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OPENNESS AND OPTIMAL MONETARY POLICY

by Giovanni Lombardo
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Abstract

We show that the composition of imports has important implications for the optimal volatility of the exchange rate. Using input-output data for 25 countries we document substantial differences in the import and non-tradable content of final demand components, and in the role played by imported inputs in domestic production. We build a business cycle model of a small open economy to discuss how the problem of the optimizing policy-maker changes endogenously as the composition of imports and of final demand is altered. Contrary to models where steady state trade openness is entirely characterized by home bias, we find that trade openness is a very poor proxy of the welfare impact of alternative monetary policies. Finally, we quantify the loss from an exchange rate peg relative to the Ramsey policy conditional on the composition of imports, using parameter values that are estimated from OECD input-output tables data. We find that the main determinant of the losses is the share of non-traded goods in final demand.

JEL Classification Numbers: E52; E31; F02; F41.

Keywords: International Trade; Exchange Rate Regimes; Non-tradable Goods; Optimal Policy

Non Technical Summary

Small and relatively open economies tend to be particularly affected by exchange rate variations. Traditional views of optimal exchange rate regimes suggest that exchange rate adjustments to shocks should be welcomed when domestic prices are not fully flexible. The nominal exchange rate, in this case, acts as a shock absorber by bringing about the necessary relative price adjustment.

Most recent studies have investigated the role of the exchange rate under alternative scenarios. For example, some recent papers show that the response of the exchange rate to shocks should be mitigated when traded goods are priced in the currency of the buyer. Others have pointed out that the presence of home bias in consumption calls for a policy that generates larger volatility of the exchange rate, compared to the case of symmetric preferences in domestic and foreign goods. In fact, the latter literature has associated the degree of home-bias in consumption (and investment) to the degree of openness of the economy: more open the economy, smaller the optimal volatility of the nominal exchange rate.

This prescription has consequences for the welfare costs of pegging the exchange rate (or joining currency unions). According to this results, the more open is the economy, the less attractive is pegging its exchange rate to the currency of its trading parter.

In this paper we show that these conclusions are not warranted. We show that the fallacy of this reasoning lies in identifying openness with the degree of home bias. We argue that the degree of openness of an economy should be linked at least to three features: the degree of home bias in the consumption of traded goods, the share of non-tradables in demand and the share of imported intermediates. These features don't necessarily share the same relationship with the optimal exchange rate volatility, so that equal degrees of openness could be linked to different degrees of optimal exchange rate volatility.

In order to investigate this view, we measure the share of imported intermediate inputs and the share of non-traded consumption and investment goods for 25 countries using OECD input-output tables. We use these measures, together with features concerning trade and production structures from these countries that can be inferred from the input-output tables, to calibrate a small open economy DSGE model. While we take our reference economy to be a small open economy like the Czech Republic, this exercise provides us with 25 different hypothetical countries that would have the trade features of the 25 economies in the OECD dataset.

The calibrated economies allow us to show that the relationship between openness and optimal exchange rate volatility documented by the recent literature is not robust. On the contrary, we show that openness and optimal exchange rate volatility are close to orthogonal measures. The immediate consequence of this result is that we cannot find any systematic relationship between openness and the cost of pegging the exchange rate. We show that the reason for this result lies in the composite nature of openness: different combinations of shares of non-traded goods and shares of intermediate inputs can generate the same degree of openness with dramatically different losses from pegging the exchange rate. In our model, the market for non-traded goods displays sticky prices while imported intermediate goods are sold in flexible-price markets. The presence of sticky prices in the non-tradable sector calls for flexible exchange rates that absorb shocks allowing relative prices to remain at their efficient level. Therefore, two equally open economies could display different losses of pegging the exchange rate depending on the share of non-traded goods relative to imported intermediate goods.

Finally, our calculations suggest that the losses of pegging the exchange are non negligible and that they vary between 0.06% (of permanent consumption) for countries with a trade structure similar to Belgium, Estonia or Poland, and 0.23% for countries with the same trade structure of the US or Japan.

Many other considerations, in the real world, must be taken into account in determining the optimal volatility of the exchange rate and in evaluating the desirability of a pegged currency. Our paper focuses on one particular, important dimension: the impact of trade on the optimal exchange rate volatility. A dimension that should not be neglected in considering the pros and cons of exchange rate regimes.

1 Introduction

Fluctuations in the nominal exchange rate have for a long time been considered essential to the efficient adjustment of international relative prices when policy needs to respond to asymmetric shocks and the adjustment of domestic prices is sluggish (Mundell, 1961 and Friedman, 1953). A growing literature recognizes that the optimal volatility of the exchange rate crucially depends on the degree of openness of the economy, which in the simplest models, where all goods are tradable, is inversely related to the degree of home bias in preferences.[1]

In this paper we study the relationship between openness and the optimal volatility of the exchange rate in an economy where the same degree of openness can be achieved through different compositions of imports across consumption, investment and intermediate goods. Our modeling approach allows countries with identical degree of openness to differ in the degree of home bias in the consumption of tradable goods, in the share of non-tradables in consumption and investment demand, and in the share of imported intermediates in the domestic production input mix, resulting in different compositions of imports. We can, for example, compare optimal policy in open economies that import mostly consumption goods, against economies importing mostly intermediate goods for domestic production. Our main conclusion is that there is no systematic relationship between openness and optimal exchange rate volatility, and thus the results from stylized models where home bias and openness are directly related cannot be generalized once the cross-country variation in the composition of imports is taken into account. When estimating the model's preference and technology parameters using OECD input-output tables data for 25 countries, we find that the welfare loss is highly correlated with the share of non-tradable goods in final demand.

The analysis proceeds as follows. First, we document from input-output tables data that differences in the composition of imports across both industrial and emerging economies are substantial, and provide estimates of the tradable and non-tradable input shares in consumption and investment for 25 countries. Second, we build a simple multi-good model to illustrate through which channels the composition of imports affects the transmission of shocks under alternative policy regimes. Finally, we quantify the welfare losses of an exchange rate peg conditional on the composition of imports using parameter values that are estimated from input-output tables data.

[1]Corsetti (2006) and Faia and Monacelli (2008) study the relationship between openness and optimal policy. While focusing on different aspects of the optimal policy, also Corsetti et al. (2008), De Paoli (2009) and Engel (2009) acknowledge the importance of home bias in their results. Our modeling approach relies on the distinction between tradable and non-tradable goods, and is close to Dotsey and Duarte (2008) and Duarte and Obstfeld (2008).

Our contribution to the study of optimal policy in open economies is twofold. First, we show that different combinations of tradable and non-tradable goods in final and intermediate demand can generate the same import to GDP ratio but dramatically different losses from pegging the exchange rate. In our model, openness and optimal exchange rate volatility turn out to be close to orthogonal variables. An exchange rate peg leads to large welfare losses in an economy where the share of imported intermediates in the domestic production input mix is high, and at the same time the bias towards non-tradable goods is high. In an equally open economy importing mainly consumption or investment goods a peg leads only to a modest welfare loss. This result also holds if we allow for some degree of local currency pricing in the import sector.

Second, we discuss the propagation mechanism of shocks in a model with multiple imported goods. In our model, households consume non-tradable goods, a tradable good which can be domestically produced or imported, and a tradable good that is only produced abroad. Production requires labor, capital and an imported intermediate good. In turn, capital in each sector is domestically produced with a technology requiring a mix of all goods. The market for non-traded goods displays sticky prices. In an economy with full pass-through where imports are sold in flexible-price markets, optimal policy results in near-complete stabilization of the non-tradable goods markup. The intuition for this result can be easily explained if we assume a zero-capital share in production. We show that the Ramsey policy (approximately) equates the marginal rate of transformation across domestically produced tradable and non-tradable goods to their relative price. This requires large movements in the exchange rate in response to shocks that directly affect this efficiency condition. In these instances, a peg is costly because it results in an additional nominal rigidity, and forces the adjustment in the tradable/non-tradable relative price on the sticky nominal price. This mechanism works through the spill-over of input prices across sectors: since labor is mobile across sectors, *any* change affecting the conditions for efficient production in one sector will spill over to the sector with nominal rigidities through changes in nominal wages, and result in inefficient fluctuations in nominal prices under a peg. On the contrary, shocks to the price of goods that are not domestically produced are only partially accommodated by the Ramsey policy, so that the exchange rate is stabilized, and is prevented from directly affecting the production efficiency conditions in each sector. Introducing local currency pricing in the import sector, which in our model results in inefficient volatility of retail import prices, provides the main incentive for policy to deviate from fully stabilizing inflation in the non-traded sector.

Our paper is related to several recent contributions. Faia and Monacelli (2008) provide a detailed analysis of the impact of home bias on optimal policy in a small open economy model with only tradable goods. As in their paper, our model results in a strong incentive for the policymaker to stabilize the price of the sectors with staggered price adjustment. They conclude that optimal exchange rate volatility is monotonically decreasing in the degree of openness. Corsetti (2006) shows in a two-country model that exchange rate volatility is optimal whenever there is home bias, even if import prices are preset in local currency, following a local currency pricing framework similar to Devereux and Engel (2003). In the presence of home bias, exchange rate fluctuations allow the policymaker to optimally respond to asymmetric shocks. The relationship between openness - proportional to the degree of home bias - and optimal exchange rate volatility is non-monotonic, although volatility increases for positive degrees of home bias (i.e. when agents prefer domestic goods more than foreign goods). The existence of several additional goods and the spill-over across sectors of sectoral shocks implies that neither of these results hold in our model.

A key assumption of our modeling approach is the existence of a non-traded good sector, as in Corsetti et al. (2010), Devereux and Engel, (2007), Dotsey and Duarte, (2008), Duarte and Obstfeld (2008). In our model, the share of imports in final demand depends both on the home bias in the tradable goods basket, and on the bias for non-tradable goods. We assume tradable goods are priced on international markets, implying that the domestic tradable goods sector is affected by fluctuations of the foreign price (and of the exchange rate) independently of the degree of home bias.

Duarte and Obstfeld (2008) present a two-country model where the existence of non-traded goods, rather than home bias, generates asymmetry in the way domestic and foreign consumption react to shocks, and result in exchange rate volatility under the optimal policy even in the absence of exchange rate pass-through. As in their work, the existence of non-traded goods in our model implies that the risk-sharing condition depends on the relative price of traded and non-traded goods, generating an incentive for the optimal policymaker to manipulate allocations through the exchange rate. Dotsey and Duarte (2008) examine the role of non-tradables for business cycle correlations in a model similar to ours. They assume a complete input-output structure in the economy, so that final non-tradable goods are an input in domestic production. We have only a partial input-output structure in the model, but parameterize the final demand aggregators using estimates of input shares, rather than final demand shares, so as to account for the shares of final goods production being used as intermediates by other sectors. In this way, our model is more easily comparable with most of the recent open economy macroeconomics literature.

The paper is structured as follows. Section 2 provides empirical results on the role of imported consumption and intermediate goods, and estimates of the tradable and non-tradable goods' shares in final demand for 25 countries. Section 3 describes the model. Section 4 discusses the propagation mechanism under the optimal policy and a peg. Section 5 describes the impact of the demand and import composition on welfare outcomes, and computes the welfare loss in 25 representative economies parameterized according to input-output tables data. Section 6 concludes.

2 Trade Flows Composition and Tradable Goods Demand across Countries

We document a number of empirical results on the composition of final demand, on the magnitude of imported consumption and investment relative to the size of the domestic economy, and on the role played by imported inputs in domestic production for 25 industrial and emerging economies using the latest release of input-output tables by the OECD.[2] The final demand share of each component of imports depends on the import share in the tradable basket, and on the share of tradable and non-tradable goods in final demand. Since these shares are separately parameterized in open economy DSGE models with a non-tradable sector, we use the input-output tables to compute estimates of the share of tradable and non-tradable goods in consumption and investment demand.

We estimate the tradable share of demand using an approach similar to that of De Gregorio et al. (1994). For each industry in the input-output tables, we define a tradability measure equal to the sum of exports and imports relative to its gross output. The output from an industry is considered tradable if its tradability measure is above a critical threshold. We consider a 10% threshold, identical across countries.[3]

We measure the content of tradable and non-tradable goods in final demand using symmetric input-output tables at basic prices, where the final dollar demand for a good is reported net of the cost paid to cover local (non-tradable) services. Thus the data allocate the value of the distribution

[2]Our dataset consists of the 2009 edition of the OECD input-output tables. For most of the countries we averaged the results obtained from the two available tables between 2000 and 2005. For Korea, Mexico, New-Zealand and Slovakia only one year was available.

[3]Ravenna and Lombardo (2010) report results using a country specific threshold, equal to the tradability measure of the wholesale and retail trade sector (which is assumed to produce non-tradable output) in each country. A 10% threshold is used by De Gregorio et al. (1994) and Betts and Kehoe (2001) and is close to the average tradability measure based on wholesale and retail sector used by Bems (2008). Our calculations based on the wholesale and retail sector show too much variability across countries and they would imply larger shares of non-tradable goods.

margin for imported goods to the appropriate (non-tradable) industry. Additionally, to account for the intermediate non-tradable (tradable) input content in the final demand of tradable (non-tradable) goods, we compute tradable input shares - rather than final demand shares - defined as the share of tradable goods embedded in a dollar of final demand throughout the whole production chain. Ravenna and Lombardo (2010) provide details on the computation using input-output tables data.

Table 1 compares the consumption and investment non-tradable input shares across our sample of countries. US and Japan are at the high end of the range, while small open economies, such as Ireland, Belgium and Luxembourg, have consumption non-tradables input shares of around 20%. [4]

Table 1 also summarizes data on openness, imports and demand composition. The data show that there is a remarkable variation both in the export to GDP ratio, a standard measure of trade openness, and in the composition of imports. Not only demand for imports can come from different components of final demand - such as consumption or investment - but countries differ also in the amount of final relative to intermediate goods imported, and in the relative importance of imported intermediates in domestic production. Italy and Portugal, for example, have nearly identical degree of openness, while the share of imported consumption goods in total consumption is nearly twice as large in Portugal (17%) than in Italy (9%), and the ratio of intermediate imports to GDP is equal to 24% in Portugal and 18% in Italy. Five countries rely on imported inputs for a value larger than 40% of GDP. Estonia and Slovakia are the largest importers of intermediates relative to the size of the economy, with a ratio of imported inputs to GDP just below 59%, while the US is at the low end of the range, with a ratio of 7.6%.

Finally, the data reported in Table 1 document a large cross-country variation in the share of tradable investment demand which is not domestically produced. For example, using the data in Table 1 the share of imported investment in total tradable investment results equal to about 22% in Germany and 43% in the Czech Republic. The main factor driving these cross country differences is the share in GDP of imported investment, with a standard deviation of 42%, while the standard deviation for the tradable investment share and the share of investment demand in GDP is respectively equal to 17% and 18%.

[4]In comparison with the existing literature, our results suggest shares of nontradable goods that are somewhat smaller than those obtained under different definitions of nontradable goods. For example, Bems (2008), using input-output tables, finds that the share of nontradable investment expenditures for OECD countries falls in the range of 59-64%. Goldberg and Campa (2010) find, consistently with our results, that the content of both non-tradable services and imported intermediate inputs in retail consumption tradable goods varies substantially across countries.

3 The Model

We develop a small open economy model with nominal rigidities, built along the lines of the new open economy macroeconomic literature, as in Corsetti and Pesenti (2001), Devereux and Engel (2002), Galí and Monacelli (2005), Obstfeld and Rogoff (2000), Sutherland (2006).

The small open economy produces a non-tradable good (N) and a domestic tradable good (H). The latter is also produced abroad and its price is exogenously determined in the world market. Household preferences are defined over a basket of tradable (T) and non-tradable (N) goods. The tradable good basket includes two goods: a foreign good (F), that must be imported, and the domestic good (H). All households' consumption is assumed to be non-durable.[5] Consumers can save by holding domestic or foreign nominal bonds. Output in both the domestic tradable sector H and the non-tradable sector N is produced combining domestic value added - a Cobb-Douglas aggregate of labor and capital - and an imported intermediate input. To introduce a role for monetary policy, we assume nominal price-rigidities in the non-tradable sector and in the import sector for the F good.

The assumptions in the model allow for consumers to have a strong preference for tradable goods, even if the economy does not have a high degree of openness. Additionally, they imply no pricing power by domestic export producers. An economy where all H sector firms have monopoly power would shelter a large share of domestic producers from direct foreign competition, since the N sector's firms produce non-tradable goods, whose price is also independent from the price of similar goods in foreign countries. An economy where all H sector firms are price-takers allows for a large fraction of domestically demanded goods to be exposed to foreign competition, and be priced on international markets, even if the share of imported goods in consumption is low. This pricing assumption is well suited for emerging market economies that produce, and export, commoditized goods (low-end apparel, for example), and helps us provide a clearer interpretation of the optimal policy.[6] Even if in our economy the terms of trade are exogenous, the optimal policymaker has an incentive to manipulate the nominal exchange rate because of its impact on the relative price of tradable and non-tradable goods.

[5]Engel and Wang (2010) have shown the importance of durable consumption in explaining the high volatility of imports and exports. Introducing durable consumption goods in our model would be an interesting extension of our analysis which we leave to future research.

[6]Additionally, our assumption is consistent with the implications for nominal variables of the Balassa-Samuelson effect in a small open economy model. See Ravenna and Natalucci (2008).

3.1 Consumption, Investment, and Price Composites

Household preferences are defined over the index C_t, a composite of non-tradable and tradable good consumption, $C_{N,t}$ and $C_{T,t}$ respectively:

$$C_t = \left[(\gamma_{cn})^{\frac{1}{\rho_{cn}}} (C_{N,t})^{\frac{\rho_{cn}-1}{\rho_{cn}}} + (1-\gamma_{cn})^{\frac{1}{\rho_{cn}}} (C_{T,t})^{\frac{\rho_{cn}-1}{\rho_{cn}}} \right]^{\frac{\rho_{cn}}{\rho_{cn}-1}} \tag{1}$$

where $0 \leq \gamma_{cn} \leq 1$ is the share of the N good and $\rho_{cn} > 0$ is the elasticity of substitution between N and T goods. The tradable consumption good is a composite of home and foreign tradable goods, $C_{H,t}$ and $C_{F,t}$, respectively:

$$C_{T,t} = \left[(\gamma_{ch})^{\frac{1}{\rho_{ch}}} (C_{H,t})^{\frac{\rho_{ch}-1}{\rho_{ch}}} + (1-\gamma_{ch})^{\frac{1}{\rho_{ch}}} (C_{F,t})^{\frac{\rho_{ch}-1}{\rho_{ch}}} \right]^{\frac{\rho_{ch}}{\rho_{ch}-1}} \tag{2}$$

where $0 \leq \gamma_{ch} \leq 1$ is the share of the H good and $\rho_{ch} > 0$ is the elasticity of substitution between H and F goods. The non-tradable consumption good N is an aggregate defined over a continuum of differentiated goods:

$$C_{N,t} = \left[\int_0^1 C_{N,t}^{\frac{\varrho-1}{\varrho}}(z) dz \right]^{\frac{\varrho}{\varrho-1}} \tag{3}$$

with $\varrho > 1$. Investment in the non-tradable and domestic tradable sector is defined in a similar manner - a composite of N, H, and F goods. However, we assume that shares and elasticities may differ from those of the consumption composites (the superscript J refers to the sector):

$$I_t^J = \left[(\gamma_{in})^{\frac{1}{\rho_{in}}} \left(I_{N,t}^J\right)^{\frac{\rho_{in}-1}{\rho_{in}}} + (1-\gamma_{in})^{\frac{1}{\rho_{in}}} \left(I_{T,t}^J\right)^{\frac{\rho_{in}-1}{\rho_{in}}} \right]^{\frac{\rho_{in}}{\rho_{in}-1}}, J = N, H \tag{4}$$

$$I_{T,t}^J = \left[(\gamma_{ih})^{\frac{1}{\rho_{ih}}} \left(I_{H,t}^J\right)^{\frac{\rho_{ih}-1}{\rho_{ih}}} + (1-\gamma_{ih})^{\frac{1}{\rho_{ih}}} \left(I_{F,t}^J\right)^{\frac{\rho_{ih}-1}{\rho_{ih}}} \right]^{\frac{\rho_{ih}}{\rho_{ih}-1}}, J = N, H \tag{5}$$

$$I_{N,t}^J = \left[\int_0^1 \left(I_{N,t}^J\right)^{\frac{\varrho-1}{\varrho}} (z) dz \right]^{\frac{\varrho}{\varrho-1}} \tag{6}$$

Households' demand functions imply that the composite good price indices can be written as:

$$P_t^c = \left[(\gamma_{cn}) (P_{N,t})^{1-\rho_{cn}} + (1-\gamma_{cn}) \left(P_{T,t}^c\right)^{1-\rho_{cn}} \right]^{\frac{1}{1-\rho_{cn}}} \tag{7}$$

$$P_{T,t}^c = \left[(\gamma_{ch}) (P_{H,t})^{1-\rho_{ch}} + (1-\gamma_{ch}) (P_{F,t})^{1-\rho_{ch}} \right]^{\frac{1}{1-\rho_{ch}}} \tag{8}$$

$$P_{N,t} = \left[\int_0^1 P_{N,t}^{1-\varrho}(z) dz \right]^{\frac{1}{1-\varrho}} \tag{9}$$

where P_t^c, $P_{T,t}^c$, and $P_{N,t}$ are the consumer price index (CPI), the price index for T consumption goods, and the price index for N consumption goods, respectively. Investment price indices (P_t^i,

$P^i_{T,t}$, and $P_{N,t}$) can be similarly obtained. The terms of trade for consumption and intermediate imports, and the consumption-based (internal) real exchange rate are defined respectively as $\frac{P_{F,t}}{P_{H,t}}$, $\frac{P_{M,t}}{P_{H,t}}$ and $\frac{P^c_{T,t}}{P_{N,t}}$.

3.2 Households

We consider a cashless economy where the preferences of the representative household are given by

$$V = E_0 \sum_{t=0}^{\infty} \beta^t \left\{ D_t(\ln C_t) - \ell \frac{(H_t)^{1+\eta_L}}{1+\eta_L} \right\} \tag{10}$$

where D_t is an exogenous preference shock, η_L is the inverse of the labor supply elasticity and H_t is the total supply of labor hours, defined as $H_t = H^N_t + H^H_t$. Let W^N_t (W^H_t) denote the nominal wage in the N (H) sector, e_t the nominal exchange rate, B_t (B^*_t) holdings of discount bonds denominated in domestic (foreign) currency, v_t (v^*_t) the corresponding price, R^N_t (R^H_t) the real return to capital that is rented to firms in the N (H) sector, Π_t nominal profits from the ownership of firms in the monopolistically competitive sectors, and T_t nominal government lump-sum taxes. The household's budget constraint is then given by

$$P^c_t C_t + e_t B^*_t v^*_t + B_t v_t + P^i_t I^N_t + P^i_t I^H_t = W^H_t H^H_t + W^N_t H^N_t + \tag{11}$$

$$e_t B^*_{t-1} + B_{t-1} + P_{N,t} R^N_t K^N_{t-1} + P_{H,t} R^H_t K^H_{t-1} + \Pi_t$$

The household's revenues come from supplying labor and renting capital to firms in the N and H sectors, from holdings of domestic/foreign bonds, and from firms' profits. These revenues are then used to purchase consumption and investment goods, or saved in domestic and foreign assets.

The household is assumed to maximize the inter-temporal utility function (10) subject to (1), (2), (3), (4), (5), (6), (11), and the law of motion for the capital stocks in each sector:

$$K^N_t = \Phi\left(\frac{I^N_t}{K^N_{t-1}}\right) K^N_{t-1} + (1-\delta) K^N_{t-1} \tag{12}$$

$$K^H_t = \Phi\left(\frac{I^H_t}{K^H_{t-1}}\right) K^H_{t-1} + (1-\delta) K^H_{t-1} \tag{13}$$

We assume that installed capital, contrary to labor, is sector-specific. Capital accumulation incurs adjustment costs, with $\Phi'(\bullet) > 0$ and $\Phi''(\bullet) < 0$.

The solution to the household decision problem gives the following first order conditions (FOCs):

$$\lambda^C_t = \beta E_t \left\{ \lambda^C_{t+1} (1+i_t) \frac{P^c_t}{P^c_{t+1}} \right\} \tag{14}$$

$$E_t\left\{\lambda^C_{t+1}\frac{P^c_t}{P^c_{t+1}}\left[(1+i_t)-(1+i^*_t)\frac{e_{t+1}}{e_t}\right]\right\}=0 \tag{15}$$

$$\lambda^C_t\frac{P^i_t}{P^c_t}Q^J_t=\beta E_t\{\lambda^C_{t+1}\left(\frac{P_{J,t+1}}{P^c_{t+1}}R^J_{t+1}\right)+\lambda^C_{t+1}\frac{P^i_{t+1}}{P^c_{t+1}}Q^J_{t+1}[\Phi\left(\frac{I^J_{t+1}}{K^J_t}\right) \tag{16}$$
$$-\frac{I^J_{t+1}}{K^J_t}\Phi'\left(\frac{I^J_{t+1}}{K^J_t}\right)+(1-\delta)]\},\quad J{=}N,H$$

$$Q^J_t=\left[\Phi'\left(\frac{I^J_t}{K^J_{t-1}}\right)\right]^{-1}\qquad J=N,H \tag{17}$$

$$C_{N,t}=\frac{\gamma_{cn}}{1-\gamma_{cn}}\left(\frac{P^c_{T,t}}{P_{N,t}}\right)^{\rho_{cn}}C_{T,t}\quad;\quad C_{H,t}=\frac{\gamma_{ch}}{1-\gamma_{ch}}\left(\frac{P_{F,t}}{P_{H,t}}\right)^{\rho_{ch}}C_{F,t} \tag{18}$$

$$I^J_{N,t}=\frac{\gamma_{in}}{1-\gamma_{in}}\left(\frac{P^i_{T,t}}{P_{N,t}}\right)^{\rho_{in}}I^J_{T,t}\quad;\quad I^J_{H,t}=\frac{\gamma_{ih}}{1-\gamma_{ih}}\left(\frac{P_{F,t}}{P_{H,t}}\right)^{\rho_{ih}}I^J_{F,t},\quad J=N,H \tag{19}$$

$$\lambda^C_t\frac{W^N_t}{P^c_t}=\ell\,(H_t)^{\eta_H}\quad;\quad\lambda^C_t\frac{W^H_t}{P^c_t}=\ell\,(H_t)^{\eta_H} \tag{20}$$

where $\lambda^C_t=\frac{1}{C_t}$ is the marginal utility of total consumption and $(1+i_t)=\frac{1}{v_t}$. Eqs. (14) to (17) are the Euler equations for the assets available to households, where Q^J_t is Tobin's Q. The conditions in (18) and (19) give the optimal choice for consumption and investment across goods. The labor supply optimality conditions in (20) imply that $\frac{W^N_t}{P^c_t}=\frac{W^H_t}{P^c_t}$, a consequence of costless labor mobility across sectors.

3.3 Firms

3.3.1 Non-tradable (N) Sector

The non-tradable sector is populated by a continuum of monopolistically competitive firms owned by households. Each firm $z\in[0,1]$ combines an imported intermediate good, $X_{N,t}$, and domestic value added, $V_{N,t}$ according to the production function:

$$Y_{N,t}(z)=\left[(\gamma_{nv})^{\frac{1}{\rho_{nv}}}\left(V_{N,t}(z)\right)^{\frac{\rho_{nv}-1}{\rho_{nv}}}+(1-\gamma_{nv})^{\frac{1}{\rho_{nv}}}\left(X_{N,t}(z)\right)^{\frac{\rho_{nv}-1}{\rho_{nv}}}\right]^{\frac{\rho_{nv}}{\rho_{nv}-1}} \tag{21}$$

Domestic value added is produced using labor and sector-specific capital as inputs:

$$V_{N,t}(z)=A^N_t[K^N_{t-1}(z)]^{\alpha_n}[H^N_t(z)]^{1-\alpha_n}$$

where A^N_t is an exogenous productivity shock. Cost minimization gives the factor demands:

$$\frac{W^N_t}{P_{N,t}}=MC^N_t(z)\,[1-\alpha_n]\,(\gamma_{nv})^{\frac{1}{\rho_{nv}}}\frac{V_{N,t}(z)}{H^N_t(z)}\left(\frac{Y_{N,t}(z)}{V_{N,t}(z)}\right)^{\frac{1}{\rho_{nv}}} \tag{22}$$

$$R_t^N = MC_t^N(z)\alpha_N (\gamma_{nv})^{\frac{1}{\rho_{nv}}} \frac{V_{N,t}(z)}{K_{t-1}^N(z)} \left(\frac{Y_{N,t}(z)}{V_{N,t}(z)}\right)^{\frac{1}{\rho_{nv}}} \tag{23}$$

$$\frac{P_{M,t}}{P_{N,t}} = MC_t^N(z)\,(1-\gamma_{nv})^{\frac{1}{\rho_{nv}}} \left(\frac{Y_{N,t}}{X_{N,t}}\right)^{\frac{1}{\rho_{nv}}} \tag{24}$$

where $MC_t^N(z)$ is the real marginal cost for firm z and $P_{M,t}$ is the domestic currency price of the imported intermediate good. We assume $P_{M,t} = e_t P_{M,t}^*$ where $P_{M,t}^*$ follows an exogenous stochastic processes. Given the first order conditions for factor demands and the aggregate demand schedule $Y_{N,t}(z) = \left[\frac{P_{N,t}(z)}{P_{N,t}}\right]^{-\varrho} (C_{N,t} + I_{N,t}^H + I_{N,t}^N)$, firm z maximizes expected discounted profits by choosing the optimal price $P_{N,t}(z)$. We assume firms are able to optimally reset the price with probability $(1-\vartheta)$ in each period, following the Calvo (1983) pricing mechanism. Non-resetting firms satisfy demand at the previously posted price. Aggregation over the N sector producers gives the standard new Keynesian forward-looking price adjustment equation for non-tradable good inflation.[7]

3.3.2 Domestic Tradable (H) Sector

The tradable good H is produced both at home and abroad in a perfectly competitive environment, where the law of one price holds:

$$P_{H,t} = e_t P_{H,t}^* \tag{25}$$

The price for the foreign-produced H good $P_{H,t}^*$ follows an exogenous stochastic process. Domestic producers combine an imported intermediate good, $X_{H,t}$, and domestic value added, $V_{H,t}$, according to the production function:

$$Y_{H,t} = \left[(\gamma_v)^{\frac{1}{\rho_v}} (V_{H,t})^{\frac{\rho_v-1}{\rho_v}} + (1-\gamma_v)^{\frac{1}{\rho_v}} (X_{H,t})^{\frac{\rho_v-1}{\rho_v}}\right]^{\frac{\rho_v}{\rho_v-1}} \tag{26}$$

Domestic value added is produced using labor and sector-specific capital as inputs:

$$V_{H,t} = A_t^H \left(K_{t-1}^H\right)^{\alpha_h} \left(H_t^H\right)^{1-\alpha_h} \tag{27}$$

where A_t^H is an exogenous productivity shock. Cost minimization gives the factor demands:

$$\frac{W_t^H}{P_{H,t}} = (1-\alpha_h)\,(\gamma_v)^{\frac{1}{\rho_v}} \frac{V_{H,t}}{H_t^H} \left(\frac{Y_{H,t}}{V_{H,t}}\right)^{\frac{1}{\rho_v}} \tag{28}$$

[7] When parameterizing the model consistently with the input-output table data, we obtain that the value for γ_{nv} is at the upper end of the parameter space. Thus the data prefer a specification where non-traded goods are produced without imported intermediates. We discuss the implications of this result for the propagation of shocks in the next section.

$$R_t^H = \alpha_h (\gamma_v)^{\frac{1}{\rho_v}} \frac{V_{H,t}}{K_{t-1}^H} \left(\frac{Y_{H,t}}{V_{H,t}}\right)^{\frac{1}{\rho_v}} \tag{29}$$

$$\frac{P_{M,t}}{P_{H,t}} = (1-\gamma_v)^{\frac{1}{\rho_v}} \left(\frac{Y_{H,t}}{X_{H,t}}\right)^{\frac{1}{\rho_v}} \tag{30}$$

3.4 Foreign Sector

We assume that the foreign-produced good F is purchased by a continuum of monopolistically competitive firms in the import sector as an input for production. Each firm z can costlessly differentiate the imported good X_F to produce a consumption good $C_F(z)$ and an investment good $I_F(z)$ using the production technology $Y_F(z) = X_F(z)$, where $X_F(z)$ denotes the amount of input imported by firm z. The nominal marginal cost of producing one unit of output is defined as $MC_t^{F,nom}(z) = e_t P_{F,t}^*$ where $P_{F,t}^*$ is the foreign-currency price of X_F and follows an exogenous stochastic process. The producer faces an aggregate demand schedule given by:

$$Y_{F,t}(z) = \left[\frac{P_{F,t}(z)}{P_{F,t}}\right]^{-\varrho} (C_{F,t} + I_{F,t}^H + I_{F,t}^N)$$

where $Y_{F,t}(z) = C_{F,t}(z) + I_{F,t}^H(z) + I_{F,t}^N(z)$. The domestic-currency price $P_F(z)$ is set by solving an optimal pricing problem symmetrical to the one solved by firms in the N sector, following Calvo (1983). The state-independent probability of resetting the price at every period t is equal to $(1-\vartheta_F)$. As Monacelli (2005) pointed out, this production structure generates deviations from the law of one price in the short run, while asymptotically the pass-through from the price of the imported good to the price of the consumption and investment basket F is complete. We will refer to this pricing arrangement as the Local Currency Pricing (LCP) case.

When producers can optimally reset prices every period, the pass-through is complete also in the short-run and the law of one price holds. In this case, the domestic-currency price of good F is

$$P_{F,t} = \mu_F e_t P_{F,t}^* \tag{31}$$

where μ_F is a constant mark-up. Note that in a symmetric equilibrium all producers charge the same price $P_{F,t}(z)$. Under LCP, the mark-up $\mu_{F,t}$ responds to business cycle shocks by altering the wedge between the price of the imported wholesale good $P_{F,t}^*$ and the price of the retail basket $P_{F,t}$.

Following Schmitt-Grohé and Uribe (2003), the nominal interest rate at which households can borrow internationally is given by the exogenous world interest rate $\tilde{\imath}^*$ plus a premium, which is assumed to be increasing in the real value of the country's stock of foreign debt:

$$(1+i_t^*) = (1+\tilde{\imath}_t^*) g(-B_{H,t}) \tag{32}$$

where $B_{H,t} = \frac{e_t B_t^*}{P_{H,t}}$ and $g(\cdot)$ is a positive, increasing function. Eq. (32) ensures the stationarity of the model.

3.5 Market Clearing

We assume government purchases a fixed amount $G_{N,t}$ of N goods. The resource constraint in the non-tradable and domestic tradable sector is given by

$$Y_{N,t} = (C_{N,t} + I_{N,t}^N + I_{N,t}^H + G_{N,t}) \int_0^1 \left[\frac{P_{N,t}(z)}{P_{N,t}} \right]^{-\varrho} dz \tag{33}$$

$$Y_{H,t} = AB_{H,t} + C_{H,t}^* \tag{34}$$

$$AB_{H,t} = C_{H,t} + I_{H,t}^N + I_{H,t}^H \tag{35}$$

where $AB_{H,t}$ is domestic absorption and $C_{H,t}^*$ are net exports of the H good.

The trade balance, expressed in units of good H, can be written as

$$NX_{H,t} = C_{H,t}^* - \frac{P_{F,t}}{P_{H,t}} X_{F,t} - \frac{P_{M,t}}{P_{H,t}} (X_{H,t} + X_{N,t}) \tag{36}$$

where $X_{F,t} = \int_0^1 Y_{F,t}(z) dz = Y_{F,t}$. With complete pass-through, it holds: $Y_{F,t} = X_{F,t} = (C_{F,t} + I_{F,t}^N + I_{F,t}^H)$. Assuming that domestic bonds are in zero net supply, the current account (in nominal terms) reads as

$$e_t B_t^* = \left(1 + i_{t-1}^*\right) e_t B_{t-1}^* + P_{H,t} NX_{H,t} \tag{37}$$

Finally, labor market clearing requires

$$H_t^d = H_t^N + H_t^H = H_t^s \tag{38}$$

Using the aggregate consumption good as numeraire, we obtain the total value added in the economy as:

$$GDP_t^c = \frac{P_{N,t} Y_{N,t} + P_{H,t} Y_{H,t}}{P_t^c} - (X_{H,t} + X_{N,t}) S_{M,t} \frac{P_H}{P_t^c} \tag{39}$$

4 Optimal Policy and Business Cycle Shocks

This section discusses how the propagation mechanism of business cycle shocks, in a model with multiple imported goods, affects the optimal policy and exchange rate volatility. The domestic monetary authority solves the problem of a benevolent planner maximizing the household's objective function conditional on the first order conditions of the competitive equilibrium. This approach provides the (constrained efficient) equilibrium sequences of endogenous variables solving the Ramsey problem.[8] We present the impulse response functions conditional on the Ramsey policy and on a fixed exchange rate policy for several simplified versions of our benchmark model, to discuss the incentives of the optimal policymaker to deviate from a peg.

4.1 An Economy with Labor as the Only Input and Full Pass-Through

Consider an economy with no capital or intermediate goods, where both traded and non-traded goods are produced only with domestic value added supplied by labor, and with staggered price adjustment in the non-traded good sector only. Households' preferences are defined over a basket of non-traded goods N, and the H and F traded goods, both priced on the international market. Domestic firms supply the N and H good, though the latter can also be imported. We assume CRS production ($\alpha_N = \alpha_H = 0$), and set the parameters ρ_{cn}, γ_{cn} and γ_{ch} at the values estimated using input-output tables data for the Czech Republic (see Table 4). All other parameters are set at the baseline values discussed in the Appendix.

In this economy, the Ramsey allocation approximately stabilizes the markup MC_N in the non-tradable sector, and thus prevents fluctuations in non-tradable goods inflation π_N.[9] Eqs. (22), (28) and the wage equalization across sector resulting from the first order conditions (20) imply that in the decentralized market allocation

$$\frac{A_{N,t}}{A_{H,t}} = \frac{1}{MC_{N,t}} \frac{e_t P^*_{H,t}}{P_{N,t}} \ . \tag{40}$$

The constrained efficient allocation requires

$$\frac{A_{N,t}}{A_{H,t}} \approx \Gamma \frac{e_t P^*_{H,t}}{P_{N,t}} \tag{41}$$

[8] For a discussion of the Ramsey approach to optimal policy, see Schmitt-Grohé and Uribe (2004), Benigno and Woodford (2006), Khan et al. (2003). As in Coenen et al., 2009, in order to compute the Ramsey policy we use a combination or our own MATLAB code and DYNARE (Juillard, 1996).

[9] If we assume full pass-through for imported goods prices, completely stabilizing π_N would replicate the flexible-price allocation, and eliminate the inefficiency arising from volatile markups and price dispersion across varieties of non-traded goods. As shown by various authors (e.g. Benigno and Woodford, 2005, Faia and Monacelli, 2008 and Benigno and Benigno, 2006), the efficient allocation from the point of view of the domestic planner is in general different from the flexible-price allocation. It can be shown that in our economy the incentive to deviate from the flexible price allocation in the efficient equilibrium with complete financial markets stems from the impact of the relative price P_T/P_N on the risk-sharing condition.

where the constant Γ is equal to the steady state markup. Effectively, the Ramsey allocation equates the marginal rate of transformation across traded and non-traded goods to their relative price (up to a constant). Since the price $P_{N,t}$ depends on current and future values of the real marginal cost MC_N, the optimal policy prevents volatility in the output price P_N, t of the sector with staggered price adjustment.

Shocks to sectoral productivity $A_{N,t}$ and $A_{H,t}$ require a change in the relative output price across the two sectors, as implied by eq. (40), which in the Ramsey allocation is achieved through movements in the nominal exchange rate, as shown in the first two rows of Figure 1. A peg generates instead a second nominal price rigidity by fixing the domestic-currency price P_H, and ends up putting the onus of the adjustment required by the equilibrium condition (40) on the real marginal cost MC_N and the non-traded sector price P_N.

Spill-over effects across sectors through wage equalization play a key role in generating inefficient deviations of a peg from the Ramsey policy. A shock to $A_{H,t}$ requires through the cost minimization condition (28), which in this economy simplifies to $W_t^H/P_{H,t} = A_t^H$, a change in the real wage, which under a peg can only be achieved by a change in the nominal wage. This, in turn, requires through the N-sector cost minimization condition (22), equal to $W_t^N/P_{N,t} = MC_t^N A_t^N$, a change in P_N, and inefficient fluctuations in MC_N. Similarly, as can be seen in the third row of Figure 1, a terms of trade shock P_H^* under a peg implies the real marginal cost of production in the H sector decreases for given nominal wage. Since productivity is unchanged, optimality requires an increase in the nominal wage, which spills over to the N production sector. To restore optimality in the N production sector, the nominal price P_N must also increase, generating inefficiency along the adjustment. The Ramsey policymaker chooses instead, in response to any shock directly affecting the efficiency condition (41), to restore equilibrium through movements in the exchange rate.

The role played by sectoral spill-over effects in generating optimal exchange rate volatility can also be assessed by considering the impact of a P_F^* shock, shown in the fourth row of Figure 1. As is the case of a P_H^* shock, the terms of trade P_F/P_H are altered, resulting in the traditional expenditure switching effect between H and F goods, and the T and N-good baskets. The Ramsey policymaker chooses a policy of near-complete stabilization of the exchange rate, allowing P_F and P_T to increase in line with the external shock. Contrary to the case of a terms of trade shock operating through a change in P_H^*, the P_F^* shock does not affect directly the Ramsey efficiency condition (41). The Ramsey policy then does not accommodate the shock through a large change in the nominal exchange rate, since it would require a proportional change in P_N and volatility in markups through eq. (40).

The preference shock D_t and the foreign interest rate shock i_t^* impact all sectors simultaneously, changing proportionally consumption of all goods. The consumption allocation is driven by the exogenous movement in preferences, in the case of a D_t shock, and by the endogenous movement in the real interest rate, in the case of an i_t^* shock. Relative to these driving forces, changes in the nominal exchange rate and in relative prices induced by policy play a limited role, resulting in allocations which are nearly identical under the optimal policy and the fixed exchange rate, as shown in the first two rows of Figure 2.

4.2 The Role of Imported Intermediate Inputs

Consider an economy with full pass-through where intermediates can be substituted for labor in the H sector, while in the N sector labor is the only input in production. We set the parameter γ_v equal to the value estimated using input-output tables data for the Czech Republic (see Table 4), and set $\rho_v = 0.5$. In this economy, movements in the foreign-currency price of intermediates P_M^* play the role of a sectoral shock, which affects the N production sector through the nominal wage adjustment channel. In addition, the introduction of intermediates affects the spill-over of all sectoral shocks, since the share of labor cost in production is reduced by the presence of intermediate inputs. As a consequence, the required wage adjustment in response to any foreign disturbance will be larger, other things equal. We can easily see these two effects by considering the optimal price equation for the H sector when the capital share is zero ($\alpha_H = \alpha_N = 0$). In this case combining equations (26), (27), (28) and (30) we obtain

$$eP_H^* = \left[(\gamma_v) \left(A_{H,t}^{-1} W_t \right)^{\rho_v - 1} + (1 - \gamma_v) \left(e_t P_{M,t}^* \right)^{\rho_v - 1} \right]^{\frac{1}{\rho_v - 1}} \tag{42}$$

A log-linear expansion of this equation yields,

$$\widehat{e_t} - \widehat{W}_t = -\widehat{A}_{H,t} + \frac{(1 - \gamma_v)}{\gamma_v} \widehat{P}_{M,t}^* - \frac{1}{\gamma_v} \widehat{P}_{H,t}^* \tag{43}$$

Eq. (43) shows that shocks to $A_{H,t}$, $P_{M,t}^*$ or $P_{H,t}^*$ will require adjustments to the nominal exchange rate, to the nominal wage or to both. Fixing the exchange rate implies the nominal wage must adjust in response to $P_{M,t}^*$ shocks - as well as in response to $A_{H,t}$ or $P_{H,t}^*$ shocks, as discussed in section 4.1. This adjustment will result in inefficient movements in the price of non-tradable goods. As shown in Figure 2 (third row), in response to an increase in $P_{M,t}^*$ the nominal rigidity in the N sector results in a modest but protracted movement in $P_{N,t}$ under a peg. On the contrary, the optimal policy achieves the same equilibrium fall in the real wage $\frac{W_t}{P_{H,t}}$ through a depreciation, preventing the sectoral spill-over and nearly completely stabilizing $P_{N,t}$.[10]

4.3 The Role of Imperfect Pass-Through

We now consider the impact on the economy with only labor inputs of allowing imperfect pass-through of the foreign price shock P_F^* into the domestic-currency price P_F.

Assume staggered price adjustment in the import sector, which uses the imported F good as an input to meet the domestic demand C_F.Volatility in P_F and the resulting price dispersion are a direct source of inefficiency, and the policymaker has an incentive to stabilize the price of the F good in response to any shock. Figure 2 (fourth row) shows the impulse response of a shock to P_F^*, where we set the per-period probability $(1 - \vartheta_F)$ of resetting the price P_F equal to 0.8. Optimality requires an appreciation of the exchange rate to stabilize the domestic-currency price P_F. The policymaker trades off inefficient movements in prices in the sectors N and F, allowing for some volatility in π_N. This holds true for any shock, since the movements in e_t induced by the policymaker generate volatility in the import sector's marginal cost, and in the retail price P_F, even if the price P_F^* is constant. Thus the Ramsey policymaker finds optimal to mute its response to shocks, in all those cases in which optimality called for depreciation or appreciation of the nominal exchange rate in the full pass-through economy.

In our model, local currency pricing provides the main incentive for policy to deviate from fully stabilizing inflation in the non-traded sector. Nevertheless, our results in the next section show that the price dispersion induced by price changes in the import sector turns out to be of limited consequence for the welfare cost of fixing the exchange rate.

5 The Welfare Impact of the Composition of Imports

Conditional on a constant exogenous volatility, we study how optimal exchange rate volatility and the welfare cost of a fixed exchange rate change as a function of the preference and technology parameters γ_{ch}, γ_{ih}, γ_v, γ_{cn}, γ_{in}, ρ_{cn}, and ρ_{in}. In equilibrium, these parameters map into different

[10] In an economy where both the traded and non-traded sectors utilize imported intermediate inputs, the Ramsey policy calls for a *lower* exchange rate volatility in response to a P_M^* shock, since the shock is symmetric across sectors and the the real wage increase is optimal across all firms.

degrees of openness and different compositions of imports.[11] We present results for economies where the parameters defining the composition of imports vary across the whole admissible range, and for economies where the import and tradable shares in the consumption and investment aggregates, and the share of intermediates in production, are estimated from input-output data.

While we also discuss results on optimal exchange rate volatility for our model economies, our quantitative analysis focuses on the welfare cost of a suboptimal policy - a fixed exchange rate - relative to the outcome of the optimal policy. The cost of deviating from the optimal policy by adopting a peg is, in our opinion, a more useful measure of the impact of the composition of international trade flows on the choices of policymakers.

To measure the welfare level associated with a given policy, we compute the expected lifetime utility conditional on the economy's state variables starting at a level equal to the non-stochastic steady state in time $t = 0$ (see Schmitt-Grohé and Uribe, 2004, for an application of this welfare measure to a closed economy). Define

$$V_0^o = E_0 \sum_{t=0}^{\infty} \beta^t U(C_t^o, H_t^o) \;\; ; \;\; V_0^a = E_0 \sum_{t=0}^{\infty} \beta^t U(C_t^a, H_t^a)$$

where C^o, H^o are the level of consumption and labor associated with the optimal Ramsey plan and C^a, H^a are the level of consumption and labor associated with an alternative policy regime, which we assume given by an exchange rate peg. All policy regimes share the same non-stochastic steady state in a given economy.[12] Define λ as the fraction of non-stochastic steady state consumption C_{SS} that a household would be willing to give up to achieve the utility level associated with the policy regime $i = [o, a]$:

$$V_0^o = E_0 \sum_{t=0}^{\infty} \beta^t U((1-\lambda_o) C_{SS}, H_t^o) \;\; ; \;\; V_0^a = E_0 \sum_{t=0}^{\infty} \beta^t U((1-\lambda_a) C_{SS}, H_t^a)$$

The welfare loss in terms of units of steady state consumption from choosing the alternative policy

[11] We keep the parameter γ_{nv} fixed at a value of one, implying the non-tradable good is produced exclusively with domestic inputs. This assumption is consistent with our estimation for the preference parameters using input-output tables data for 25 OECD countries, discussed in section 5.4, where the numerical algorithm reaches the upper bound for γ_{nv} if the parameter choice is left unconstrained.

[12] For each regime the average state of the economy will be different. Therefore there exists the possibility that the conditional welfare ranking of policies depends on the initial condition. Note that using the unconditional expected lifetime utility as welfare measure runs into the problem that the policy-maker ranks policies based on *different* initial conditions.

a relative to the optimal policy o is then given by:

$$loss = \lambda_a - \lambda_o$$

5.1 Model Parameterization and the Composition of Imports

The parameters γ_{ch}, γ_{ih}, γ_v are equal in steady state to the shares C_H/C_T, I_H^J/I_T^J, X_H/Y_H. Implicitly, the ratios C_H/C_F and I_H/I_F also depend each exclusively upon γ_{ch}, γ_{ih}. The parameters γ_{cn}, γ_{in} do not uniquely define the steady state tradable shares C_T/C, I_T^J/I^J, since these will depend on the endogenous internal real exchange rates $\frac{P_{T,t}^i}{P_{N,t}}$, $\frac{P_{T,t}^c}{P_{N,t}}$ and on the elasticities ρ_{cn}, ρ_{in}. The remaining parameters are chosen in line with the international business cycle literature and with macroeconomic evidence for OECD countries. To facilitate the reading of our theoretical results, we set the consumption and investment aggregator parameters to identical values, assuming $\gamma_{ij} = \gamma_{cj}$ for $j = [N, H]$. We drop this simplifying assumption when we use the input-output tables data to estimate the parameters.

In the model, business cycle fluctuations are generated by three domestic shocks (total factor productivity in the tradable and non-tradable good sector, shifts in household preferences) and four foreign shocks (price of the domestically-produced tradable good, price of the imported intermediate input, price of the imported tradable good, interest rate on foreign-denominated debt). To measure welfare levels as the composition of demand and imports varies, we choose a baseline parameterization for the exogenous shocks' stochastic process (when not observable from the data) that ensures a business cycle behavior consistent with observations from emerging market economies, and assuming monetary policy follows a Taylor rule with i.i.d. shocks. In the baseline parameterization used to calibrate the shocks' volatility, we assume the values for γ_{ch},γ_{ih},γ_v, γ_{cn}, γ_{in}, ρ_{cn}, and ρ_{in} are equal to the estimates obtained from input-output tables data for the Czech Republic (see Table 4). The Appendix provides details on the parameterization and the business cycle properties of the model.

The welfare numbers we report summarize several channels through which the preference and technology parameters impact on the optimal policy. As discussed in the previous section, the parameterization affects the transmission mechanism of shocks across sectors in the economy. In addition, it also affects the incentive to correct for inefficient staggered pricing, since this inefficiency exists only in some sectors of the economy, and the size of each sector depends on the parameterization. Finally, it affects welfare by making the economy more or less exposed to shocks originating in the foreign sector.

Capital accumulation, absent from the simplified model discussed in the previous section, also plays an important role. Allowing production to use capital as an input changes the impact of nominal exchange rate movements, since production of capital in any sector requires in equilibrium all three investment goods, I_N, I_H and I_F. Therefore the optimal policy needs to trade off the expenditure-switching impact on consumption of changes in P_F and P_H resulting from nominal exchange rate movements, with the impact of the same movements on both the cost and the demand for new capital needed for domestic production in any sector. For example, a depreciation in the nominal exchange rate switches demand from foreign to domestic goods, but additionally makes production of domestic goods more costly, because the imperfectly substitutable inputs X_H and, indirectly, I_F and I_H enter into the domestic firms' production function.

5.2 Trade Openness and Welfare

Figure 3 shows welfare isoquants as a function of the share of imported intermediate goods in domestic output (captured by γ_v) and the bias for non-tradable goods in domestic demand (captured by γ_{cn}, where we assume $\gamma_{in} = \gamma_{cn}$) for four separate values of the home-bias parameter γ_{ch} (where we assume $\gamma_{ih} = \gamma_{ch}$). All other parameters are set according to our benchmark parameterization using data for the Czech Republic (see Table 4). Consider the welfare loss as a function of γ_{cn}, for a given value of γ_v. The loss from fixing the exchange rate increases with γ_{cn}. This behavior of the welfare function reflects the cost from pegging the exchange rate as the economy becomes more and more closed. As γ_{cn} increases, the higher share of business cycle volatility explained by domestic shocks requires larger and larger deviations from a stable exchange rate at optimum, and deviating from the efficient policy by following an exchange rate peg becomes more and more costly as the size of the sector N with staggered price adjustment increases its share in consumption and investment.

While Figure 3 suggests that the welfare loss from fixing the exchange rate increases the more the economy is closed to trade, this result does not hold unconditionally in our economy. The same figure shows that as γ_v decreases, so that tradable goods are produced with a *larger* amount of imported intermediates, the welfare loss *increases*, even if the economy is more open to trade with the rest of the world. This behavior reflects a different incentive for the optimal policymaker, highlighted by Mundell (1961) and Friedman (1953). The smaller γ_v, and the larger the share of imported intermediates in domestic production, the larger the role played by the exchange rate in preventing inefficient adjustments in the price of non-tradables. To explain this result we resort once more to the production efficiency condition (43) that holds in an economy with only labor and intermediates as inputs, which we report here for convenience:

$$\widehat{e}_t - \widehat{W}_t = -\widehat{A}_{H,t} + \frac{(1-\gamma_v)}{\gamma_v}\widehat{P}^*_{M,t} - \frac{\widehat{P}^*_{H,t}}{\gamma_v}.$$

The model predicts under a peg a larger movement in the nominal wage the more open is the economy to intermediate imports, and the smaller γ_v, in response to the sectoral shocks $P^*_{H,t}$ and $P^*_{M,t}$. As discussed in section 4.3, the resulting nominal wage volatility spills over to the non-traded sector and results in inefficient volatility in P_N. A flexible exchange rate allows the policymaker to adjust the relative price of tradable and non-tradables to reflect the relative production costs across sectors, avoiding inefficient changes in sticky nominal prices. In summary, being more open through a low γ_{cn} or a low γ_v has opposite effects of our welfare measure.

The relationship between openness, the composition of imports and welfare can be examined directly using the contour plots. The isoquants for our measure of openness - the steady state share of imports to GDP - are overlaid to the welfare isoquants in Figure 3. This figure is best read by starting from any curve corresponding to a particular degree of openness. Moving along the curve different values for the welfare cost of a peg are found. Along the isoquants representing openness, the same degree of openness is consistent with different compositions of the demand and production input mix. The fact that isoquants of the imports/GDP ratio are not parallel to the ones of the welfare loss implies that two countries with the same degree of openness can experience different losses from pegging the exchange rate.[13]

An important observation is that the welfare isoquants in Figure 3 become more parallel to the horizontal axis as γ_{cn} decreases. That is, γ_v becomes less and less relevant for welfare as the economy becomes more biased towards tradables. At the same time, the welfare loss itself becomes smaller for low values of γ_{cn}. This is not a consequence of the fact that the allocation under a fixed exchange rate is closer to the Ramsey plan. The allocation might be very far from the Ramsey plan; but for low values of γ_{cn} the size of one of the two sectors with staggered pricing gets smaller, and monetary policy becomes less effective. Therefore the Ramsey planner has less room to improve on the fixed exchange rate allocation.

[13]Our estimates of γ_v and γ_{cn} capture very well the degree of openess in the sample. Defining $openness \equiv \frac{export}{GDP} + \frac{Imp.Inv.}{GDP} + \frac{Imp.Cons.}{GDP} + \frac{Imp.Interm.}{GDP}$ and regressing $openness$ on γ_{cn} and γ_v we obtain

$$Openness = \underset{[13.5]}{4} \; \underset{[-7.87]}{-3.65}\,\gamma_v \; \underset{[-8.07]}{-2.12}\,\gamma_{cn} : \; R^2 = 0.89,$$

where t-statistics are in square brackets and where we have omitted γ_{in} as its correlation with γ_{cn} is 0.996.

Consider now the impact of γ_{ch}, shown across the four different panels. Under incomplete pass-through a change in γ_{ch} changes the share of the tradeable good absorption across the F and H good, and thus the share of the sector with inefficient staggered price adjustment for given γ_{cn}. In our model, local currency pricing provides the main incentive for policy to deviate from fully stabilizing inflation in the non-traded sector. In the benchmark parameterization, the volatility of π_N under the Ramsey policy is equal to 0.17%. If we assume instead producer currency pricing for the F good, the optimal volatility of π_N drops to 0.007%, thus the Ramsey policy approximately stabilizes the non-tradable sector markup. LCP plays an important role - it drives the Ramsey allocation away from approximating the flexible price allocation. Yet it has only a limited impact on the cost of fixing the exchange rate. Figure 3 shows that while a change in γ_{ch} has a large effect on the openness measure, it has a small effect on the welfare loss for a given level of the imports to GDP ratio.

Similarly to the case of consumption goods, imperfect pass through is close to irrelevant for investment goods. If we allow for changes in the imported tradable share of investment goods only (a change in γ_{ih} keeping γ_{ch} constant), the welfare and imported investment share measure turn out to be uncorrelated for any choice of γ_{in}, γ_{cn}.[14]

A large part of the literature on optimal monetary policy in open economies focuses on the optimal volatility of the nominal exchange rate. We chose to characterize the impact of openness and the import composition on the optimal policy in terms of welfare cost relative to a benchmark policy, since a welfare measure best summarizes the incentive to adopt alternative policies. The same degree of optimal exchange rate volatility can instead map, as openness and the composition of imports changes, into a different welfare cost of deviating from a peg. Nevertheless, our basic result on the irrelevance of standard measures of openness for the choice of monetary policy holds also when using the exchange rate volatility metrics. Figure 4 shows the openness contour plots, as a function of γ_v, γ_{cn}, against the optimal exchange rate volatility. Similarly to the results in Figure 3, the same degree of openness is consistent with different levels of optimal exchange rate volatility. The Figure clearly shows the more limited characterization of optimal policy given by

[14] While the limited role of LCP for our results depends on the interaction of several channels as the trade composition changes, our assumptions on the nature of the inefficiency induced by LCP is also relevant. The nominal rigidity in the non-tradable sector induces undesired variations in labor supply due to output dispersion, while the nominal rigidity in the import sector implies only temporary increases in the cost of importing goods F per unit of effective demand.

the exchange rate volatility. For open economies importing a large enough share of intermediate inputs, the optimal exchange rate volatility is effectively uncorrelated with the non-tradable share in consumption and investment - while the correlation with welfare cost from adopting a peg is positive.

5.3 Home Bias and Optimal Exchange Rate Volatility

We use our parameterized model to discuss the relationship between the home-bias parameter γ_{ch} in the choice of tradable goods, and the optimal volatility of the exchange rate under the Ramsey monetary policy. Figure 5 shows this relationship for different values of the share of imported intermediate goods in domestic output γ_v and the bias for non-tradable goods in domestic demand γ_{cn}.

Faia and Monacelli (2008) find that exchange rate volatility is (monotonically) increasing in the degree of home-bias, in a small open economy model where all goods are tradable and openness is inversely related to the home-bias parameter. Figure 5 shows that in our model the positive relationship between home-bias and optimal exchange rate volatility holds true only under particular combinations of values for the non-tradable bias and intermediate inputs share parameters. When γ_v is low enough, and correspondingly the share of intermediate inputs in domestic production is sufficiently large, exchange rate volatility and home bias are positively correlated, as in Faia and Monacelli (2008). Note that in the context of our model a low γ_{cn} and a small γ_v imply the economy is relatively open for any degree of home-bias. On the contrary, when the share of intermediate inputs in production is low enough (the case of $\gamma_v \geq 0.5$) the relationship between optimal exchange rate volatility and home bias can become negative, depending on the non-tradable bias γ_{cn} in final demand. The result in the stylized model of Faia and Monacelli (2008) relies on the risk-sharing incentive for the Ramsey planner to manipulate the terms of trade. In our model, the existence of sectoral spill-overs implies that the Ramsey planner's incentive to move the exchange rate can decrease or increase as the inputs and demand composition changes, since changes in the composition affect at the same time the propagation mechanism of each shock, and the exposure of the economy to each shock. When all these channels are accounted for, the unconditional relationship between home bias and optimal exchange rate volatility need not hold.

5.4 Welfare Results in Representative Economies

In this section we examine the welfare cost of pegging the exchange rate for specific combinations of the parameters $\gamma_{ch}, \gamma_{ih}, \gamma_{cn}, \gamma_{in}, \gamma_{v}, \rho_{cn}, \rho_{in}$ affecting the demand, import and production composition of the model, rather than having these parameters vary independently across a given range. We estimate parameters' combinations by minimizing the norm of the distance between eight steady state ratios computed from the OECD input-output tables data and those produced by the model. Table 2 compares the moments in the data and as returned by the estimation for two sample countries, Germany and the Czech Republic. We set the other parameters, including the volatility of exogenous shocks, at the values used in our benchmark parameterization. In the estimation we impose Beta priors on the γ and Gamma priors on the ρ parameters. All priors have very large standard deviations. The use of priors reduces the chance that our numerical algorithm generates large differences in parameter estimates starting from small differences in moment conditions. Figure 6 shows the estimates for the seven parameters, conditional on each set of steady state ratios for the 25 countries in our data set.

This experiment is of interest since variability across parameters combinations does not necessarily translate into variability across welfare outcomes for a given policy. Our representative economies may be different across dimensions that prove to be irrelevant for welfare. Additionally, the analysis in the previous section assumed that all parameter combinations, and the implied import composition, are equally likely, while the estimated parameters may be correlated, so that some parameter combinations are not observed at all in the data.

Given our parameterization, the welfare losses from pegging the exchange rate relative to the Ramsey policy range from about 0.06% to about 0.23% of steady-state consumption. Similar values can be found in the literature assessing sub-optimal policies in DSGE models (e.g. Coenen et al., 2009).[15] Figure 7 shows a bubble-plot of the welfare losses in relation to the share of consumption demand for non-tradable goods and the parameter γ_{cn}, the households' bias for non-tradable consumption. The size of the circles' area is proportional to the welfare loss. We assign the name of a country as label to each parameters' combination, but clearly we are examining welfare outcomes for representative economies, rather than for specific countries, since we do not estimate the country-specific volatility of the exogenous shocks driving the business cycle. Table 3 reports

[15] The losses are sensitive to the definition of the tradability measure used to compute input shares. For example using a country-specific tradability threshold equal to the import share of the wholesale and retail sector, as in Bems (2008), the estimated parameters would generate losses that are about three times as large.

the values used to build the plot.

The estimates show that very large economies (Japan, US) - for which the export over GDP ratio is low - are the ones for which the cost of limiting the flexibility in the exchange rate has the higher cost. We do not find, in general, a high correlation between measures of openness and welfare loss, showing that the composition of imports plays an important role. Portugal and Mexico, for example, have similar degree of openness in terms of exports over GDP, yet the cost of pegging the exchange rate is more than twice as large for Mexico than for Portugal. Figure 7 shows instead a large positive correlation between the households' bias for non-tradable consumption γ_{cn} and the cost of pegging the exchange rate. In our model, the tradable share in consumption depends on the steady state value of P_T/P_N and so can differ from γ_{cn}. The figure shows that in our sample the correlation between empirical measures of the non-tradable goods share in consumption and the households' bias parameter γ_{cn} is positive and very large. In our exercise, we find the correlation of the non-tradable goods share in consumption with γ_{cn} and with the welfare loss respectively equal to 0.93 and 0.9.[16]

Our theoretical results showed that the correlation between welfare loss and γ_{cn} only holds conditional on the intermediate input share parameter γ_v, while in the representative economies the correlation holds unconditionally. The result obtained for the estimated parameter combinations is the consequence of the correlation across steady state ratios in the input-output tables data. Figure 8 shows pair-wise scatter plots of the share of intermediate goods in GDP, the share of tradable goods in consumption and the share of tradable goods in investment. Countries with a large non-traded share in the consumption basket tend to have a large non-traded share also in the investment basket. In addition, a large non-traded consumption share in the data is highly correlated with a low share of imported intermediates in GDP.

6 Conclusions

We study the relationship between openness, the optimal volatility of the exchange rate and the welfare cost of an exchange rate peg in a model economy where the same degree of openness can be achieved through different compositions of imports across consumption, investment and intermediate goods. Our paper shows that the optimal volatility of the exchange rate depends on the composition of imports, and that simple measures of the degree of openness can be close to irrelevant for the

[16]In our estimation, the correlation between the welfare loss from a peg, the investment non-tradable share and the non-tradable bias in investment γ_{in} is even larger than for consumption.

ranking of alternative monetary policies. A similar result applies to the degree of home bias, which in simpler models parameterizes the degree of openness.

We conduct our analysis using a DSGE model with multiple imported goods, a tradable and non-tradable sector, and domestic production requiring, through the factor inputs, a mix of all goods. Nominal rigidities in the pricing of non-tradable goods and in part of the import sector allow monetary policy to impact real allocations. Inefficiencies in the import sector pricing provide the main incentive for the Ramsey planner to deviate from full stabilization of the non-tradables price, but have a small impact on the welfare cost of a peg. Inefficiencies in the non-tradable sector pricing and the spill-over of shocks across sectors through labor mobility result, under the optimal policy, in substantial volatility of the nominal exchange rate, especially in response to sectoral shocks. A peg forces instead the adjustment of relative prices after sectoral shocks on the sticky non-tradable price. Overall, we show that in our economy an exchange rate peg leads to large welfare losses if the share of imported intermediates in the domestic production input mix is high, and at the same time the bias towards non-tradable goods is high. In an equally open economy importing mainly consumption or investment goods a peg leads only to a modest welfare loss.

The relevance of our results is supported by the high variance in the composition of demand and international trade flows that we find in the data. We document from the latest release of the OECD input-output tables that differences in the composition of imports across both industrial and emerging economies are substantial, and provide estimates of the tradable and non-tradable input shares in consumption and investment for 25 countries. Using these data, we parameterize the consumption, investment and production input baskets for 25 representative economies to examine how the variability in parameters implied by the data affects the welfare loss from a peg. Our results show that welfare losses ranges between 0.06% and 0.23% of steady state consumption, with relatively closed economies (e.g. US and Japan) scoring the larger losses. Finally, we find that our estimates of the share of non-tradable goods in consumption and investment are good predictors of the welfare cost from adopting a fixed exchange rate policy, despite the fact that in the model the relationship between non-tradable share and welfare loss holds only conditional on the share of imported intermediates in the domestic production input mix.

Appendix

Baseline Parameterization

We assume the values for $\gamma_{ch}, \gamma_{ih}, \gamma_v, \gamma_{cn},\ \gamma_{in},\ \rho_{cn},$ and ρ_{in} are equal to the estimates obtained from input-output tables data for the Czech Republic. Table 4 reports these benchmark values. The remaining parameters are in line with the international business cycle literature and with macroeconomic evidence for OECD countries. The elasticity of substitution ρ_v between the imported intermediate good $X_{H,t}$ and domestic value added $V_{H,t}$ is set equal to 0.5 . We assume that the foreign and domestic goods in the tradable consumption and investment index are closer substitutes, and set $\rho_{ih},\ \rho_{ch}$ equal to 2. The quarterly discount factor β is set equal to 0.99, which implies a steady-state real world interest rate of 4 percent in a steady state with zero inflation. The elasticity of labor supply is set equal to $\frac{1}{2}$, and the ratio of average hours worked relative to total hours equal to $\frac{1}{3}$. We assume 40 percent of domestic non-tradable output is absorbed by the government sector in steady state, while no tradable goods is purchased by the government. This (approximately) consistent with OECD input-output data. The elasticity of Tobin's Q with respect to the investment-capital ratio is set equal to 0.5 . We assume there are no capital adjustment costs in steady state. The quarterly depreciation rate of capital, δ, is assigned the value of 0.025. Following Cook and Devereux (2006) the tradable sector is assumed to be more capital-intensive than the non-tradable sector, with $\alpha_h = 0.67$ and $\alpha_n = 0.33$. The speed of price-adjustment in the non-tradable sector is assumed to be slower than in the US, and on the upper end of estimates for European countries reported by Galí et al. (2001). The unconditional probability $(1 - \vartheta)$ of adjusting prices in any period is set equal to 0.2. With larger values, CPI inflation would be too volatile, given the estimate for the shares of non-tradable consumption and investment goods. The steady-state mark-up in the non-tradable sector is set equal to 10 percent, consistent with macroeconomic evidence for OECD countries. The markup and the price-adjustment speed in the consumption good import sector are assumed identical to the non-traded good sector.

The monetary authority adjusts the nominal interest rate according to the rule:

$$(1 + i_t) = \left[\left(\frac{1 + \pi_t}{1 + \pi_{ss}} \right)^{\omega_\pi} \left(\frac{e_t}{e_{ss}} \right)^{\omega_e} \left(\frac{Y_t}{Y_{ss}} \right)^{\omega_Y} \right]^{(1-\chi)} [(1 + i_{t-1})]^{\chi} \varepsilon_{i,t} \tag{44}$$

where ω_π , $\omega_e, \omega_Y \geq 0$ are the feedback coefficients to CPI inflation, nominal exchange rate, and GDP in units of domestic consumption aggregate (Y_t), $\chi \in [0, 1)$ is the degree of smoothing and $\varepsilon_{i,t}$ is an exogenous shock to monetary policy. The subscript ss indicates the steady-state value of a variable. We set $\omega_\pi = 1,\ \omega_Y = 0.4, \omega_e = 0.1,\ \chi = 0.8.$

The parameterization of the exogenous stochastic processes ensures that he business cycle properties of the model economy are consistent with data on small open emerging market economies. The resulting values are in line with the recent literature on micro-founded open-economy model with nominal rigidities (Galí and Monacelli, 2005, Kollmann, 2002, Kollmann, 1997, Laxton and Pesenti, 2003, Monacelli, 2005).The exogenous stochastic processes for the total factor productivity shock in the tradable and non-tradable good sector, the household preference shifter, the foreign-currency price of the tradable goods H and F and the imported intermediate input, and the foreign interest rate follow an AR(1) specification in logs:

$$a_t^H = \rho_{a^H} a_{t-1}^H + \varepsilon_{a^H,t}$$

$$a_t^N = \rho_{a^N} a_{t-1}^N + \varepsilon_{a^N,t}$$

$$d_t = \rho_d d_{t-1} + \varepsilon_{d,t}$$

$$p_{H,t}^* = \rho_{p_H} p_{H,t-1}^* + \varepsilon_{p_H,t}$$

$$p_{F,t}^* = \rho_{p_F} p_{F,t-1}^* + \varepsilon_{p_F,t}$$

$$p_{M,t}^* = \rho_{p_M} p_{M,t-1}^* + \varepsilon_{p_M,t}$$

$$i_t^* = \rho_{i^*} i_{t-1}^* + \varepsilon_{i^*,t}$$

where $\varepsilon_{j,t}$ is normally distributed with variance $\sigma_{\varepsilon_j}^2$. The productivity shock innovation volatility is set in both sectors equal to $\sigma_a = 0.008$ with $\rho_a = 0.95$. These values are in line with the international business cycle literature, and close to the ones in Gali and Monacelli (2005) and to the average estimate in Kollman (2002) for UK, Japan, Germany over the 1973-1994 sample. The coefficients for the unobservable preference shock process d_t are left as free parameters, and are adjusted to ensure sufficient volatility in domestic output. We set $\rho_d = 0.85$ and $\sigma_d = 0.009$. These values are larger than those in Laxton and Pesenti (2003) ($\rho_d = 0.7$ and $\sigma_d = 0.004$) and similar to the values reported by Monacelli (2005). To parameterize the process for the foreign interest rate we use Eurostat data on the average money market rate in the EU-15, resulting in estimates of $\rho_{i^*} = 0.95$ and $\sigma_{i^*} = 0.001$. The exogenous innovation $\varepsilon_{i,t}$ in the monetary policy rule follows an i.i.d. process, and its standard deviation is set at $\sigma_i = 0.001$.

To parameterize the stochastic process for the foreign prices we use data for the Czech Republic over the period 1994-2002. The time series for p_j^*, $j = F, M$, is obtained from detrended import commodity price indices converted in units of foreign currency (euro) using the nominal effective exchange rate . The weights for the foreign intermediate and consumption goods' price indices are the 1997-2006 average Commodity Composition of Imports as reported by IMF (2002), the Czech

Statistical Office, and the Czech National Bank (July 2006 data). p_H^* is obtained from the aggregate export price index converted in units of foreign currency using the nominal effective exchange rate.

Under the baseline parameterization the volatility of output in percentage terms is 2.64 . Neumeyer and Perri (2005) find an average GDP volatility for Argentina, Brazil, Korea, Mexico, and the Philippines equal to 2.79 percent over the period 1994-2001. Among the eight Central and Eastern European new EU members, GDP volatility ranged from 0.72 percent (Hungary) to 2.83 percent (Lithuania) in the 1998-2002 period (Darvas and Szapary, 2004).

The standard deviation of consumption and net exports is equal to 2.9 and 1.8 (respectively 3.63 and 2.40 across five emerging markets economies, Neumeyer and Perri, 2005). The policy rule implies a large volatility for the nominal exchange rate, equal to 8 percent (Kollmann, 1997 reports an average value of 9.13 percent for Japan, UK, and Germany over the 1973-1994 period).

The volatility of inflation for the composite of tradable goods is 0.68, more than twice as large as the volatility of the non-tradable good inflation (0.31), owing to the larger share of flexible prices in the tradable good sector. The volatility for CPI inflation is equal to 0.55.

Table 1: Non-tradable input shares, demand and import allocation for 25 countries from Input-output tables data.

Country	Imp. inv./gdp	Imp. cons./gdp	Cons./gdp	Inv./gdp	Interm./gdp	N-cons. share	N-inv. share	export/gdp
aut	0.061	0.096	0.507	0.236	0.283	0.237	0.263	0.469
bel	0.062	0.095	0.505	0.204	0.459	0.166	0.208	0.894
can	0.052	0.066	0.518	0.197	0.251	0.31	0.333	0.479
cze	0.083	0.089	0.478	0.274	0.541	0.227	0.288	0.725
deu	0.031	0.056	0.556	0.195	0.197	0.295	0.287	0.391
dnk	0.041	0.066	0.422	0.19	0.127	0.256	0.261	0.487
esp	0.042	0.067	0.569	0.273	0.216	0.378	0.42	0.244
est	0.11	0.122	0.513	0.305	0.588	0.207	0.144	0.807
fin	0.033	0.049	0.442	0.201	0.276	0.513	0.42	0.463
fra	0.026	0.062	0.53	0.197	0.173	0.378	0.406	0.274
gbr	0.035	0.092	0.626	0.169	0.162	0.311	0.393	0.262
grc	0.046	0.103	0.697	0.222	0.184	0.47	0.49	0.179
ita	0.028	0.051	0.571	0.209	0.18	0.449	0.418	0.257
jpn	0.013	0.028	0.567	0.246	0.08	0.687	0.585	0.131
kor	0.056	0.042	0.587	0.314	0.324	0.345	0.269	0.42
mex	0.031	0.035	0.662	0.198	0.196	0.387	0.412	0.252
nld	0.044	0.067	0.47	0.193	0.313	0.241	0.311	0.744
nzl	0.057	0.064	0.563	0.222	0.181	0.329	0.346	0.339
pol	0.068	0.074	0.61	0.221	0.226	0.253	0.24	0.335
prt	0.053	0.107	0.62	0.256	0.244	0.303	0.399	0.26
svk	0.081	0.12	0.529	0.266	0.586	0.183	0.251	0.764
svn	0.09	0.125	0.51	0.266	0.425	0.359	0.362	0.612
swe	0.05	0.056	0.436	0.172	0.278	0.324	0.207	0.492
tur	0.038	0.043	0.716	0.184	0.17	0.217	0.287	0.204
usa	0.015	0.039	0.686	0.197	0.076	0.701	0.577	0.091

Table 2: Moments for Germany and the Czech Republic used in estimation of trade parameters. Input-output tables data and values returned by the estimation.

	Deu		Cze	
Ratio	Model	Data	Model	Data
Imported inv./ gdp	0.034	0.031	0.083	0.083
Imported cons./ gdp	0.061	0.056	0.089	0.089
Cons./gdp	0.47	0.556	0.489	0.478
Inv./gdp	0.313	0.195	0.314	0.274
export over gdp	0.299	0.391	0.711	0.725
Intermediates/gdp	0.204	0.197	0.539	0.541
Non-tradable consumption share	0.293	0.295	0.221	0.227
Non-tradable investment share	0.385	0.287	0.308	0.288

Table 3: Estimated non-tradable bias for consumption and investment goods, and loss from pegging the exchange rate in percent of steady state consumption.

Country	γ_{cn}	γ_{in}	Loss
1) bel	0.104	0.144	0.063
2) est	0.089	0.117	0.065
3) pol	0.154	0.184	0.067
4) aut	0.147	0.188	0.07
5) dnk	0.188	0.218	0.072
6) tur	0.183	0.216	0.075
7) svk	0.105	0.165	0.079
8) swe	0.187	0.208	0.084
9) deu	0.213	0.242	0.089
10) nld	0.188	0.229	0.09
11) cze	0.126	0.2	0.093
12) nzl	0.232	0.267	0.094
13) kor	0.19	0.213	0.094
14) prt	0.23	0.265	0.096
15) can	0.23	0.265	0.101
16) gbr	0.286	0.321	0.107
17) esp	0.272	0.302	0.116
18) fra	0.307	0.341	0.123
19) svn	0.221	0.273	0.128
20) mex	0.325	0.352	0.138
21) grc	0.363	0.386	0.142
22) ita	0.344	0.371	0.143
23) fin	0.375	0.401	0.192
24) jpn	0.56	0.568	0.213
25) usa	0.617	0.63	0.233

Table 4: Benchmark parameter values

Description	symbol	value	Description	symbol	value
Depreciation	δ	0.025	Capital share H	α_H	0.67
Elasticity H-V	ρ_{hv}	0.5	Capital share N	α_N	0.33
Discount factor	β	0.99	Intertemporal elast.	σ	1
Weight on labor	ℓ	24.065	Labor elasticity	η	0.5
Cons. share H-goods	γ_{ch}	0.74	Inv. share H-goods	γ_{ih}	0.65
Inv. bias N-goods	γ_{in}	0.2	Cons. bias N-goods	γ_{cn}	0.13
Elasticity bond premium	–	0.01	Share value added H	γ_v	0.54
Share of gov. spending N	–	0.4	Elasticity of demand	θ	-11
Calvo probability H	ϑ	0.8	Calvo probability F	ϑ_F	0.8
Cons. dem. elasticity H	ρ_{ch}	2	Inv. dem. elasticity H	ρ_{ih}	2
Cons. dem. elasticity N	ρ_{cn}	0.7	Inv. dem. elasticity N	ρ_{in}	0.75
Elasticity Invest. adj. cost	–	0.5			
Shocks					
Autocorrelation a^H	ρ_{a^H}	0.95	Autocorrelation a^N	ρ_{a^N}	0.95
Autocorrelation d	ρ_d	0.85	Autocorrelation policy shock	ρ_i	0
Autocorrelation p_H^*	ρ_{pH}	0.75	Autocorrelation p_F^*	ρ_{pF}	0.71
Autocorrelation i^*	ρ_{i^*}	0.95	Autocorrelation p_M^*	ρ_{PM}	0.85
Std. dev. a^H	σ_{a^H}	0.533%	Std. dev. a^N	σ_{a^N}	0.533%
Std. dev. p_H^*	σ_{pH}	0.735%	Std. dev. d	σ_d	0.9%
Std. dev. i^*	σ_{i^*}	0.05%	Std. dev. policy shock	σ_i	0.05%
Std. dev. p_M^*	σ_{pM}	1.39%	Std. dev. p_F^*	σ_{pF}	2.12%
Policy					
Policy smoothing	χ	0.8	Policy resp. output	ω_y	0.4
Policy resp. exchange rat.	ω_E	0.1	Policy resp. infl.	ω_π	2

Figure 1: Selected responses to four (1%) shocks under peg (circled line) and Ramsey policy (thin line). Economy with labor as the only input and full pass-through. Rows show response to a productivity shock in the tradable and in the non-tradable sector, a shock to the foreign-currency price of the H good, a shock to the foreign-currency price of the F good.

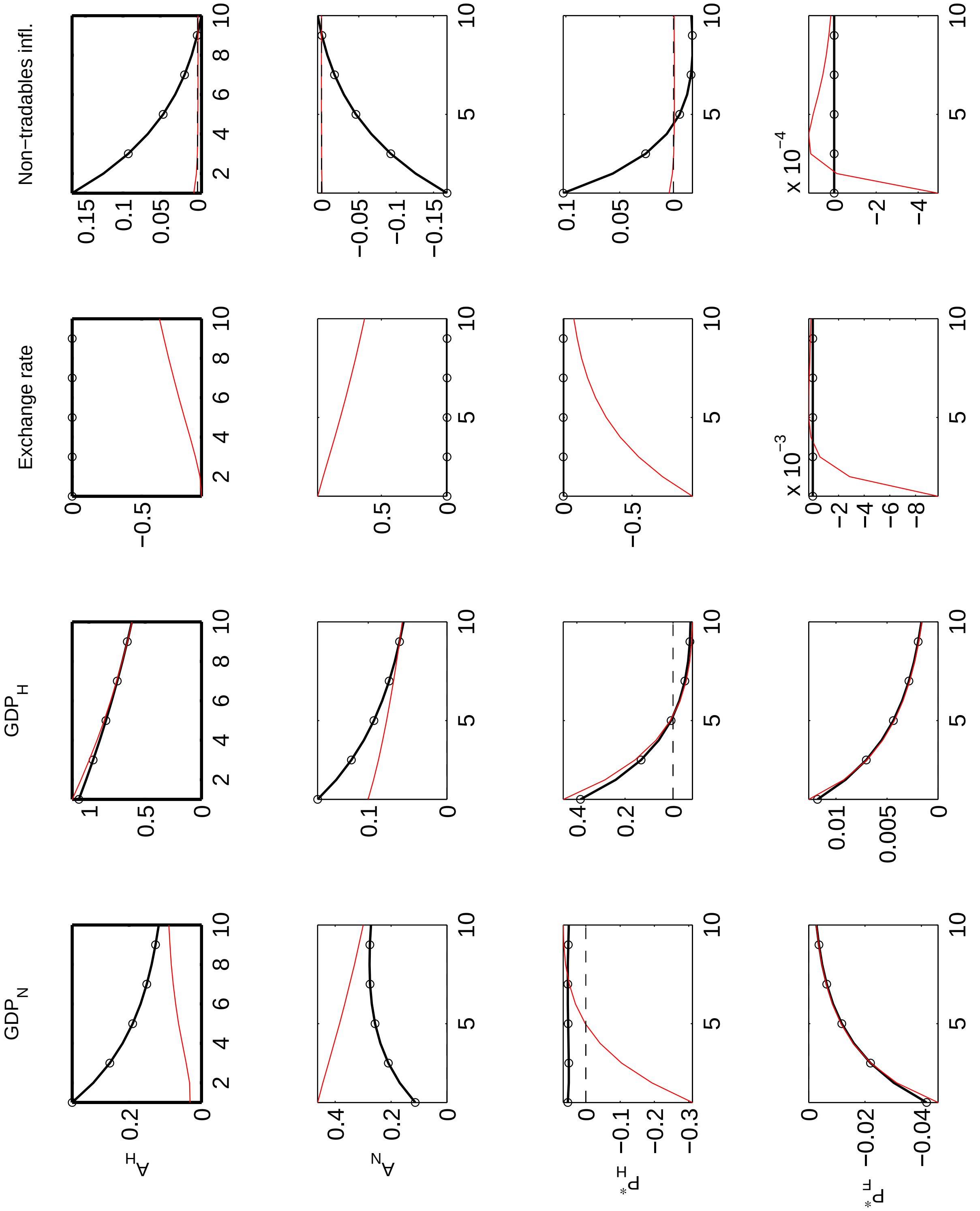


Figure 2: Selected responses to (1%) shocks under peg (circled line) and Ramsey policy (thin line). Rows 1 and 2: preference and a foreign policy shock in economy with labor as the only input and full pass-through. Row 3: shock to foreign-currency price of intermediate input in economy with imported intermediates in H sector. Row 4: shock to foreign-currency price of F good in economy with labor as the only input and incomplete pass-through.

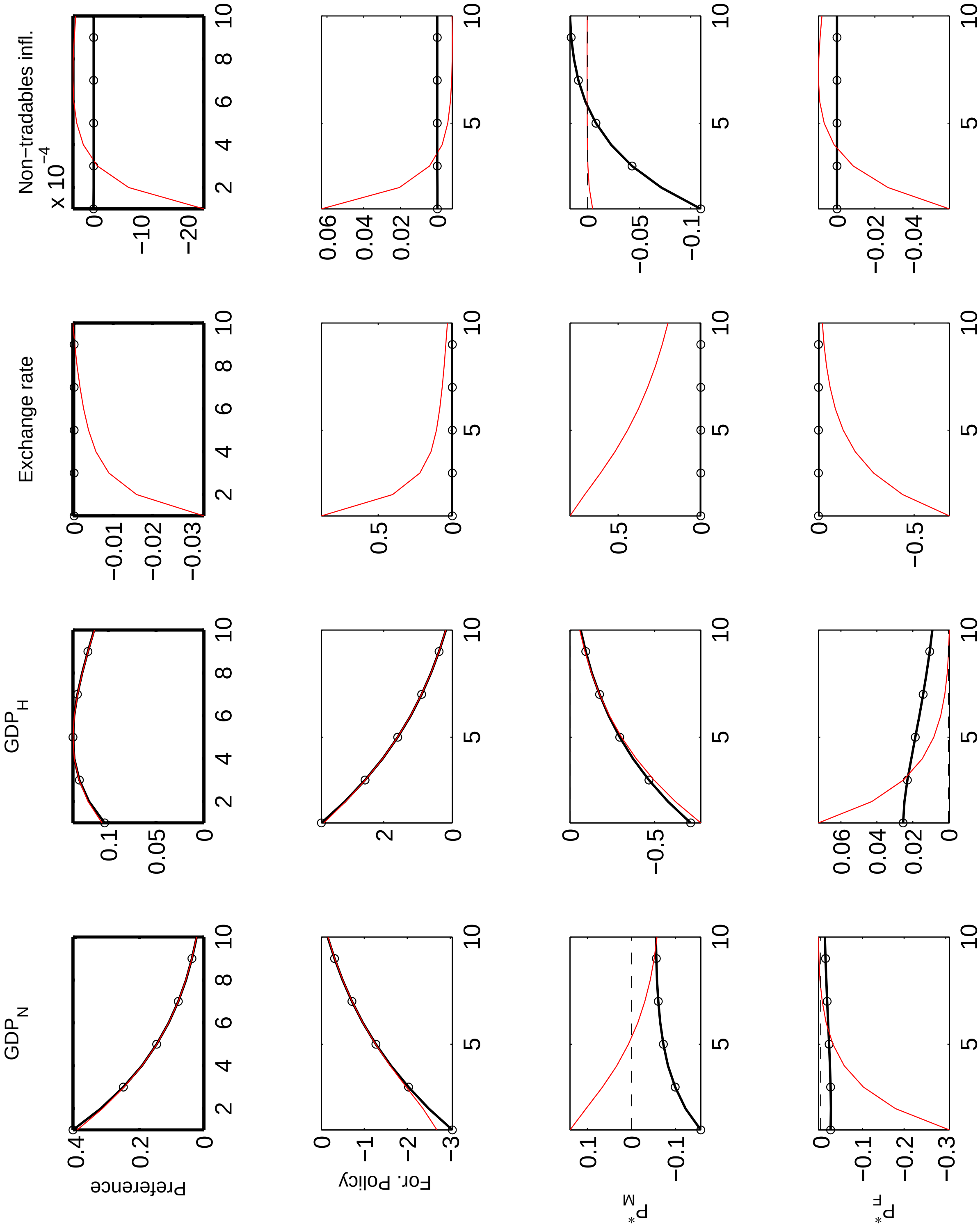


Figure 3: Openness and welfare, contour plots for selected trade parameters (assuming $\gamma_{cn} = \gamma_{in} = \gamma_N$ and $\gamma_{ch} = \gamma_{ih} = \gamma_H$). Welfare measured as loss from a pegged exchange rate relative to optimal policy, in percent of steady-state consumption units.

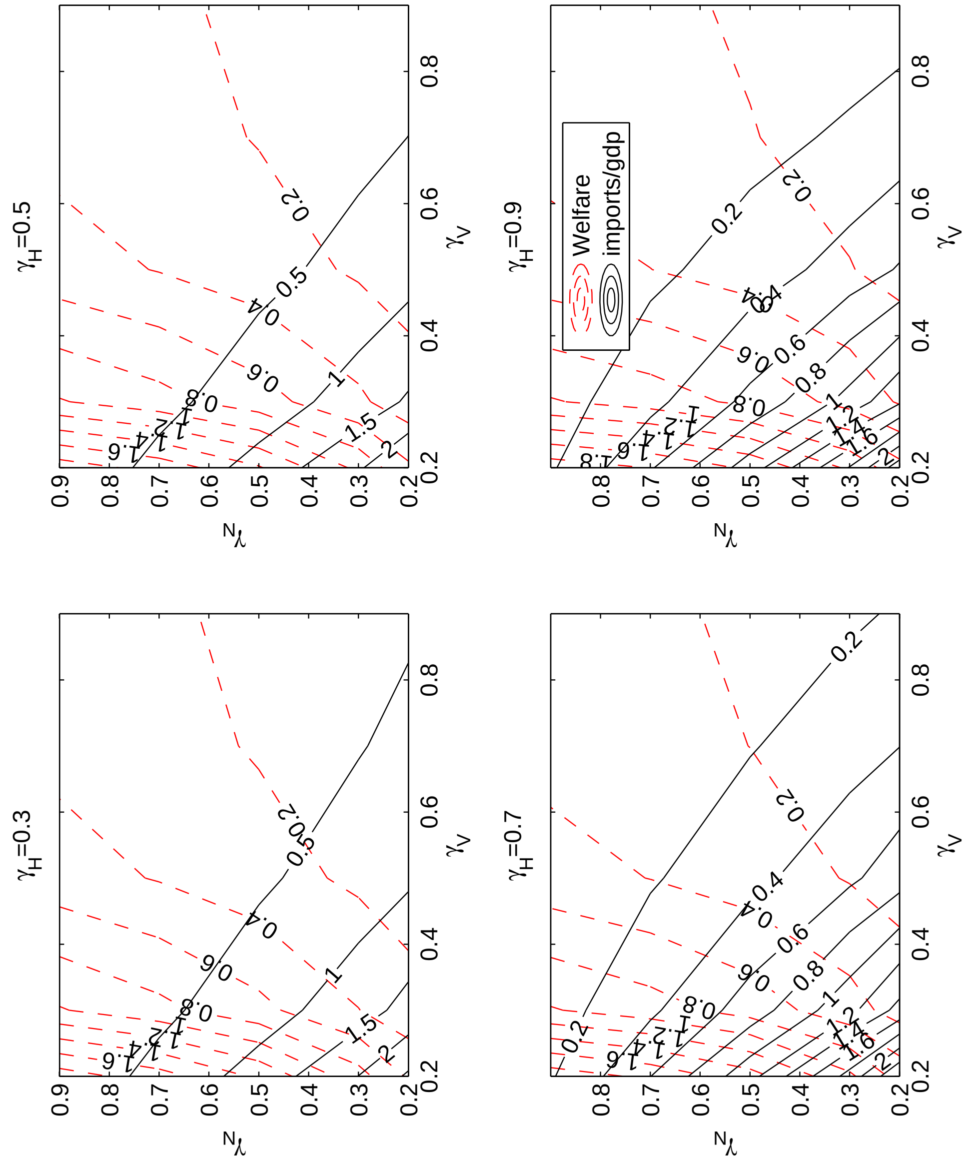


Figure 4: Openness and optimal exchange rate volatility, contour plots for selected trade parameters (assuming $\gamma_{cn} = \gamma_{in} = \gamma_N$ and $\gamma_{ch} = \gamma_{ih} = \gamma_H$). Volatility measured as standard deviation of nominal exchange rate percent depreciation.

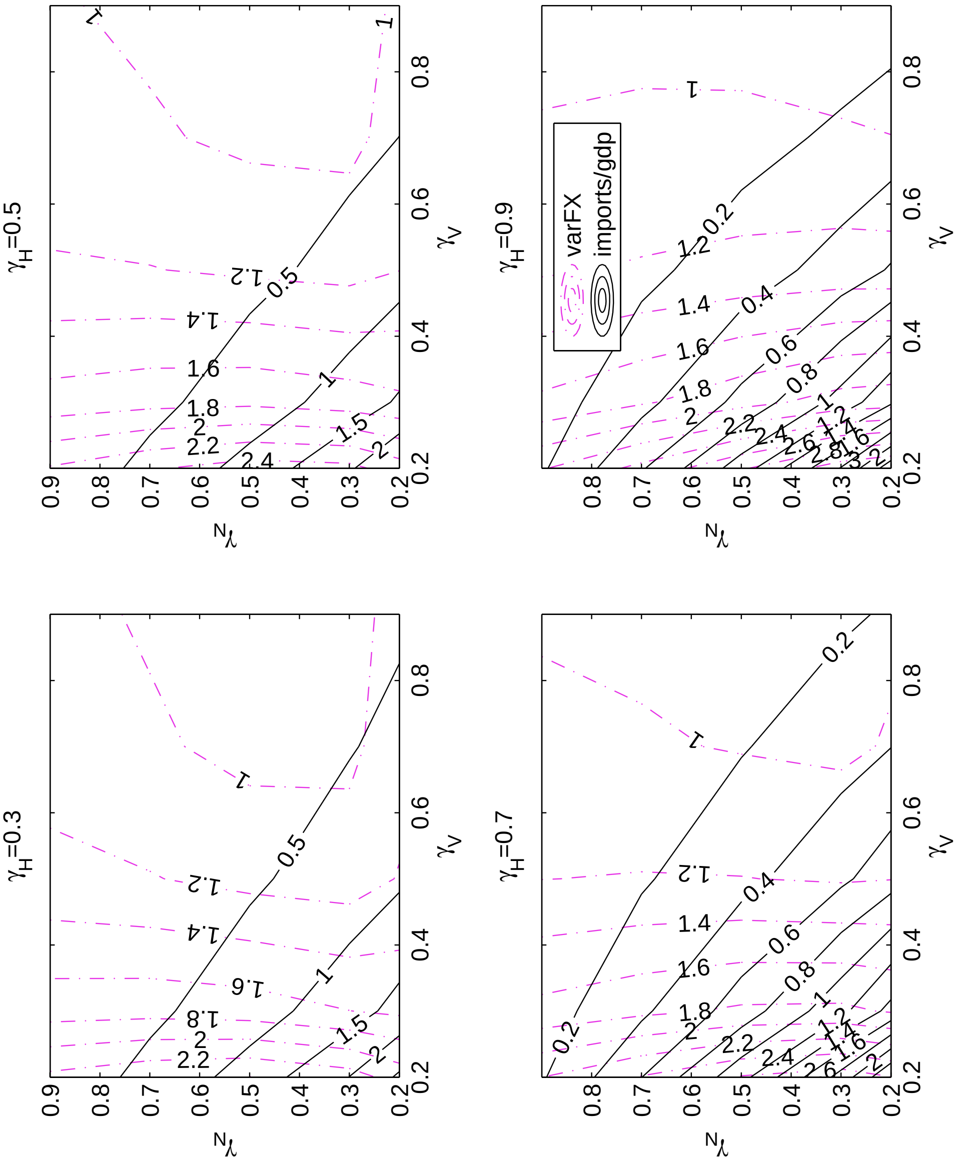


Figure 5: Home-bias γ_H and optimal exchange rate volatility (assuming $\gamma_{cn} = \gamma_{in} = \gamma_N$ and $\gamma_{ch} = \gamma_{ih} = \gamma_H$). Volatility measured as standard deviation of nominal exchange rate percent depreciation.

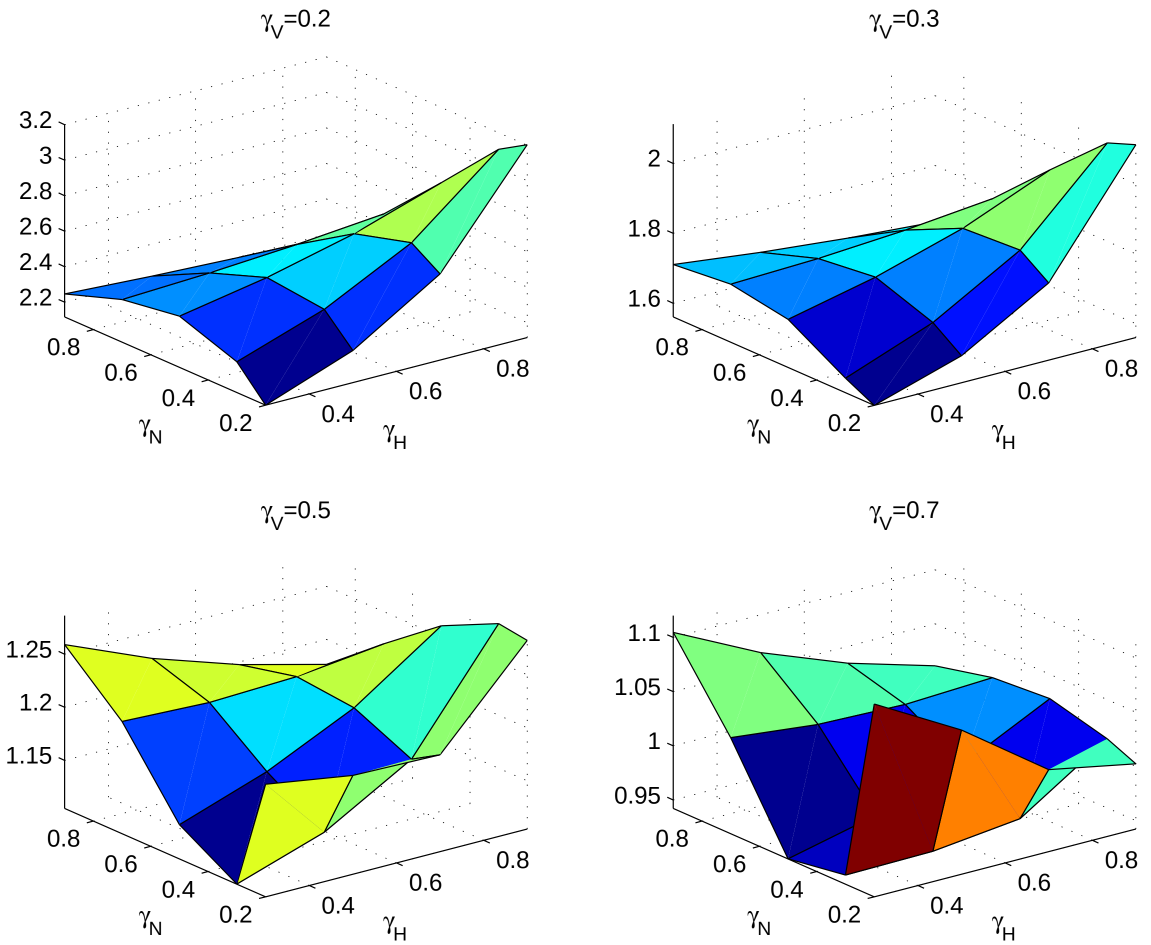


Figure 6: Estimated bias and elasticity parameters from Input-output tables for 25 countries.

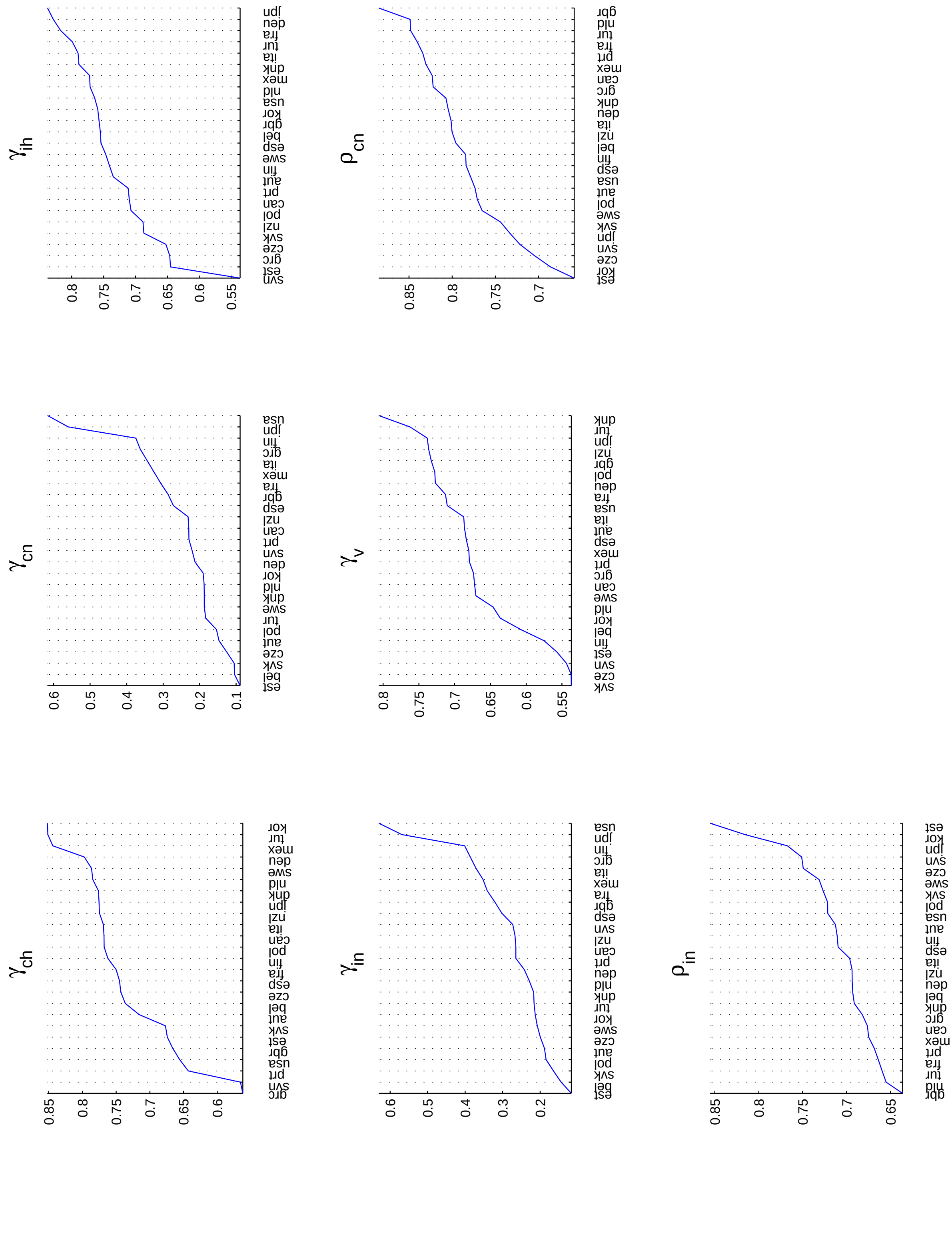


Figure 7: Welfare loss from exchange rate peg vs. non-tradable share in consumption and non-tradable consumption bias γ_{cn} for 25 representative economies with trade parameter combinations estimated from Input-output tables. Loss is proportional to circles' area.

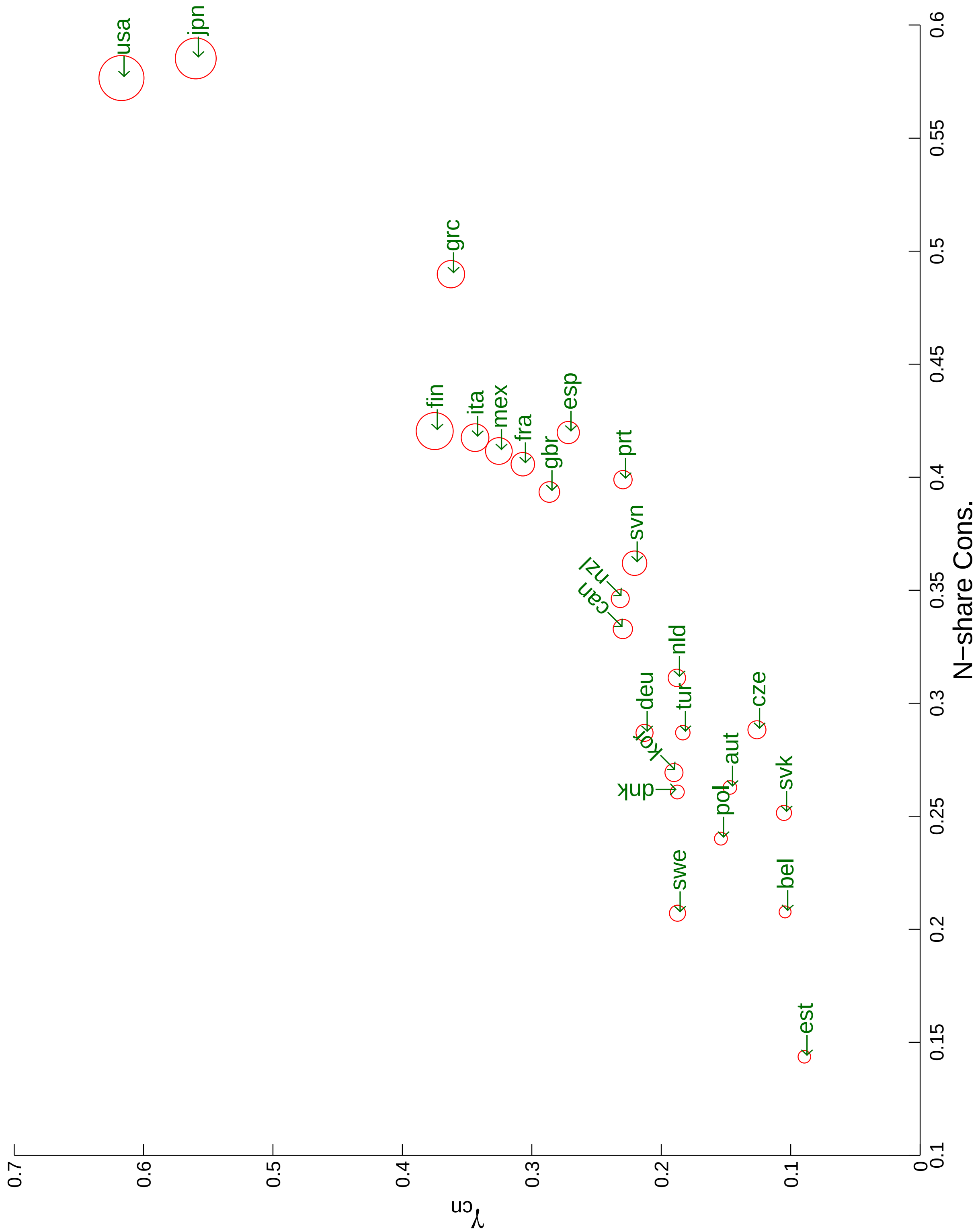
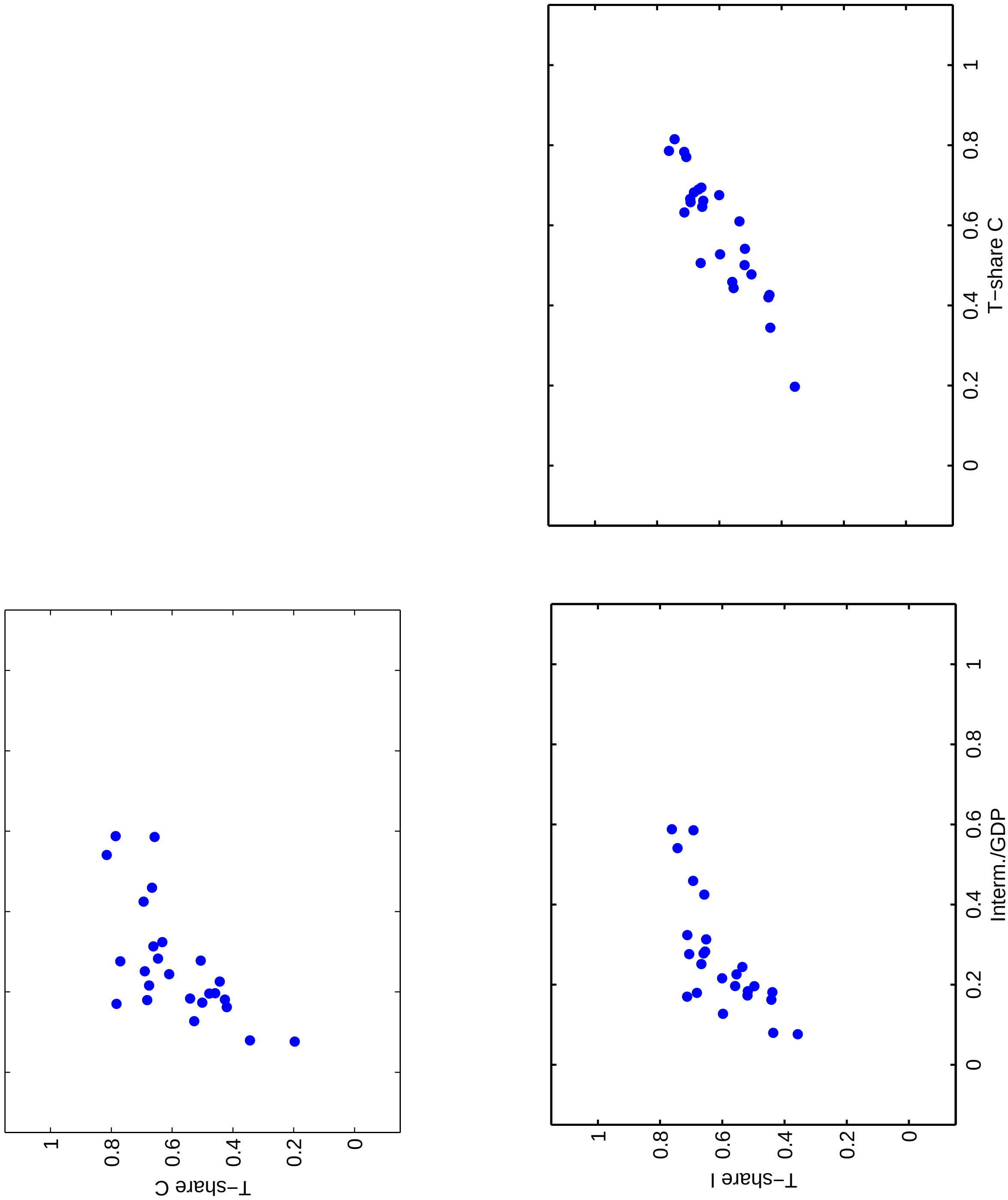


Figure 8: Correlation between tradable share in final demand and intermediate imports for 25 representative economies with trade parameter combinations derived from Input-output tables.



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