right)^2 + \phi_H^d \left(\frac{D_{t+1,H} - D_{t,H}}{D_{t,H}} \right) \right) ,$$

and similarly for $D_{t,N}$ and $D_{t,F}$.. The homogenous final output is sold by the finished intermediates producer to a continuum of distributors.

[20] This is of course verified in the course of numerical simulations.

3.3.3 Distributed Intermediates

Intermediates distributors are price takers in their input market, taking M_t^D as given, and monopolistic competitors in their output market, selling at the numeraire price level P_t to producers of output Ω_t. The latter demand a composite of distributed varieties with elasticity of substitution θ_d^D:

$$D_t = \left[\int_0^1 D_t^{\Pr od}(k)^{\frac{\theta_d^D - 1}{\theta_d^D}} dz \right]^{\frac{\theta_d^D}{\theta_d^D - 1}} .$$

This implies goods demands

$$D_t^{\Pr od}(k) = \left(\frac{P_t(k)}{P_t} \right)^{-\theta_d^D} D_t .$$

Each distributor faces a quadratic adjustment cost of changing the rate of change of his prices. In particular, it is costly to set a firm-specific inflation rate that differs from the observed lagged inflation rate for the entire sector, similar to the specification of wage rigidities above. The optimization problem therefore takes the following form:

$$\underset{P_t(k)}{Max} \left(\frac{P_t(k) - M_t^D}{P_t} \right) \left(\frac{P_t(k)}{P_t} \right)^{-\theta_d^D} D_t - \frac{\Phi^d}{2} \left(\frac{P_t(k)}{P_{t-1}(k)} - \frac{P_{t-1}}{P_{t-2}} \right)^2 \tag{39}$$
$$-E_t \left[\frac{\pi_{t+1}}{i_t} \frac{\Phi^d}{2} \left(\frac{P_{t+1}(k)}{P_t(k)} - \frac{P_t}{P_{t-1}} \right)^2 \right] .$$

All firms face an identical problem and therefore behave identically. In equilibrium we therefore have $P_t(k) = P_t$. The first-order condition for this problem is therefore as follows:

$$D_t \left((1 - \theta_d^D) + \theta_d^D m_t^d \right) = \Phi^d \pi_t (\pi_t - \pi_{t-1}) - \frac{\pi_{t+1}}{i_t} \Phi^d \pi_{t+1} (\pi_{t+1} - \pi_t) . \tag{40}$$

3.4 Output

3.4.1 Finished Output

Producers of finished output are perfectly competitive price takers in both their input markets and their output market. They sell output $\Omega_t^{\Pr od}$ at the price P_t^o to a distribution sector. Producers use inputs of intermediates D_t and of second stage value added $Y_{t,O}$, with the CES production function given by

$$\Omega_t^{\Pr od} = \left(\xi_o^{\frac{1}{\theta_o}} \left(D_t \right)^{\frac{\theta_o - 1}{\theta_o}} + \left(1 - \xi_o \right)^{\frac{1}{\theta_o}} \left(Y_{t,O} \right)^{\frac{\theta_o - 1}{\theta_o}} \right)^{\frac{\theta_o}{\theta_o - 1}} \quad . \tag{41}$$

The production function for second-stage value added $Y_{t,O}$ has the same form as (20), except for the absence of the varieties-index z and of the variety specific productivity term $a(z)$. The conditions (28)-(30) for optimal value added input choices are therefore identical to those for intermediates varieties production, while (31) is replaced by

$$\left[1 + \frac{1 - \xi_v}{\xi_v} \left(\frac{m_t^u}{r_t^g} \right)^{\theta_v - 1} \right] m_t^u U_{t,O} = \frac{m_t^v}{x_t} Y_{t,O} \quad , \quad j = H, N. \tag{42}$$

Cost minimization furthermore implies the following producer price of finished goods

$$m_t^o = \left[\xi_o + (1 - \xi_o) \left(\frac{m_t^v}{x_t} \right)^{1 - \theta_o} \right]^{\frac{1}{1 - \theta_o}} \quad , \tag{43}$$

and the cost-minimizing demands

$$D_t = \xi_o \Omega_t^{\Pr od} \left(m_t^o \right)^{\theta_o} \quad , \tag{44}$$

$$Y_{t,O} = (1 - \xi_o) \Omega_t^{\Pr od} \left(\frac{m_t^o}{(m_t^v / x_t)} \right)^{\theta_o} \quad . \tag{45}$$

3.4.2 Distributed Output

The optimization problem of this sector is identical in nature to (39), with the appropriate change of notation. Specifically,

$$\Omega_t = \left[\int_0^1 \Omega_t^{\Pr od}(k)^{\frac{\theta_o^D - 1}{\theta_o^D}} dz \right]^{\frac{\theta_o^D}{\theta_o^D - 1}} \quad .$$

We therefore obtain the optimality condition

$$\Omega_t \left((1 - \theta_o^D) + \theta_o^D \left(\frac{m_t^o}{p_t^o} \right) \right) = \Phi^o \pi_t^o (\pi_t^o - \pi_{t-1}^o) - \frac{\pi_{t+1}^o}{i_t} \Phi^o \pi_{t+1}^o (\pi_{t+1}^o - \pi_t^o) \quad , \tag{46}$$

where Ω_t is final output sold by the distribution sector and p_t^o/π_t^o are the relative price/inflation rate for that output. Final output is sold either as an investment good, to domestic or foreign households, or as a consumption good, to domestic or foreign producers of consumption goods.

3.5 Consumption Goods

3.5.1 Finished Consumption Goods

Producers of finished consumption goods are perfectly competitive price takers in their input markets and output market. They sell output $C_t^{\Pr od}$ at the price M_t^C to a distribution sector. Producers use inputs of Home final output C_t^H and of Foreign final output C_t^F, at prices $p_t^H = p_t^o$ and $p_t^F = (p_t^{o^*} s_t)/(1-\tau_t)$. Note that imports at this level are assumed to be subject to the same transport costs as imports of intermediates further up the production chain. The overall production function for finished consumption goods is given by

$$C_t^{\Pr od} = \left[(\xi_c)^{\frac{1}{\theta_c}} \left(C_t^H\right)^{\frac{\theta_c - 1}{\theta_c}} + (1-\xi_c)^{\frac{1}{\theta_c}} \left(C_t^F\right)^{\frac{\theta_c - 1}{\theta_c}} \right]^{\frac{\theta_c}{\theta_c - 1}} . \tag{47}$$

Producers of $C_t^{\Pr od}$ face a cost of adjusting the individual sub-components C_t^H and C_t^F. As above, in the present version of the model this cost is simply a quadratic adjustment cost, but future versions will also include delivery time-lags. Then producers solve the following problem:

$$Max\ E_0 \sum_{t=0}^{\infty} I_t^{DF} \left\{ M_t^C \left[(\xi_c)^{\frac{1}{\theta_c}} \left(C_t^H\right)^{\frac{\theta_c - 1}{\theta_c}} + (1-\xi_c)^{\frac{1}{\theta_c}} \left(C_t^F\right)^{\frac{\theta_c - 1}{\theta_c}} \right]^{\frac{\theta_c}{\theta_c - 1}} \right. \tag{48}$$
$$\left. - \sum_{j=H,F} P_t^j \left[C_t^j + \frac{\phi_j^c}{2} \frac{\left(C_t^j - C_{t-1}^j\right)^2}{C_{t-1}^j} \right] \right\} .$$

The solution to this problem for C_t^H is

$$\begin{aligned} m_t^C (\xi_c)^{\frac{1}{\theta_c}} \left(\frac{C_t^{\Pr od}}{C_t^H} \right)^{\frac{1}{\theta_c}} &= p_t^H \left(1 + \phi_H^c \left(\frac{C_t^H - C_{t-1}^H}{C_{t-1}^H} \right) \right) \\ &\quad - \frac{\pi_{t+1}}{i_t} p_{t+1}^H \left(\frac{\phi_H^c}{2} \left(\frac{C_{t+1}^H - C_t^H}{C_t^H} \right)^2 + \phi_H^c \left(\frac{C_{t+1}^H - C_t^H}{C_t^H} \right) \right) , \end{aligned} \tag{49}$$

and similarly for C_t^F. The homogenous final output is sold by the finished intermediates producer to a continuum of distributors.

3.5.2 Distributed Consumption Goods

The optimization problem of this sector is identical in nature to (39), again with the appropriate change of notation. Specifically,

$$C_t = \left[\int_0^1 C_t^{\Pr od}(k)^{\frac{\theta_c^D - 1}{\theta_c^D}} dz \right]^{\frac{\theta_c^D}{\theta_c^D - 1}} .$$

We therefore obtain the optimality condition

$$C_t \left((1 - \theta_c^D) + \theta_c^D \left(\frac{m_t^c}{p_t^c} \right) \right) = \Phi^c \pi_t^c (\pi_t^c - \pi_{t-1}^c) - \frac{\pi_{t+1}^c}{i_t} \Phi^c \pi_{t+1}^c (\pi_{t+1}^c - \pi_t^c) \ , \tag{50}$$

where C_t is final output sold by the distribution sector and p_t^c/π_t^c are the relative price/inflation rate for that output.

3.6 Government

Fiscal policy in both countries is monetary dominant in that fiscal lump-sum transfers are endogenous to the implications of monetary policy choices. Monetary policy is characterized by interest rate feedback rules. For the analysis we employ a simple inflation-forecast-based (IFB) rule where the short-term interest rate (i_t) depends on its own lag, as well as a 3-quarter-ahead model-consistent forecast of year-on-year inflation,

$$\log(i_t) = \lambda_i \log(i_{t-1}) + (1 - \lambda_i) \log(\pi 4_{w,t+3}/\beta) + \lambda_\pi \log(\pi 4_{w,t+3}/\overline{\pi}) + u_t^i, \tag{51}$$

where $\pi 4_{w,t}$ is a weighted sum of the rate of change in consumer prices and the price of domestic output, $\overline{\pi}$ is a fixed long-term inflation objective, and u_t^i is stochastic disturbance term. Relative to other IFB rules used in the literature, the only novel feature of this form of the rule is that it allows for the possibility that interest rates respond to expected movements in headline CPI inflation (π_t^c) in addition to a measure of domestic inflation (π_t^o):

$$\log(\pi 4_{w,t}) = w_c \log(\pi_t^c \pi_{t-1}^c \pi_{t-2}^c \pi_{t-3}^c)/4 + (1 - w_c) \log(\pi_t^o \pi_{t-1}^o \pi_{t-2}^o \pi_{t-3}^o)/4 \tag{52}$$

These types of rules have been employed extensively in central bank models to characterize monetary policy because interest rates settings are typically based on forecasts of measures of underlying inflationary pressures.[21] They can be augmented with a measure of the output gap, but for simplicity, we ignore that in this paper.

3.7 Market Clearing Conditions and the Current Account

The following relationships hold between intermediate varieties sectoral output levels Y and finished intermediates sectoral input levels D (always with corresponding relationships for Foreign):

$$Y_{t,H} = p_{t,H} D_{t,H} + p^*_{t,H} D^*_{t,H} s_t \quad , \tag{53}$$

$$Y_{t,N} = p_{t,N} D_{t,N} \quad . \tag{54}$$

Factor market clearing conditions are:

$$\alpha L_t = L_{t,H} + L_{t,N} + L_{t,O} \quad , \tag{55}$$

$$\alpha K_t = K_{t,H} + K_{t,N} + K_{t,O} \quad , \tag{56}$$

$$\alpha G = G_{t,H} + G_{t,N} + G_{t,O} \quad . \tag{57}$$

And the output market clearing condition is:

$$\Omega_t = \alpha (C^H_t + J^H_t) + (1-\alpha) \frac{(C^{H^*}_t + J^{H^*}_t)}{(1-\tau_t)} \quad . \tag{58}$$

[21] Because IFB rules provide a reasonable summary of the entire dynamics in a forecast, they are usually found to be more robust than Taylor rules, which respond to "observed" measures of year-on-year inflation and the output gap—see Levin, Wieland and Williams (2001). This will be the case in models with richer sources of dynamics that are difficult to summarize adequately in the current "observed" values of some measure of inflation and the output gap. IFB rules have been used extensively by many central banks with either explicit and implicit inflation-targeting frameworks and have been relied upon in some cases for well over a decade—see Laxton, Rose and Tetlow (1993).

After consolidating the budget constraints of domestic households and their government, and taking account of transfers, we obtain the following aggregate flow resource constraint of Home vis-a-vis Foreign:

$$\alpha f_{t-1}\frac{i^*_{t-1}\varepsilon_t}{\pi_t}+p^*_{t,H}D^*_{t,H}s_t+(1-\alpha)s_t p^{H^*}_t(C^{H^*}_t+J^{H^*}_t)=\alpha f_t+p_{t,F}D_{t,F}+\alpha p^F_t(C^F_t+J^F_t) \quad (59)$$

Then the bond market clearing condition is given by:

$$\alpha f_t+(1-\alpha)f^*_t s_t=0 \ . \quad (60)$$

4 Calibration

The model's parameters have been calibrated to be consistent with those employed in the literature. We assume that the size of the accession candidates (Home country) represents only 5 percent of that of the euro area (Foreign country). As a result, the accession countries create few spillovers for the euro area.

4.1 Base-Case Parameter Values

Table 1 reports on a number of fundamental parameters which are assumed to be the same across the two countries. Consumers discount the future at the rate of 1 percent per quarter (4 percent per year) ($\beta=0.99$), while firm's capital depreciates by 2.5 percent (10 percent) over the same time frame ($\Delta=0.025$).

The intertemporal elasticity of substitution (σ) and the degree of habit persistence (ν) are 0.83 and 0.72, respectively. These estimates are taken from a study by Juillard and others (2004), although they are somewhat higher than those estimated for the euro area by Smets and Wouters (2002b). These coefficients, together with adjustment costs on the components of consumption expenditures, generate the lagged and hump-shaped responses to interest hikes typically found in empirical models.[22]

[22] Without the adjustment costs, even higher parameter estimates may be needed. For example, Bayoumi, Laxton and Pesenti (2004) show that estimates as high as 5.0 and 0.97 are required for σ

Given the paucity of evidence on mark-ups in the accession countries, elasticities of substitution (EOS) across firms and workers are set at 5, a typical value used for industrial countries, which implies markups of 25 percent for labor and for distribution sectors.[23] In the analysis we also consider cases where these elasticities are higher and lower, and are asymmetric across to the two economies. The EOS between imported and domestically produced capital (θ_k) is set at one in the baseline, implying fixed nominal shares are spent on these goods, and we consider alternative cases where it is both higher ($\theta_k = 1.50$) and lower ($\theta_k = .50$). The EOS between capital and labor is one, the EOS between capital/labor and land (θ_v) is 0.50 in the baseline, and we again examined alternative cases where it is both higher ($\theta_v = 1$) and lower ($\theta_v = .25$).

There is little reliable evidence about the magnitude of wage and price rigidities in the accession countries, but they are generally assumed to be smaller than in the euro area. For our base-case, coefficients defining wage and price stickiness parameters have all been set to 400 in the accession countries, half of the value in the euro area. These values were chosen to produce plausible impulse responses for interest rate shocks.

Turning to time-to-build lags, following Murchison, Rennison and Zhu (2004), we assume that it takes one quarter to plan an investment project and 5 quarters to complete it.[24] In addition, we set the adjustment cost parameters that govern investment dynamics to be consistent with the hump-shaped pattern seen in response to interest rate cuts that peak at around 4-6 quarters and, in the case of accession countries, the relatively long-lived nature of

and ν to generate the hump-shaped responses to interest rate shocks that can be found in the ECB's Area-Wide Model (AWM) of the monetary transmission mechanism—see Fagan, Henry and Mestre (2001).

[23] In reviewing existing empirical work on markups for the euro area, Bayoumi, Laxton and Pesenti (2004) employ a price markup of 35 percent and a wage markup of 30 percent. They argue that these are significantly higher than price and wage markups in the United States, which they argue are closer to 23 percent and 16 percent, respectively.

[24] Time-to-build dynamics are becoming an important feature of the new generation of macro models that are being designed inside central banks. For example, the work by Murchison, Rennison and Zhu (2004) at the Bank of Canada builds on earlier work at the Fed by Edge (2000a, 2000b). For more information on the importance of time-to-build dynamics for the internal propagation mechanism of DSGE models, see Casares (2004). In particular, Casares (2004) provides a very useful study showing the effects on macroeconomic dynamics of adding time-to-build lags that range between 1 and 8 quarters.

the recent boost to the investment to GDP ratio. To reflect the greater difficulties of building and maintaining international supplier relationships, we set the adjustment parameter on imported capital goods to be twice as high as on domestically produced capital goods. We have imposed adjustment costs on imports of intermediate inputs and consumption goods in a similar manner. The model therefore generates moderate changes in trade volumes in response to short run real exchange rate fluctuations but large changes in response to permanent shocks, as has been observed in the transition economies—see Erceg, Guerrieri, and Gust (2003) and Laxton and Pesenti (2003).

Finally, we set the parameters that determine the endogenous risk premium on bonds to ensure that changes in the risk premium are sufficient to prevent implausibly large current account deficits.

4.2 Determinants of Per Capita Income and Trade Flows

As discussed in Section 2, there have been major changes in the transition countries over the last decade. This section describes the initial steady state that broadly characterizes a typical accession country in the mid-1990s. While these economies have changed significantly subsequently, this provides a relatively neutral equilibrium from which to evaluate the impact of EMU. In the initial equilibrium, per capita consumption (measured at purchasing power parity) in the accession countries is assumed to be just over half of the value in the euro area. We assume that the same proportion of time is allocated to work in both countries, but that total factor productivity in the accession countries is only half that in the euro area.

Turning to trade, we assume the baseline parameterization of relative productivity $\chi A(z)$ reported in Table 2. The interaction of the aggregate term $\chi = x/x^*$ (where the Home country is assumed to be only half as productive as the Foreign country) with the industry-specific term $A(z)$ implies that the accession countries enjoy a 25 percent productivity advantage in their most productive industry (at $z = 0$) while the euro area is five times more productive than the accession countries in its most productive sector (at $z = 1$).

As reported in Table 3, for the accession countries both the import-to-GDP and export-to-GDP ratios are assumed to be 30 percent, with trade in intermediate inputs comprising half of the total and the remainder being allocated equally between final consumption and investment goods, approximately the magnitude and composition of trade flows for the Czech Republic in the mid-1990s.[25] The values of trade flows in the euro area reflect the mirror image of these values, and hence they are considerably smaller as a percentage of overall activity as the euro area is assumed to be large relative to the accession group.

Finally, the steady-state value of labor income has been set at 64 percent of nominal GDP in both economies, roughly the share of labor income in the euro area. With no government sector, the savings rate was set at 30 percent, approximately the average value in the euro area after excluding government output from nominal income.

4.3 Responses to Monetary-Induced Interest Rate Increases

To illustrate the dynamic properties of the model, Figure 8 reports results for a 1/2percentage point increase in euro area interest rates on the domestic economy. This allows us to compare the model's response with existing models of the euro area. In our model, real GDP and CPI inflation decline and reach troughs of about one quarter percent below baseline after 3-4 quarters and one third percentage points below baseline after 4 quarters, respectively, while the real exchange rate appreciates by slightly over 1 percent on impact. Consumption and investment responses are hump-shaped, reflecting habit persistence, time-to-build, and costs of adjustment. Reassuringly, these results are relatively similar to those from the ECB's Area Wide Model (AWM), although the monetary transmission mechanism is somewhat faster and inflation responds more in this model than AWM—see Bayoumi, Laxton and Pesenti (2004) for a discussion of AWM dynamics in response to interest rate

[25] These values were obtained by appropriate coefficient restrictions on final consumption and investment demands as well as trade costs. The implied restriction for trade costs is consistent with some empirical estimates that suggest they represent about one third of the value of goods.

hikes. Results from the same experiment for the accession countries are reported in Figure 9. Output responds more in the open economy because the appreciation in the real exchange rate has a larger impact on net exports in the more open economy. This is consistent with previous work that indicates the monetary transmission mechanism may be faster and stronger in small open economies than in relatively larger and more closed economies like the euro area.

5 Simulation Results

This section reports simulations illustrating the implications of reducing the costs of trade in the model, focusing on the implications for trade, GDP, consumption, and welfare using the parameterization discussed above for the accession countries (Home country) and the euro area (Foreign country). To explore the properties of the model, we report the steady-state results from the base calibration and for a range of alternative assumptions about the technologies and linkages of the accession countries and the Euro area, before examining some dynamic simulations showing the adjustment path to the new equilibrium.

5.1 Long-Run Comparative Statics

The top panel of Figure 10 shows the comparative advantage schedule under the base case parameterization. Trading costs are assumed to be 34 percent of the value of a good. Trade is balanced as, although relatively few goods are produced exclusively by the accession countries, the vast majority of such goods go to the euro area (reflecting its larger economic size). The opposite is true of the much larger number of goods produced exclusively by the euro area. To illustrate the workings of the model, Figure 10 illustrates how the mixture of traded and nontraded goods changes when trading costs are lowered by 10 percentage points. In response, the range of nontraded goods produced by both countries (the distance between z^l and z^h) shrinks, consistent with a large increase in economic integration.

Table 4 reports detailed results for a smaller change in trade costs, namely a one percentage point reduction. It turns out that the effects of reductions in trade costs are approximately linear for small changes in values.[26] This can therefore be used as a "handy reckoner" to calculate the effects of different changes in trade costs. We refer the reader to the middle column of the table, which reports our base case results. Exports and imports rise by 6.2 percent, while openness—calculated as the ratio of exports to GDP—rises by 1.6 percentage points. About two-thirds of the increase in openness comes from higher trade in intermediate goods, both exports and imports, consistent with the empirical observation that economic integration disproportionately favors this component of trade. But in addition, and again consistent with the empirical evidence for relatively poorer countries, about half of the remaining increase in trade results from the accession countries importing more intermediate goods and assembling more final consumption goods for re-export to the euro area. Finally, there is also an increase in bilateral trade in final consumption goods, due to the reduction in trading cost distortions at that level.

This increase in economic integration is associated with large increases in welfare in the accession countries. Real consumption and labor productivity rise by 1.0 and 1.1 percent, respectively, and labor effort drops by 0.15 percent. This is despite the fact that the real exchange rate depreciates modestly, the opposite of a Balassa-Samuelson effect. The gains in trade and welfare are due to the exploitation of comparative advantage. As economic integration increases, goods are increasingly produced in the country with the greatest relative efficiency. The result is a better use of resources, and hence lower prices, and higher real output and productivity. At 1.0 percent the increase in welfare, measured as the Lucas (1987) compensating variation in consumption, reflects increases in both consumption and leisure. Finally, the euro area also benefits through higher consumption and a fall in hours worked, although the effect is relatively small reflecting the relative sizes of the two regions.[27]

[26] This is much less true for large changes, when the nonlinearities intrinsic to the model become significantly more important.

[27] It is important to note that we are not trying to measure the benefits of trade for the existing euro area. Obviously, these would be much larger if we modeled all the trade linkages between

To gain some perspective on these welfare benefits, it is useful to compare them to those from other experiments using similar models. One obvious comparison is between the benefits emanating from lowering trade costs and other structural policies that increase competition by lowering the mark-up on prices and wages by one percent. Strikingly, the increase in welfare in the accession countries from a one-percentage-point reduction in trade costs appears to be of the same magnitude as that from a one-percentage point reduction in the mark-up of euro goods (Bayoumi, Laxton, and Pesenti). Given that the implied price wedges of the two distortions are also similar (both raise the cost of goods by around one-third), this suggests that trade liberalization may be as potent in producing large welfare gains over time as policies to raise domestic competition, at least for small open economies. By contrast, even radical changes to macroeconomic policy rules only rarely exceed welfare gins of the order of 1 percentage point of consumption. As noted by Lucas (2003), the disproportionate gains from better structural policies (in this case lowering trade costs) compared to reducing macroeconomic volatility, comes from the fact that the former permanently increase the level of output and hence welfare, while the latter only reduce undesirable fluctuations due to the curvature of the utility function.

A key parameter in the model is the level of competition in goods and labor markets. The model assumes that several goods markets (the three distribution sectors) and the labor market are imperfectly competitive, with the level of the markup over underlying costs that firms (workers) can extract from exploiting their market power being inversely proportional to the elasticity of substitution across goods or workers. In the base case reported in the middle column of Table 4, this elasticity is set at 5, implying markups of 25 percent, broadly in line with existing estimates (see Bayoumi, Laxton and Pesenti (2004)). Table 4 also reports the results of a 1 percentage point reduction in trading costs for the baseline case (middle column) and for higher and lower levels of competition in both the accession countries and the euro area. A higher level of competition (simulated by raising

the existing euro area and all of its trading partners.

the elasticity of substitution from 5 to 6) increases the boost to trade openness compared to the initial situation by about one-sixth, with roughly proportional reductions if this key elasticity is lowered from 5 to 4.[28] As might be expected, more competitive and nimble economies are better able to exploit the opportunities coming from greater opportunities to trade. Interestingly, however, the opposite pattern is seen in the welfare benefits. In the less competitive economy, even though trade rises by less, the increase in consumption and welfare is about 10 percent larger. This is a manifestation of the theory of second best. While a reduction in trade costs reduces one source of distortion in both economies, lack of competition acts as a separate layer of inefficiency. On the one hand, this reduces the degree to which individual firms are able to exploit new trading opportunities, but on the other it magnifies the benefits from trade in any particular good. For the overall economy, the latter effect dominates, explaining why less competitive economies gain more than their more competitive rivals. It should nevertheless be stressed that in all cases the benefits remain substantial.

These results naturally beg the question of the effects of a reduction in trading costs if one economy is more competitive than the other. To shed light on this question, Table 5 reports the base case (in the middle column) and simulations in which the accession countries are more (less) competitive while the euro area is less (more) so, in the right (left) column. As can be seen, the increase in trade is similar across the three scenarios. However, in comparison to the base case, the macroeconomic benefits for the accession countries are boosted when competition is lower in the accession countries and higher in the euro area, and lower when the opposite is true. Furthermore, a comparison with Table 4 indicates that, for the same level of competition in the accession countries, a more competitive euro area significantly raises the welfare benefits accruing to the accession countries. Again, the intuition is that lack of competition operates as an additional level of inefficiency. While

[28] As with all subsequent simulations, the model is recalibrated so the level of trade is the same as in the base case, hence the results continue to mimic the actual situation faced by accession countries.

producers in the more competitive country are better able to exploit the rise in opportunities to trade, the benefits are largest in the less competitive one as the benefits of switching from inefficiently produced local goods to efficiently created foreign ones is greater. In short, while both countries continue to benefit, reducing trade costs transfers some of these benefits from the more to the less competitive economy.

We next investigate another key aspect of technology, the impact of the slope of the comparative advantage schedule. A flatter (steeper) schedule means that relative productivity is less (more) dispersed across the two countries. This has two effects. Flatter schedules make trade volumes more sensitive to trade costs, but also reduce the gain in efficiency from trade as the gap in productivity between the two countries is smaller. In Table 6 the center column reports the results from the base case, where the maximum relative productivity for the Home country (at $z = 0$) is 125 percent of Foreign productivity. In the left column, that relative productivity is lowered to 100 percent producing a flatter comparative advantage schedule, while in the right panel it is increased to 150 percent. As anticipated, a flatter schedule produces a larger increase in trade as, for a given fall in trade costs, more goods switch from being nontraded to traded. However, the macroeconomic benefits follow the opposite pattern, being larger for a steeper schedule. These results are reminiscent of those coming from changing competition across both countries. While a flatter schedule implies greater opportunities for trade, there are smaller benefits from realizing them. As in the earlier case, the benefits from the former effect are outweighed by the latter, so that the larger increase in trade is associated with smaller macroeconomic benefits.

5.2 Dynamic Simulations

The advantage of combining a microeconomic model of trade with a well-specified macroeconomic model is that it allows examination of both the long-run equilibrium and the dynamic path by which this equilibrium is reached. Accordingly, this section examines some of these dynamic properties.

The solid lines in Figure 11 show the paths of key macroeconomic variables in response to a one percentage point reduction in trade costs phased in over 10 years, using a linearized version of the model.[29] In this and subsequent simulations, the reduction in trade costs due to accession and the introduction of the euro accumulates gradually over time, with the majority of the reductions accruing within the first five years. This reflects the natural lags involved as individuals discover and exploit the opportunities provided by this fundamental change in economic structure, such as adapting outmoded rules and regulations, learning about the requirements involved in exporting and importing for firms that were initially only supplying the domestic market, and building new relationships with clients.

As expected, the real and nominal rigidities in the model produce a relatively smooth increase in trade and consumption over time. One of the striking aspects of the simulations is the amount of time taken to reach the new equilibrium—over 100 quarters (the model is quarterly) or 25 years. The transition has an S-shape, but these shifts in the rate at which the new equilibrium is reached are not large—about one fifth of the increase in trade occurs after 5 years. These lags are obviously dependent on a series of assumptions about adjustment costs, where the latter have been calibrated to mimic the short-term responses of consumption and investment to shocks, thus making this a plausible representation of the actual underlying dynamics.

Details of the transitional response of real variables appear reasonable. Exports and imports slowly build up and openness eventually rises by over six percent. Consumption also responds smoothly and eventually increases by almost 1 percent. This is a result both of habit persistence in preferences and of time-to-build markets technologies in production. The increased consumption demand is accompanied by an initial real appreciation that makes imported intermediate inputs cheaper to use. Demand is therefore initially satisfied through

[29] This experiment has the advantage of displaying the properties of the model very clearly by focusing solely on the effects of one key shock. But this also has limitations because it does not consider other shocks that may be relevant to describe the situation of a typical accession country. A more comprehensive combination of shocks will be considered in Section 6.

increased imports of foreign intermediates giving rise to a trade and current account deficit and a risk premium that crowds out investment in the short run. As the rise in consumption slows, the real exchange rate starts to depreciate, thereby reducing the use of intermediates and improving the trade balance and current account. At that point investment picks up and rises by 0.9 percent in the long run, while the trade balance moves into surplus to pay the costs of higher foreign borrowing.

The dashed line in Figure 12 reports the results of a reduction in trade costs that is anticipated to occur after 5 years. Trade starts to rise significantly in anticipation of the benefits of future integration, and after 5 years this is some two-thirds of the increase in trade compared to the case where costs are cut immediately. This suggests that reductions in trade costs that are well anticipated, as entry into the euro has been, can have effects well before the entry date. That said, the slow adjustment to the new equilibrium implies that significant further benefits accrue over a long period.

6 Policy Implications

There has been an enormous literature on the potential costs and benefits of membership of EMU. However, this work has generally used different methodologies and models to estimate the microeconomic benefits coming from more efficient goods and financial market transactions with a single currency, and the potential macroeconomic costs due to the loss of monetary autonomy. Indeed, a large proportion of the existing literature has focused exclusively on one aspect or the other.

In particular, there is a burgeoning literature on the impact of a currency union on trade. Initial estimates that a common money multiplies trade several-fold (Rose, 2000) have been whittled down over time, but cross-country studies still suggest gains of 30-90 percent (Rose, 2004). Focusing on EMU specifically, a number of studies have also concluded that EMU has increased trade within the euro area by some 10 percent some five-years after its creation (see Micco, Stein, and Ordonez, 2003, and Faruqee, 2004, although a much more skeptical view is contained in Gomes and others, 2004). Turning to the potential macroeconomic costs, these have been studied in the context of the correlation of underlying shocks (Bayoumi and Eichengreen, 1993) or model-based estimates of the losses in macroeconomic flexibility (see IMF, 2003). Even work that has aimed to examine the overall consequences of EMU (such as EU Commission, 1991, or H. M. Treasury, 2003a) have used very different frameworks and approaches to examine these benefits and costs.

This paper has taken a first step at providing a unified framework in which to examine the benefits to trade and costs to macroeconomic flexibility. To do this, we constructed a modern simulation model fusing a microeconomic model of trade with the real and nominal rigidities typical of macroeconomic models used to study monetary issues such as the impact of EMU on macroeconomic volatility. This paper has focused on the dynamic path and long-term benefits from lower trade costs due to EMU membership. Over time, we anticipate using the model to compare the benefits and costs of EMU membership using a single measure, namely the change in welfare of a typical consumer.

Some commentators have expressed skepticism that euro adoption will increase trade by a large amount, suggesting that as these countries are members of the EU free trade area the direct reduction in trade costs associated with monetary union will be small . In our view, this reflects an overly narrow view of the process of economic integration. In addition to lowering the costs of changing money, adopting the euro reduces the risk of abrupt and unpredictable future price changes, uncertainty that may be difficult to hedge when making long-term decisions such as the location of a production plant. The fillip to integration from this greater certainty generates strong forces towards economic integration, such as more uniform commercial law and regulation. As transactions increase, so does the demand for standardized contracts and the like. This can be seen within many currency unions, such as the United States, where, even though commercial law is largely the responsibility of states, relative uniformity exists, lowering costs of trade very significantly. This is much less true of even close economic relationships without a single currency, such as the United States and Canada (McCallum, 1995, argues that underlying trade across Canadian provinces relative to trade between Canadian provinces and U.S. states is many times larger than what would exist without a Canadian-US border).

Our simulations use a two-country version of the model, calibrated to represent the accession countries and the existing euro area. The most striking result is that even relatively modest falls in trade costs across countries can create significant long-term increases in trade. For example, in our base case calibration a 1 percentage point reduction in trading costs increases the trade of accession countries by 6 percent over the long term, and experiments with alternative underlying parameters indicate that this result is relatively robust. The size of this effect helps explain how the introduction of a single currency could generate the large effects on trade estimated in the cross-country empirical literature. The rise in trade in the existing members of EMU due to the inclusion of the accession countries in EMU is, of course, much more limited because the economies of the accession countries as a group are so much smaller than the aggregate of existing euro area members.

Turning to the impact on welfare, the model finds that lower trade costs due to the introduction of the euro also generate large welfare gains. Again focusing on the base case calibration, a one percentage point decrease in trade costs, which as we have seen raises trade by six percent, raises the long-term welfare of accession countries by the equivalent of about one percent of consumption. Hence, if one assumes that trade will rise by around fifty percent in the long run, an estimate broadly consistent with existing empirical estimates, the welfare benefits could be of the order of ten percent (measured in consumption equivalent). The main benefit comes from higher output and consumption, although there is also some decrease in hours worked and hence an increase in leisure. The existing euro area members also benefit, but again these effects are much smaller due to the relative sizes of the two areas.

One of the advantages of including real and nominal rigidities is that the model also provides information about how these gains to trade accumulate over time. Dynamic simulations indicate that trade is boosted quite slowly, with the full increase in trade occurring over a period of many years. Strikingly, we find that around one-fifth of the increase in trade occurs after 5 years. This implies that the estimated increase in trade of around 10 percent in the 5-years since the introduction of the euro would translate into a long-term impact of 50 percent, which, as noted above, is broadly consistent with empirical estimates of the long-term benefits. In addition, dynamic simulations indicate that the prospect of entering EMU in the future produces an anticipatory increase in trade. While this boost is somewhat less rapid than that generated by actual membership, anticipation of future benefits drives much of the increase in trade and welfare observed in the simulations.

The results also suggest that the lower transactions costs at the border generated by EMU lead to a larger increase in trade in intermediate goods than in final goods. This is consistent with the stylized facts on economic integration. The result occurs because the supply of intermediate goods sold to other firms is more price-sensitive than that of more completed products. This breaking-up of the production chain also helps in explaining the large increase in trade relative to GDP, as trade is based on gross output while GDP measures value added.

Putting all of this together, Figure 12 reports the results of a dynamic simulation in which trade costs are reduced by 10 percentage points, creating a short-term rise in trade of a similar magnitude to that seen in euro area members over the last 5 years and a long-term rise in trade of a magnitude similar to those estimated in the existing literature. In addition, it is assumed that the initial capital stock in the accession countries is 20 percent below its equilibrium level, creating a long-lived boost to investment that is financed partly with a current account deficit. This latter assumption can be seen as a rough approximation to the gains coming from financial integration and lower real interest rates. The result is a generalized boom including steady and large increases in trade, consumption and welfare, accompanied by a more rapid boost to investment as the capital stock catches up. This is paid for through foreign borrowing which is repaid in the long-term through a trade surplus.

While we have not examined the potential costs of the loss of monetary independence for EU accession countries and existing euro members in this specific model, results from those with similar macroeconomic frameworks can be used to draw inferences. In particular, existing studies indicate that even radical changes in monetary policy rarely generate welfare costs of more than a percent of consumption, and most estimates are much lower. Given existing results about the long-term impact of a single currency on trade and our estimate of the associated welfare benefits, it seems extremely unlikely that the long-term benefits from higher trade could be offset by macroeconomic losses, particularly as these will probably fall as countries become more integrated (Frankel and Rose, 1993). However, given that the macroeconomic costs of the a single currency occur immediately, while the trade benefits build slowly over time, the issue is less clear-cut in the short term. Hence, there could well be some transition hurdles to be overcome in realizing the long-term benefits.

It is also worth emphasizing that the welfare benefits tend to be larger when the accession countries are assumed to be less economically efficient, even though trade generally increases by less in these circumstances. This is true whether this inefficiency comes from lower domestic competition or more diversity in relative productivity with respect to the euro area. It reflects the fact that lower efficiency implies greater scope for gains in productivity within the country. Hence, even though trade increases by less, domestic economic efficiency rises more. A very different result occurs with respect to the euro area. Greater euro area efficiency boosts both trade and welfare of accession countries, as the latter are better able to exploit the trade opportunities provided by lower trading costs.

This paper represents a first step in analyzing the effects of EMU membership in an integrated, modern macroeconomic model. Clearly, uncertainties exist as to the generality of the results from a single model, reflecting as it does a myriad of specific modeling and parameter choices. Interestingly, our results do not include a trend appreciation of the real exchange rate in accession countries, a prominent stylized fact in their recent experience that might be expected to further increase the welfare benefits to accession countries. This suggests that the appreciation of the real exchange rate may be coming from forces other than higher trade integration, such an closer financial ties.

Even at an early stage, the model is capable of providing a range of important insights into the possible implications of EMU on accession economies. First, the long-run benefits are likely to be large, both in absolute terms and compared to the macroeconomic costs. Second, the benefits from trade are likely to occur gradually, and to involve a greater increase in trade in components than in final products. Given that the potential macroeconomic costs stemming from higher volatility occur immediately, while the benefits from increased integration of trade occur more slowly, the key policy issue would appear to be ensuring that the transition to a single currency occurs relatively smoothly.

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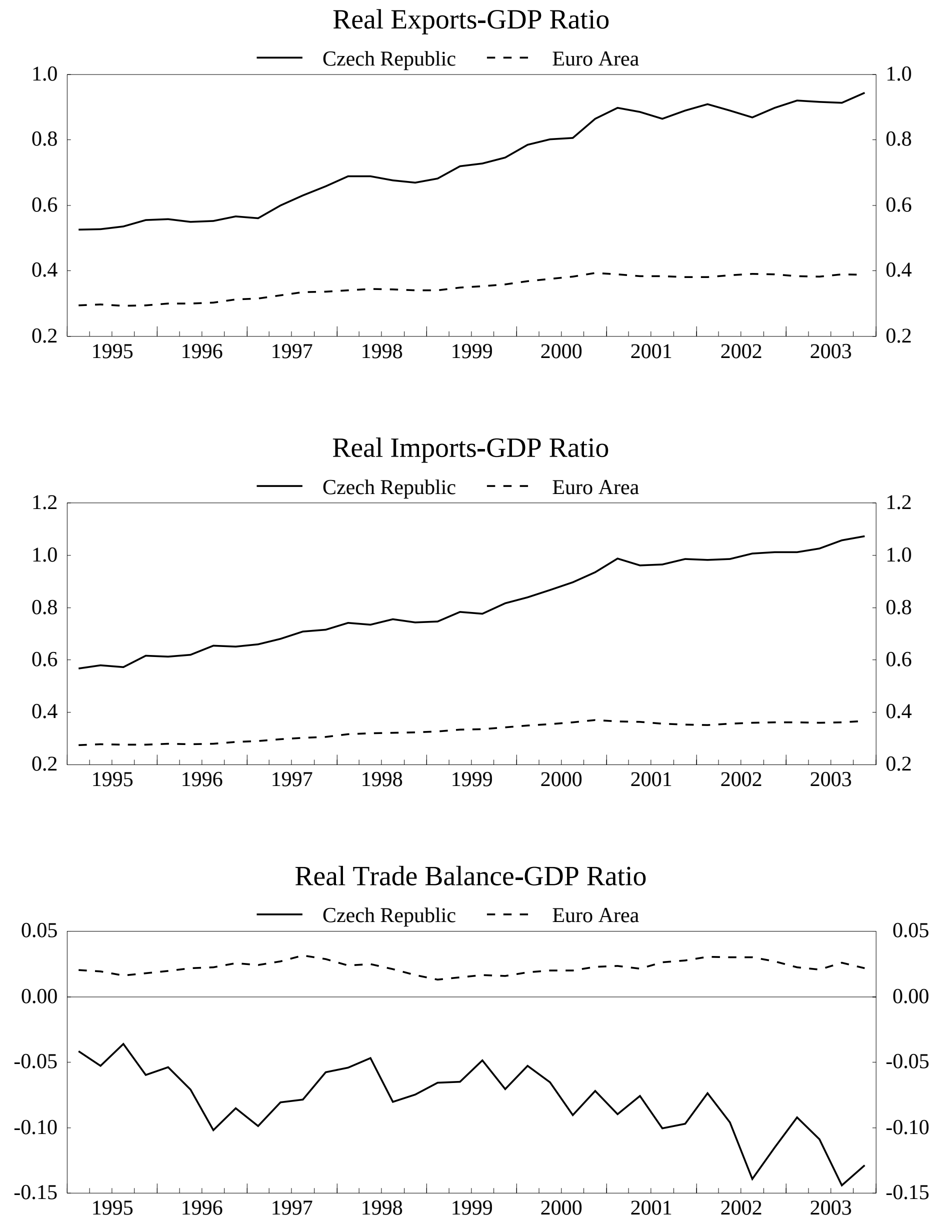
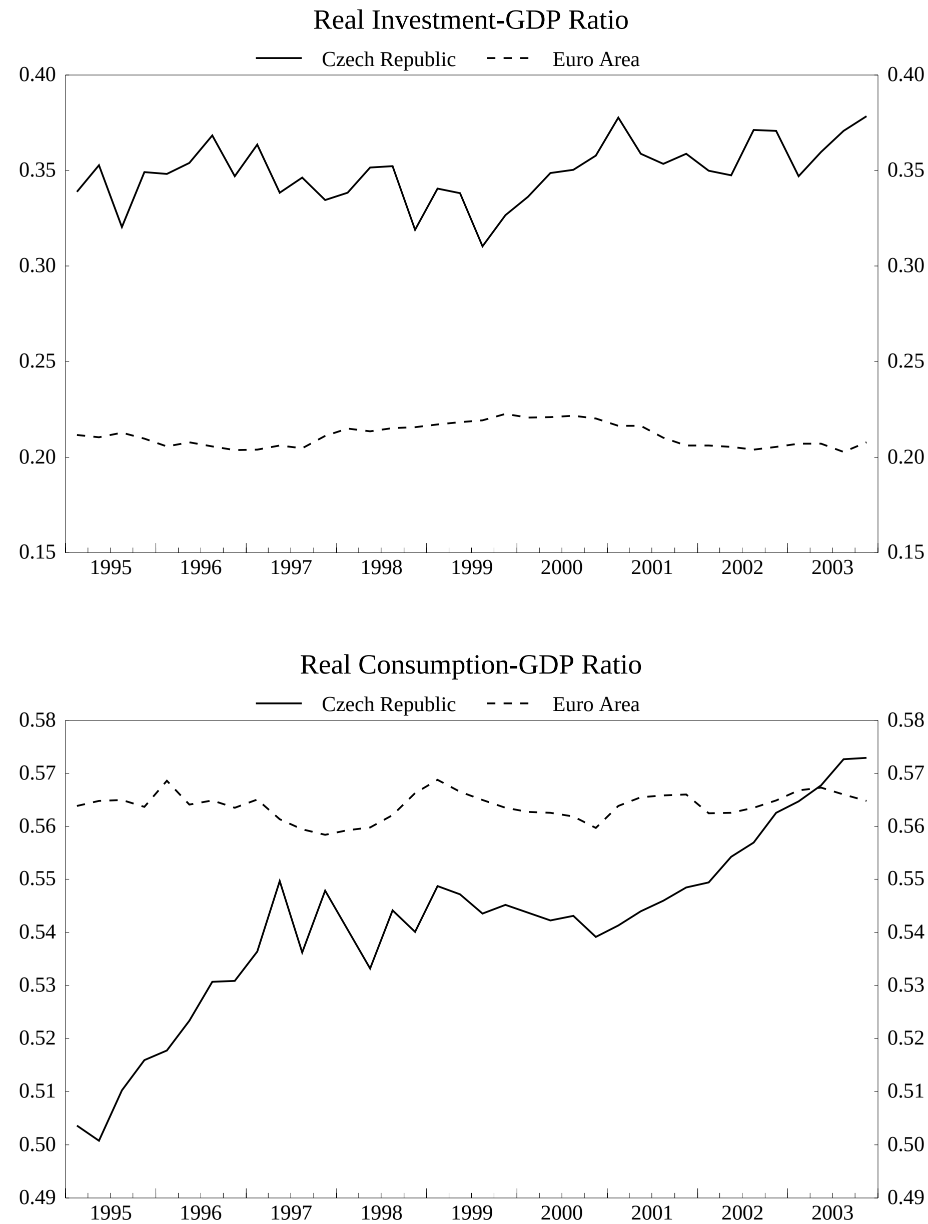
Figure 1: Trade



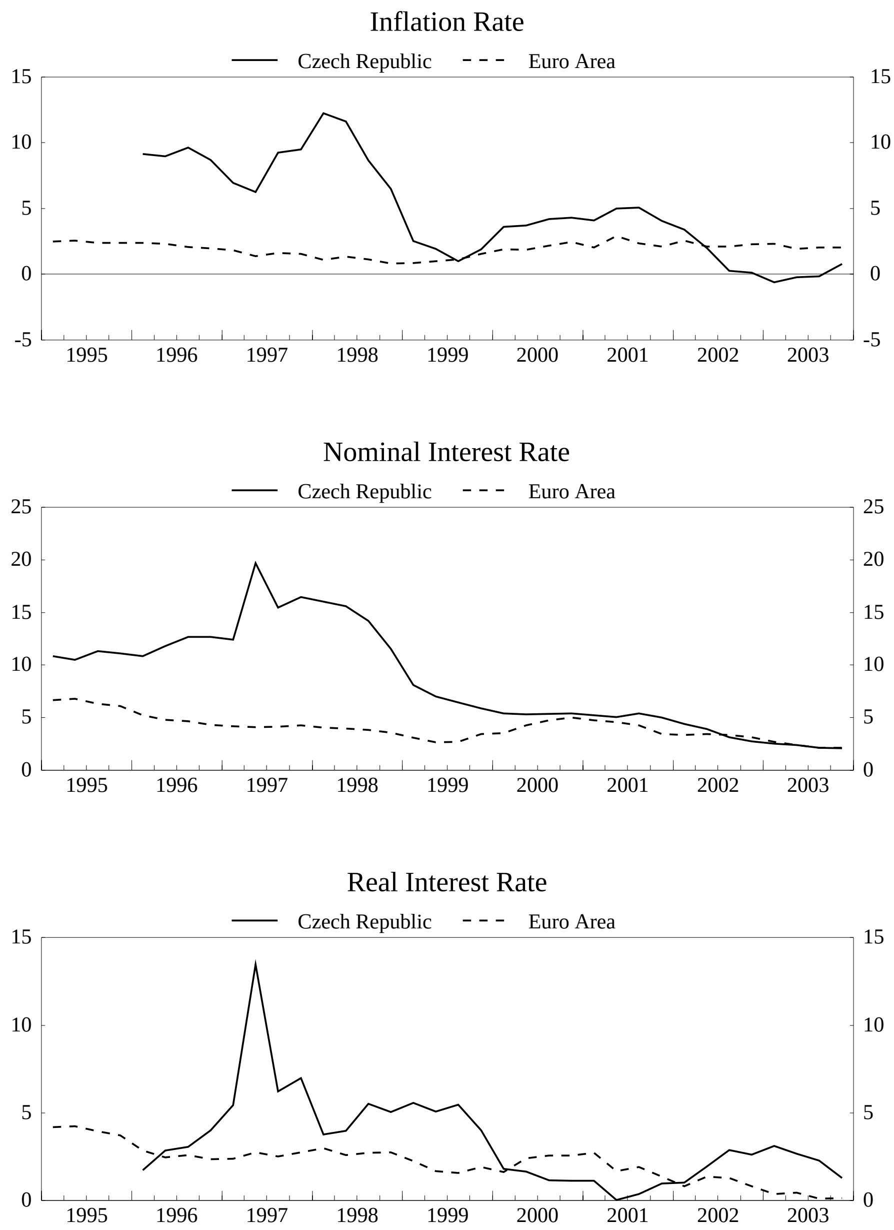
Source: Eurostat

Figure 2: Investment, Consumption and the Trade Balance



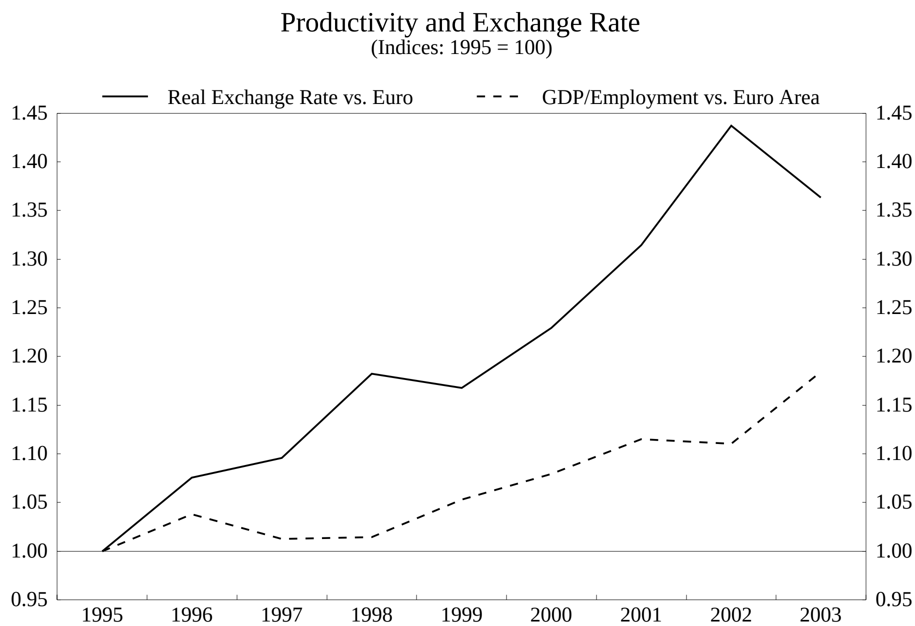
Source: Eurostat

Figure 3: Inflation and Interest Rates



Source: Eurostat

Figure 4: Relative Productivity and Real Exchange Rate



Source: Eurostat

Figure 5: Detailed Structure of Production

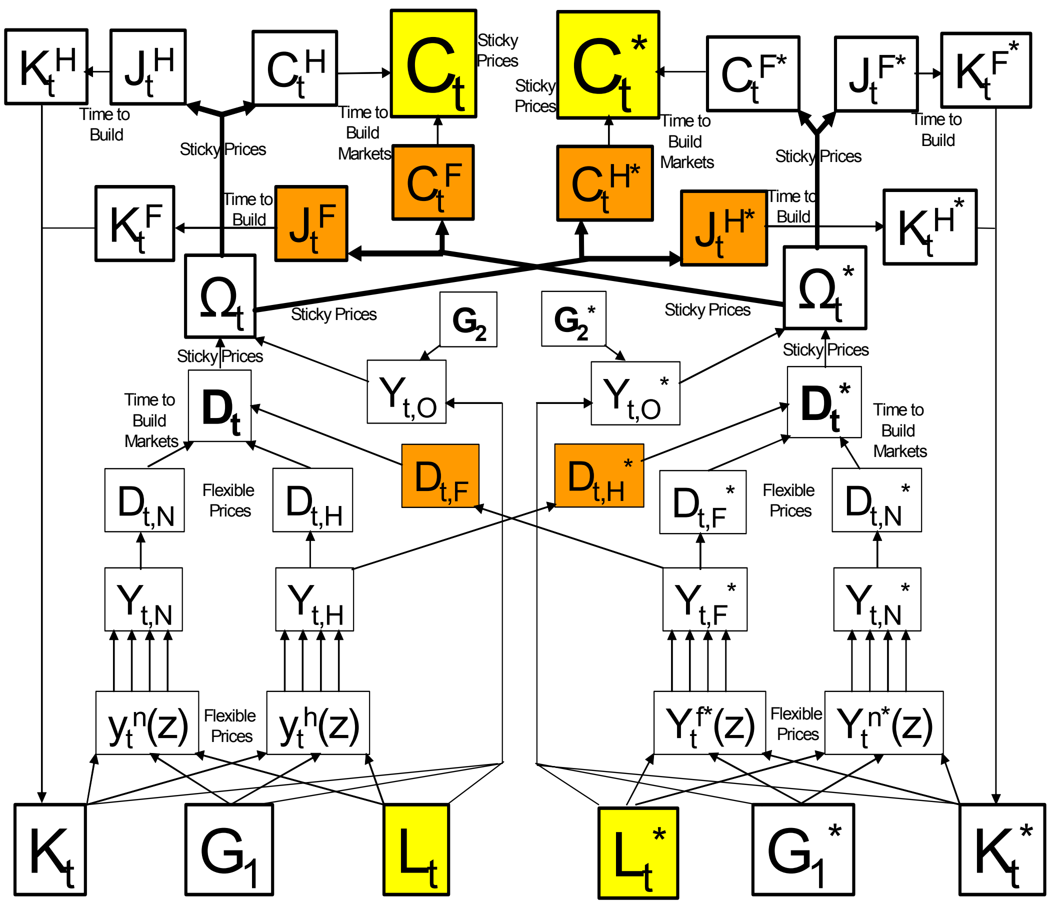


Figure 6: Base-Case Comparative Advantage Schedule

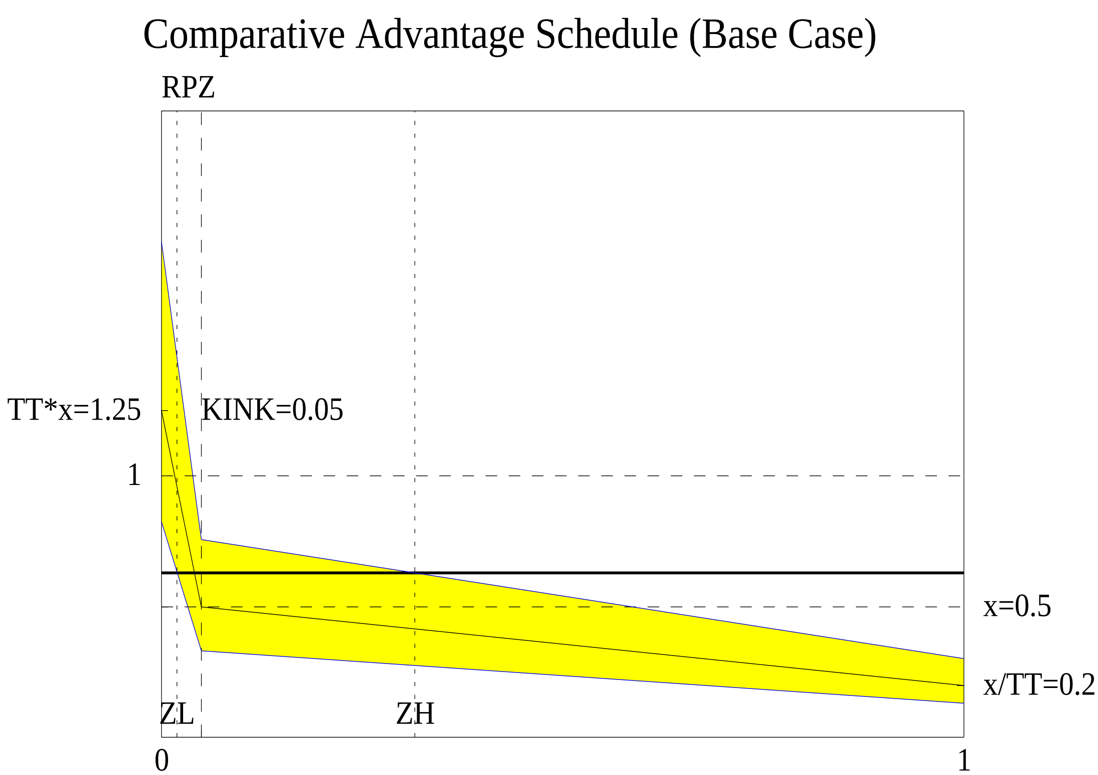


Figure 7: Trade Pattern

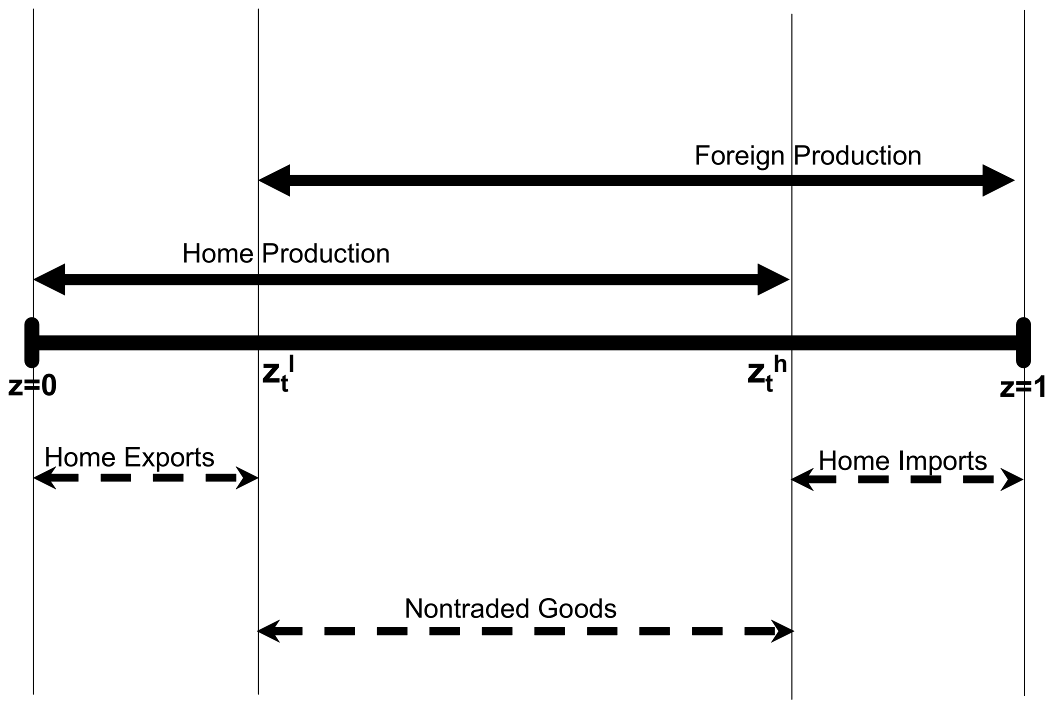


Figure 8: Foreign Responses to a Monetary Induced-Interest Rate Hike in the Foreign Economy

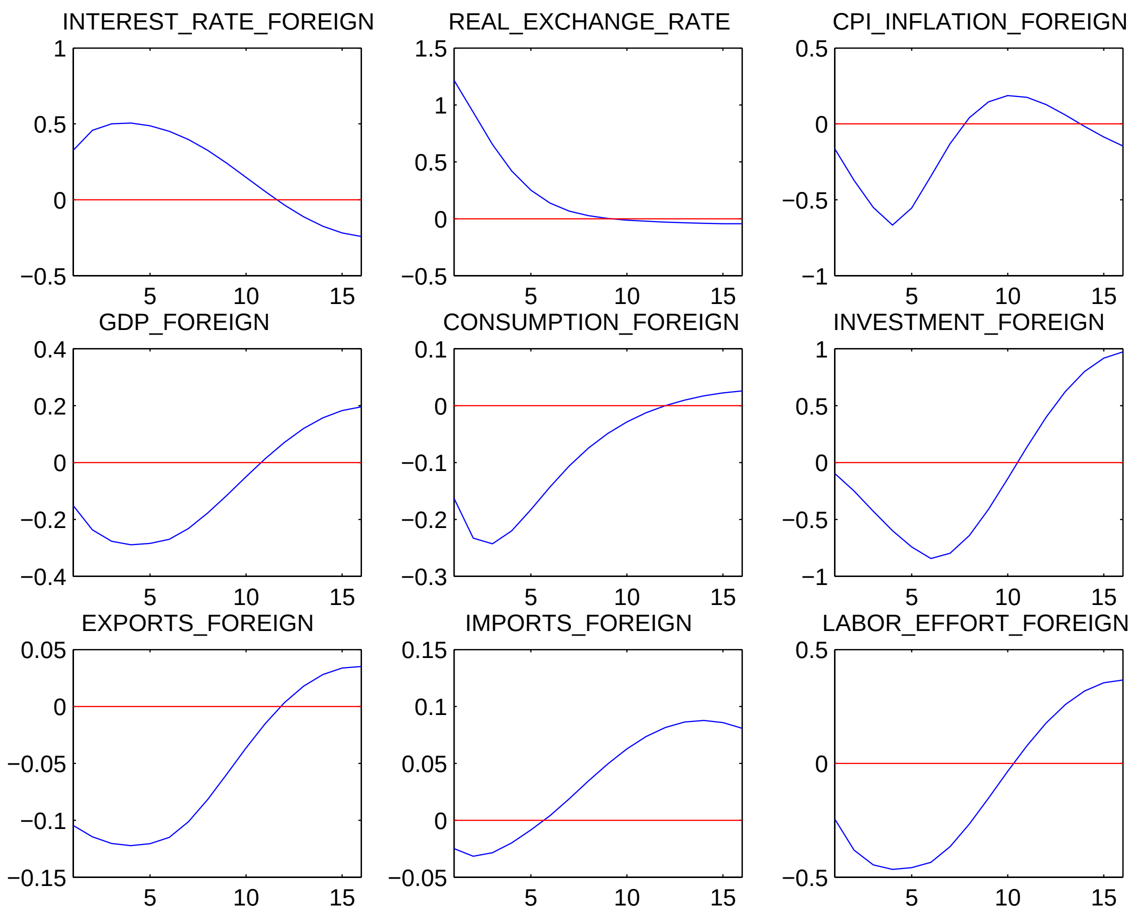


Figure 9: Home Responses to an Interest Rate Hike in the Home Economy

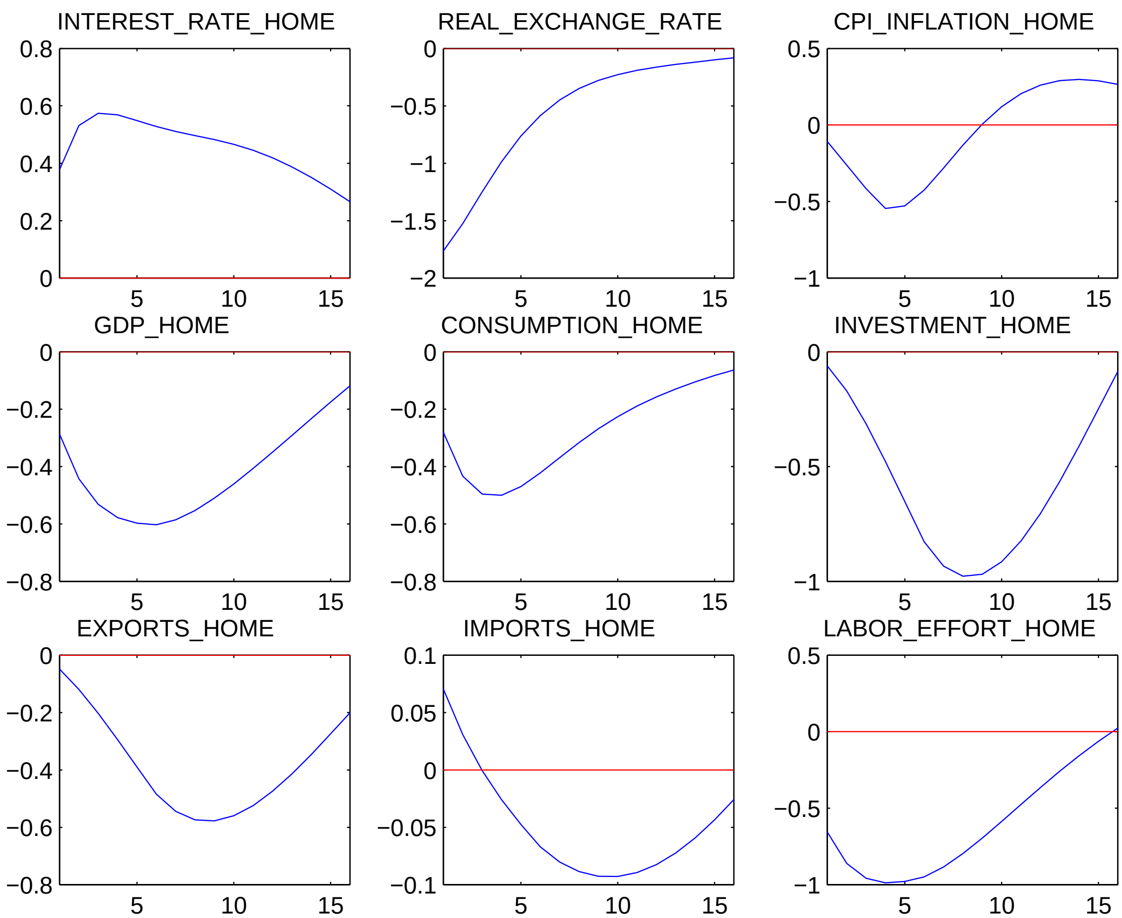
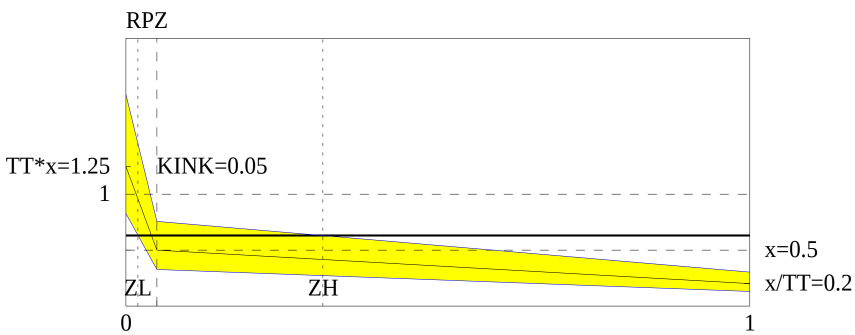
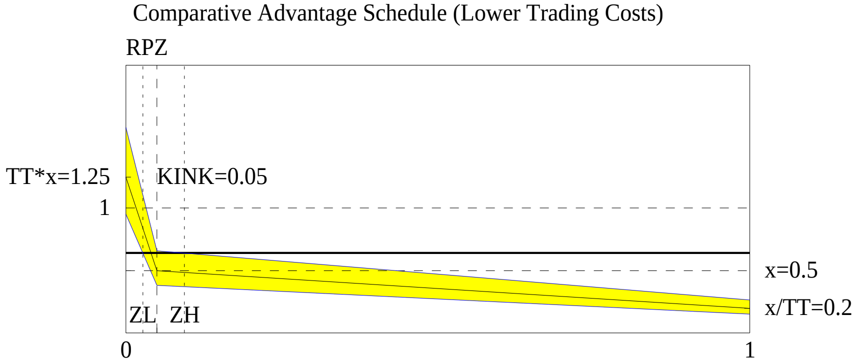


Figure 10: Effects of a Permanent 10 Percentage Point Reduction in Trading Costs

Comparative Advantage Schedule (Base Case)



Comparative Advantage Schedule (Lower Trading Costs)



Deviation from Baseline:

Home Export-to-GDP ratio:	17.83
Intermediate Inputs	11.47
Final Consuption Goods	6.81
Final Investment Goods	-0.45
Home Import-to-GDP ratio:	17.83
Intermediate Inputs	14.49
Final Consuption Goods	3.43
Final Investment Goods	-0.09

Percent Deviation from Baseline:

Home Exports	78.03
Home Labor Productivity	14.24
Home Consumption Equivalent	12.59
Home Consumption	11.90
Home Labor Effort	-2.25
Real CPI Exchange Rate	4.79
Foreign Consumption	0.30
Foreign Labor Effort	-0.02

Figure 11: Effects of a Reduction in Trading Costs (Current Reduction versus an Anticipated Reduction 5 years in the Future)

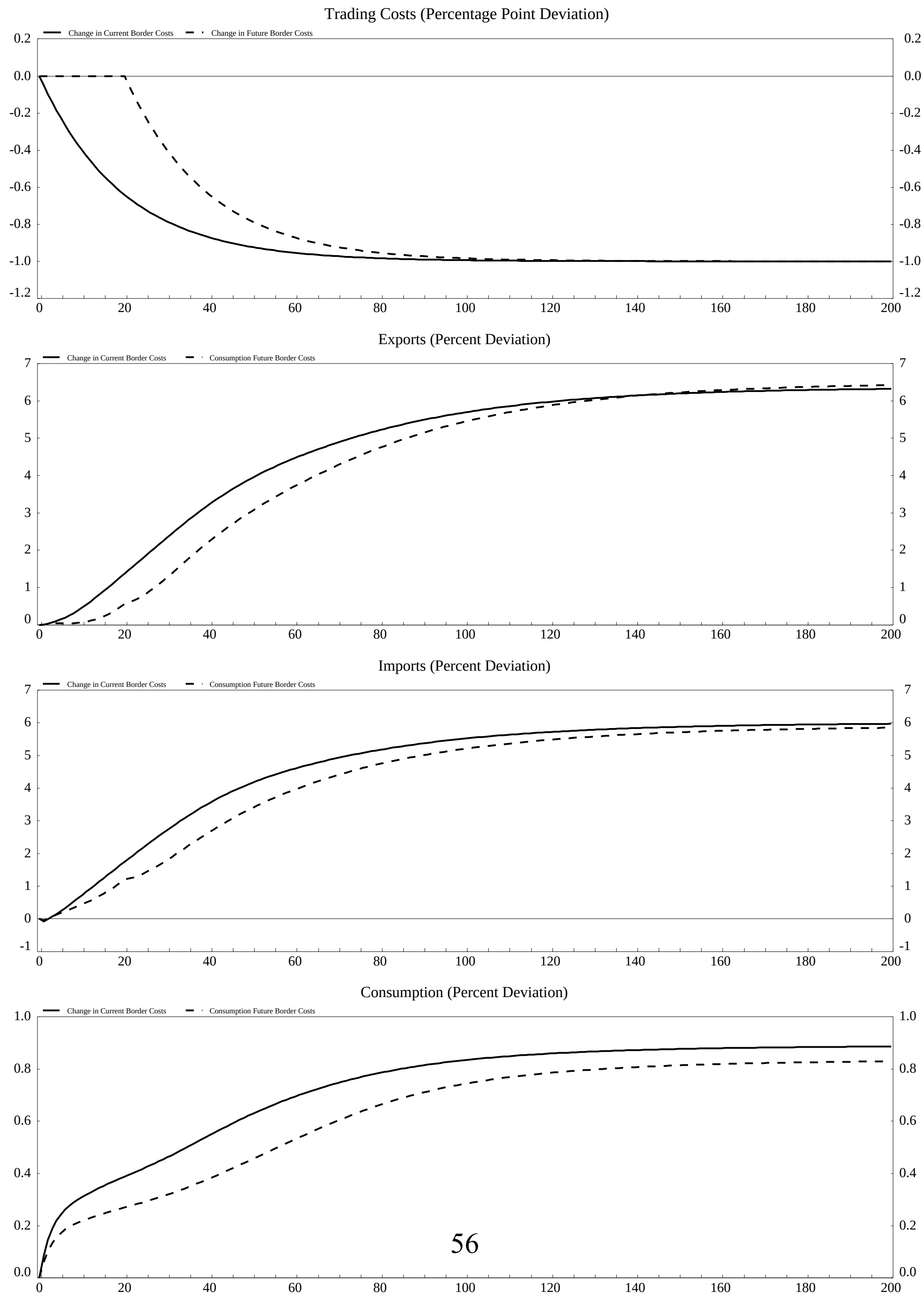


Figure 12: Effects of a Reduction in Trading Costs and a Lower Initial Starting Point for the Capital Stock

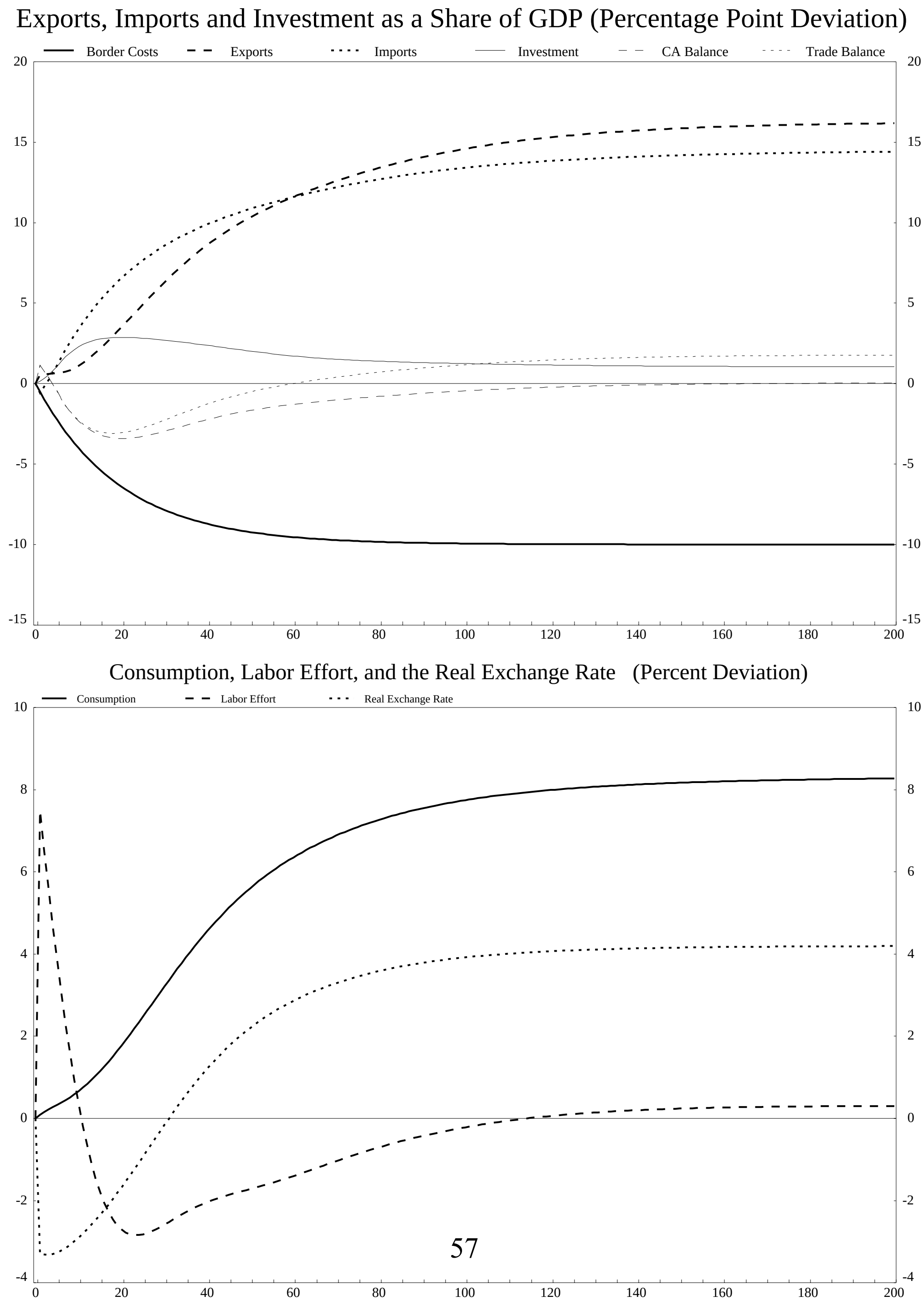


Table 1: Key Behaviorial Parameters

	Home	Foreign
Size α	0.05	0.95
Discount Rate β	0.99	0.99
Depreciation Rate on Capital Δ	0.025	0.025
Habit Persistence Parameters ν	0.55	0.55
Intertemporal EOS: σ	0.80	0.80
EOS: Final Goods Bundle θ_c	5.00	5.00
EOS: Final Goods Bundle θ_{cd}	5.00	5.00
EOS: Final Goods Bundle θ_{od}	5.00	5.00
EOS: Intermediates θ_d	5.00	5.00
EOS: Domestic Final Output θ_{dd}	5.00	5.00
EOS: Labor η	5.00	5.00

Table 2: Determinants of Per Capita Income

	Home	Foreign
Labor Effort	0.33	0.33
Aggregate Productivity (x)	0.50	1.00
TT	2.50	2.50
KINK	0.05	0.05
Trading Costs	0.34	0.34
Per Capita Consumption	1.47	2.68

Table 3: Steady-State Flows

Percent of Nominal GDP	Home	Foreign
Exports:	*30.0*	*1.5*
...Intermediate Inputs	*15.0*	*0.8*
...Final Consumption Goods	*7.5*	*0.4*
...Final Investment Goods	*7.5*	*0.4*
Imports:	*30.0*	*1.5*
...Intermediate Inputs	*15.0*	*0.8*
...Final Consumption Goods	*7.5*	*0.4*
...Final Investment Goods	*7.5*	*0.4*

Table 4: Long-Run Effects of Lower Trading Costs Under Alternative Assumptions about Key Elasticities of Substitution (EOS)

	Lower EOS = 4	Base-Case EOS=5	Higher EOS = 6
Trading Costs (Δ)	-1.00	-1.00	-1.00
Home Exports (%)	5.29	6.17	6.89
Home Export-to-GDP Ratio:	1.26	1.55	1.79
...Intermediate Inputs (Δ)	0.91	1.10	1.23
...Final Consumption Goods (Δ)	0.39	0.50	0.60
...Final Investment Goods (Δ)	-0.04	-0.04	-0.04
Home Imports-to-GDP Ratio:	1.26	1.55	1.79
...Intermediate Inputs (Δ)	1.02	1.21	1.36
...Final Consumption Goods (Δ)	0.24	0.35	0.44
...Final Investment Goods (Δ)	-0.00	-0.00	-0.00
Home GDP (90)	1.03	0.94	0.86
Home Labor Productivity (%)	1.21	1.10	1.00
Home Consumption Equivalent (%)	1.10	1.02	0.95
Home Consumption (%)	1.06	0.98	0.90
Home Labor Effort (%)	-0.17	-0.15	-0.14
Real Exchange Rate (%)	0.46	0.37	0.32
Foreign Consumption (%)	0.03	0.03	0.02
Foreign Labor Effort (%)	-0.00	-0.00	-0.00

Table 5: Long-Run Effects of Lower Trading Costs Under Asymmetric Assumptions about Key Elasticities of Substitution (EOS)

	Home EOS = 4 Foreign EOS = 6	Home EOS = 5 Foreign EOS = 5	Home EOS = 6 Foreign EOS = 4
Trading Costs (Δ)	-1.00	-1.00	-1.00
Home Exports (%)	6.05	6.17	6.03
Home Export-to-GDP Ratio:	1.45	1.55	1.57
...Intermediate Inputs (Δ)	1.15	1.10	0.95
...Final Consumption Goods (Δ)	0.35	0.50	0.65
...Final Investment Goods (Δ)	-0.06	-0.04	-0.03
Home Imports-to-GDP Ratio:	1.45	1.55	1.57
...Intermediate Inputs (Δ)	1.17	1.21	1.20
...Final Consumption Goods (Δ)	0.25	0.35	0.38
...Final Investment Goods (Δ)	0.00	-0.00	-0.01
GDP	1.17	0.94	0.76
Home Labor Productivity (%)	1.32	1.10	0.92
Home Consumpton Equivalent (%)	1.23	1.02	0.85
Home Consumption (%)	1.19	0.98	0.80
Home Labor Effort (%)	-0.15	–0.15	-0.15
Real Exchange Rate (%)	0.35	0.37	0.41
Foreign Consumption (%)	0.02	0.03	0.04
Foreign Labor Effort (%)	0.00	-0.00	-0.01

Table 6: Long-Run Effects of Lower Trading Costs Under Alternative Assumptions about the Comparative-Advantage Schedule

	$\check{T}$=2.0	Base-Case $\check{T}$ = 2.5	$\check{T}$= 3.0
Trading Costs (Δ)	-1.00	-1.00	-1.00
Home Exports (%)	6.39	6.17	6.03
Home Export-to-GDP Ratio:	1.64	1.55	1.50
...Intermediate Inputs (Δ)	1.20	1.10	1.03
...Final Consumption Goods (Δ)	0.48	0.50	0.52
...Final Investment Goods (Δ)	-0.04	-0.04	-0.04
Home Imports-to-GDP Ratio:	1.64	1.55	1.50
...Intermediate Inputs (Δ)	1.32	1.21	1.15
...Final Consumption Goods (Δ)	0.32	0.35	0.36
...Final Investment Goods (Δ)	-0.00	-0.00	-0.00
Home GDP	0.88	0.94	0.97
Home Labor Productivity (%)	1.03	1.10	1.13
Home Consumption Equivalent (%)	0.96	1.02	1.04
Home Consumption (%)	0.92	0.98	1.00
Home Labor Effort (%)	-0.15	-0.15	-0.15
Real Exchange Rate (%)	0.36	0.37	0.38
Foreign Consumption (%)	0.02	0.03	0.03
Foreign Labor Effort (%)	-0.00	–0.00	-0.00