Internationalized Production in a Small Open Economy

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Abstract

This paper shows that accounting for internationalized production, modelled as trade in intermediate goods, brings the dynamics of a small open economy closer to that observed in the data. Building a stylized New Keynesian small open economy model, we show that when production is internationalized, movements of international relative prices affect the economy through an additional channel, denoted as the "cost channel". Both qualitatively and quantitatively, this channel (i) acts as an automatic stabilizer since macroeconomic volatility is dramatically reduced (ii) increases the share of output variance explained by foreign shocks consistently with empirical evidence and (iii) implies that the exchange rate pass-through is closer to estimated values.

Keywords: Small open economy, internationalized production, macroeconomic volatility, exchange rate pass–through.

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1 Introduction

Recently the New Keynesian synthesis models have been extensively applied to the study of monetary policy in small open economies.[1] These models, enriched with many frictions (habit in consumption, price and wage indexation), also became the workhorse of empirical studies. Most of these models assume that the traded good is a consumption good. However, a closer look at the data reveals that a non-negligible part of trade occurs at the intermediate goods level. For instance Feenstra (1998) and Hummels, Ishii & Yi (2001) show that the internationalization of production processes has dramatically increased over the last thirty years. Indeed recent EMU data confirm that intermediate goods trade is a major component of total trade, since the degree of intra-zone openness is 4.39% for capital goods, 16.46% for intermediate goods and 9.22% for consumption goods.[2] Moreover, for most inflation targeting small open economies, trade of the intermediate imports represents approximately half of their total trade flows. For example, during the last ten years, the average share of intermediate goods imports in total imports has been around 45% for New Zealand and Australia, and 56% for Chile.[3] These numbers imply that the international transmission of shocks may not only be through consumption decisions of households but also through the internationalization of production structures.

Despite this empirical observation, little attention has been devoted to the role of imported producer inputs in determining business cycle properties of small open economies. This paper aims to fill this gap by analyzing the role of intermediate goods trade within a dynamic stochastic general equilibrium model of a small open economy with imperfect competition and nominal rigidities. Our model follows Galí & Monacelli (2005) but allows the intermediate goods to be traded internationally. The consumption good is thus produced using a composite index of intermediate goods produced in the domestic economy and in the rest of the world. The intensity with which foreign imports are used in the production of consumption goods is governed by one parameter of the final goods production function. Therefore, we can analyze

[1] Some important contributions comprise Clarida, Gali & Gertler (2001), Galí & Monacelli (2005), McCallum & Nelson (2000), Monacelli (2005), Corsetti & Pesenti (2001), Smets & Wouters (2002).

[2] Data available at http://sdw.ecb.europa.eu/.

[3] Data available from Haver.

the role of various levels of intermediate trade on business cycles properties of key domestic variables such as output, inflation and exchange rates.

We document an additional channel through which movements of relative prices and exchange rates are passed through macroeconomic aggregates. As long as intermediate output can be sold internationally, movements in exchange rates modify the demand for domestically produced intermediate goods. Since the relative price of intermediate goods enter the marginal cost of consumption goods producers and, *via* the Phillips Curve, inflation dynamics, exchange rates exert an effect on inflation and output through this additional channel, denoted as the "cost channel". We show that the magnitude of this channel depends on the level of internationalization of production and on the elasticity of substitution between imported and domestically produced intermediate goods in the production function.

We find that the assumption of intermediate goods trade has major consequences on the macroeconomic dynamics caused by standard shocks – such as domestic and foreign productivity shocks, and provides new insights concerning the characteristics of business cycles in a small open economy.

First, the volatility of key variables, such as output, consumption or PPI inflation is dramatically reduced under standard monetary policy rules. Trade in intermediate goods thus appears to act as an automatic stabilizer for the domestic economy.

Second, the share of domestic variables variances explained by foreign shocks increases by several orders of magnitude. Indeed, standard small open economy DSGE models are mostly unable to account for the observed large effects foreign shocks on domestic variables of small open economies. For instance, Justiniano & Preston (2010) estimate a small open economy DSGE model on Canadian data and find that the share of foreign shocks in the variance decomposition is virtually zero. On the contrary, empirical studies suggest that foreign shocks play an important role in the domestic business cycle of small open economies. For instance, Kose, Otrok & Whiteman (2003) document that world factors have a substantial role in country-level economic fluctuations. At the individual country-level, Justiniano & Preston (2010) for Canada and Karagedikli & Thorsrud (2010) for New Zealand, find a sizeable share of foreign shocks in the variance decomposition of domestic variables.

Third, the exchange rate pass-through is reduced and much more consistent with the data when trade occurs at the intermediate level. Complementary to the results of McCallum & Nelson (2000), the exchange rate pass-through to consumer price inflation is affected both by the share of intermediate goods imports in total imports and by the elasticity of substitution between domestic and foreign intermediate goods.

The remainder of the paper is organized as follows. Section 2 summarizes some related literature. Section 3 details the theoretical model. Section 4 presents the steady state and derives a log-linearized version of the model. Section 5 analyzes the dynamics of the economy after standard domestic and foreign productivity shocks. Section 6 discusses the cyclical properties of the model and Section 7 concludes.

2 Related literature

Theoretically, Findlay & Rodriguez (1977) are among the first to study the economic policy implications of introducing an imported intermediate input into an open economy model. They focus on fiscal policy issues in an otherwise standard Mundell-Fleming model and show that oil trade may give some stabilization power to fiscal policy even in a flexible exchange rate system. More recently, several authors consider the role of multinational production on the dynamics of inflation and exchange rates and on the design of monetary policy.[4] In most of these contributions, prices are preset and monetary aggregates are considered as the monetary policy instruments. In contrast, our model allows for staggered price setting *à la* Calvo and monetary policy is conducted using interest rate rules, as in most modern central banks.

The closest to our model is Huang & Liu (2007) who consider the role of intermediate goods trade with multiple stages of processing in a two-country model. They show that their model can improve the standard open-economy model in several dimensions. However, the focus of their paper, is the change in the transmission of monetary policy shocks under internationalized production. Instead our focus in this paper is the transmission of productivity shocks. In addition, they only report the correlations of domestic variables with foreign varaibles using

[4]See for example Cavallari (2004), Shi & Xu (2007), Devereux & Engel (2007).

data simulated in presence of demand shocks and don't report the variance decomposition of domestic variables.

Finally, McCallum & Nelson (2000) consider a model in which imports are solely used in the production process together with domestic labor. International trade thus occurs exclusively at the intermediate level and producer price inflation and consumer inflation are perfectly identical. They argue that this simple setting is able to replicate the stylized fact about the exchange rate pass-through to prices, which is lower in the data than in standard models, such as Galí & Monacelli (2005). Our model can be seen as a generalization of their model, in that we can calibrate the share of intermediate goods trade in total trade flows to intermediate values.

3 The model

Our model closely follows Galí & Monacelli (2005) except for the role of the intermediate goods sector. The world economy is formed by a continuum of small open economies. The optimality conditions characterizing the optimal decision of households and firms are identical across countries and the size of each economy is small relative to the rest of the world. In terms of notation, the counterpart of a variable y in domestic economy is noted y^* for the rest of the world.

Households The home country is populated by infinitely-living households whose number is normalized to one. The representative household of the home country maximizes the following welfare index

$$E_0 \sum_{t=0}^{\infty} \beta^t u\left(c_t, n_t\right) \tag{1}$$

subject to the budget constraint

$$E_t\left\{\ell_{t,t+1} b_{t+1}\right\} + p_{c,t} c_t = b_t + \chi_t + w_t n_t + tax_t \tag{2}$$

and subject to the appropriate transversality condition on the portfolio. Let λ_t denote the multiplier associated with the budget constraint.

In (1), the parameter β is the subjective discount factor, c_t denotes the aggregate consumption, and n_t the quantity of labour competitively supplied to the firms. In (2), w_t is the nominal wage rate, $\chi_t = \int_0^1 \chi_t(j)dj$ denotes the claims on consumption goods producers' profits, b_t is the value of a portfolio of state contingent assets hold in period $t-1$, $\ell_{t,t+1}$ is the stochastic discount factor for one-period ahead nominal payments attached to the portfolio, and $p_{c,t}$ is the consumer price index (CPI). Finally, tax_t is a lump-sum transfer.

The representative household chooses c_t, n_t, and b_{t+1}. First order conditions imply

$$-\frac{u_{n,t}}{u_{c,t}} - \frac{w_t}{p_{c,t}} = 0 \tag{3}$$

$$\beta\left(\frac{u_{c,t+1}}{u_{c,t}}\right)\left(\frac{p_{c,t}}{p_{c,t+1}}\right) = \ell_{t,t+1}. \tag{4}$$

Equation (3) is a standard open economy labor supply function, describing the intratemporal trade-off between consumption and leisure by equating the marginal rate of substitution between consumption and leisure to the real wage. Equation (4) is the Euler equation relating the intertemporal choice of consumption as a function of the CPI inflation rate and the return on the financial portfolio. Denoting $r_t = \frac{1}{E_t\{\ell_{t,t+1}\}}$ as the gross return on a riskless one-period bond, and taking conditional expectations on both sides of (4), the standard Euler equation writes

$$r_t \beta E_t\left\{\left(\frac{u_{c,t+1}}{u_{c,t}}\right)\left(\frac{p_{c,t}}{p_{c,t+1}}\right)\right\} = 1$$

After Galí & Monacelli (2005), we assume home bias in the final consumption bundles. The aggregate consumption index includes consumption of goods produced in the home country (h) and consumption of goods produced in the rest of the world (f)

$$c_t = \left[(1-\alpha)^{\frac{1}{\mu}}\left(c_{h,t}\right)^{\frac{\mu-1}{\mu}} + \alpha^{\frac{1}{\mu}}\left(c_{f,t}\right)^{\frac{\mu-1}{\mu}}\right]^{\frac{\mu}{\mu-1}}.$$

We assume that the law of one price holds. The companion consumption price index is thus

$$p_{c,t} = \left[(1-\alpha)\left(p_t\right)^{1-\mu} + \alpha\left(\varepsilon_t p_t^*\right)^{1-\mu}\right]^{\frac{1}{1-\mu}}$$

where ε_t is the nominal exchange rate, defined as the price of a unit of the foreign currency in terms of the domestic currency and where $(1-\alpha) \in [0,1]$ is the home bias in consumption. α also measures the share of imported consumption goods in total consumption, and thereby is directly related to the degree of openness of consumption goods markets. In these expressions, μ is the elasticity of substitution between domestic and foreign goods. We define the terms of trade and the real exchange rate respectively as[5]

$$s_t = \frac{\varepsilon_t p_t^*}{p_t}, \text{ and } q_t = \frac{\varepsilon_t p_{c,t}^*}{p_{c,t}}.$$

The standard Dixit & Stiglitz (1977) consumption subindexes are

$$c_{h,t} = \left[\int_0^1 c_{h,t}(j)^{\frac{\theta-1}{\theta}} dj\right]^{\frac{\theta}{\theta-1}}, \qquad c_{f,t} = \left[\int_0^1 c_{f,t}(j)^{\frac{\theta-1}{\theta}} dj\right]^{\frac{\theta}{\theta-1}}$$

where $c_{h,t}(j)$ (respectively $c_{h,t}(j)$) is the consumption of a typical variety j produced in the home country (resp. in rest of the world) by the representative consumer and $\theta > 1$ is the elasticity of substitution between national varieties of consumption goods.

The optimal allocation of consumption between home and and foreign goods gives rise to following demand function according to which individual consumption depend on the relative price of each good and on the aggregate consumption:

$$c_{h,t} = (1-\alpha)\left(\frac{p_t}{p_{c,t}}\right)^{-\mu} c_t, \qquad c_{f,t} = \alpha\left(\frac{p_{f,t}}{p_{c,t}}\right)^{-\mu} c_t,$$

Accordingly, optimal variety demands depend on the relative prices of varieties and on the aggregate level of consumption for home and foreign goods:

$$c_{h,t}(j) = \left(\frac{p_t(j)}{p_t}\right)^{-\theta} c_{h,t}, \qquad c_{f,t}(j) = \left(\frac{p_{f,t}(j)}{p_{f,t}}\right)^{-\theta} c_{f,t},$$

Risk-sharing Under the assumption of complete international markets of state-contingent assets, a relation similar to Equation (4) holds in the rest of the world

$$\beta\left(\frac{u_{c^*,t+1}}{u_{c^*,t}}\right)\left(\frac{p_{c,t}^*}{p_{c,t+1}^*}\right)\left(\frac{\varepsilon_t}{\varepsilon_{t+1}}\right) = \ell_{t,t+1}$$

which, combined with Equation (4) gives the following risk-sharing condition

$$\frac{u_{c,t}^*}{u_{c,t}} = \epsilon\frac{\varepsilon_t p_{c,t}^*}{p_{c,t}} \tag{5}$$

Equation (5) states that relative marginal utilities are related to the real exchange rate up to a constant ϵ that depends on initial conditions for the relative net foreign asset position. Assuming symmetric initial conditions simply amounts to setting $\epsilon = 1$, which is consistent

[5]The definition of the terms of trade is meant to be consistent with the definition of the real exchange rate.

with the symmetric steady state around which we study the dynamic properties of the model. Finally, combining both Euler equations with (5) implies that the uncovered interest rate parity holds, i.e.

$$r_t = r_t^* E_t \{\varepsilon_{t+1}\} / \varepsilon_t.$$

Firms Two types of producers operate in this economy: intermediate goods producers and consumption goods producers. In both the small open economy and in the rest of the world, intermediate goods producers operate on perfectly competitive markets. Intermediate goods producers use national labor according to a linear production function

$$x_t = a_t l_t$$

where a_t is the productivity of labor, following an AR(1) process with iid innovations of constant variance. Firms sell their products exactly at their nominal marginal production cost, w_t/a_t. Consumption goods producers operate on monopolistically competitive markets. Each producer is the single supplier of a variety produced by combining domestic and foreign intermediate goods according to

$$y_t(j) = \left[(1-\gamma)^{\frac{1}{\phi}} (x_{h,t}(j))^{\frac{\phi-1}{\phi}} + \gamma^{\frac{1}{\phi}} (x_{f,t}(j))^{\frac{\phi-1}{\phi}} \right]^{\frac{\phi}{\phi-1}}.$$

In this expression, $x_{h,t}(j)$ (resp. $x_{f,t}(j)$) is the quantity of intermediate goods produced in the home country (resp. in the rest of the world) demanded by consumption goods producer j in the home country. $(1-\gamma) \in [0,1]$ is the home bias in the production of consumption goods and ϕ is the elasticity of substitution between intermediate goods produced in the home country and in the rest of the world. As long as $\gamma > 0$, consumption goods producers trade intermediate goods along the production process, the production is internationalized and the corresponding nominal marginal production cost is

$$mc_t = \left[(1-\gamma) (w_t/a_t)^{1-\phi} + \gamma (\varepsilon_t w_t^*/a_t^*)^{1-\phi} \right]^{\frac{1}{1-\phi}}.$$

Prices of consumption goods producers are governed by Calvo (1983) contracts. Each period, a fraction $1-\eta$ of randomly selected firms is allowed to set new prices while the remaining fraction η of firms keeps selling prices unchanged. The corresponding optimal price set by a typical domestic firm allowed to reset is

$$\overline{p}_t(j) = \varphi \frac{\sum\limits_{v=0}^{\infty} (\eta\beta)^v E_t \{\lambda_{t+v} y_{t+v}(j) mc_{t+v}\}}{\sum\limits_{v=0}^{\infty} (\eta\beta)^v E_t \{\lambda_{t+v} y_{t+v}(j)\}}$$

where, $y_t(j)$ is the aggregate demand addressed to firm j and $\varphi = \frac{\theta}{(\theta-1)(1-\tau)}$ is the steady state mark-up signalling the distortion of the first-best allocation caused by monopolistic competition. τ is a constant tax/subsidy that may compensate this distorting effects. Aggregating among final firms and given that Calvo producers set the same price when authorized to reset, the aggregate production price index is

$$p_t = \left[(1-\eta)\, \overline{p}_t(j)^{\ 1-\theta} + \eta p_{t-1}^{1-\theta} \right]^{\frac{1}{1-\theta}}.$$

Rest of the world The rest of the world is characterized by identical equilibrium conditions but is considered as a closed economy, i.e. the small open economy does not impact on the rest of the world.

Equilibrium. We define the aggregate output as $y_t = \left[\int_0^1 y_t(j)^{\frac{\theta-1}{\theta}} dj \right]^{\frac{\theta}{\theta-1}}$. The assumption that the small open economy has negligible effects on the CPI in the rest of the world implies $p^*_{c,t} \simeq p^*_t$. Similarly, the domestic economy is too small to affect the marginal cost of foreign consumption goods producers, i.e. $mc^*_t = \frac{w^*_t}{a^*_t}$. Consequently, using the definition of CPIs, the definition of consumption goods terms of trade and making use of the risk-sharing condition, *i.e.* $\frac{u^*_{c,t}}{u_{c,t}} = q_t$, we can eliminate foreign consumption from the market clearing condition of consumption goods produced in the domestic economy

$$y_t = f(c_t, q_t) = g(c_t, s_t).$$

The market clearing condition of consumption goods produced in the rest of the world yields

$$y^*_t = c^*_t.$$

By the same reasoning, the market clearing condition of domestically produced intermediate goods is

$$\begin{aligned} x_t &= (1-\gamma)\left((1-\gamma) + \gamma \rho_t^{1-\phi} \right)^{\frac{\phi}{1-\phi}} y_t + \gamma \rho_t^{\phi} y^*_t \\ &= (1-\gamma)\left((1-\gamma) + \gamma \rho_t^{1-\phi} \right)^{\frac{\phi}{1-\phi}} y_t + \gamma \rho_t^{\phi} c^*_t \end{aligned}$$

where ρ_t denotes the intermediate goods terms of trade, defined as

$$\rho_t = \frac{\varepsilon_t w_t^* / a_t^*}{w_t / a_t}.$$

The market clearing condition of intermediate goods produced in the rest of the world is

$$x_t^* = a_t^* l_t^* = y_t^*$$

Finally, labour markets clearing conditions are

$$n_t = l_t, \quad n_t^* = l_t^*.$$

4 Dynamic properties

Preferences Considering the dynamic properties of the model requires to specify the utility function of the households. We assume standard CRRA separable preferences,

$$\begin{cases} u\left(c_t, n_t\right) = \frac{c_t^{1-\sigma}}{1-\sigma} - \frac{n_t^{1+\psi}}{1+\psi} \text{ if } \sigma > 1 \\ u\left(c_t, n_t\right) = \log c_t - \frac{n_t^{1+\psi}}{1+\psi} \text{ if } \sigma = 1 \end{cases}$$

where σ is the inverse of the intertemporal elasticity of substitution in consumption and ψ is the inverse of the elasticity of labor supply.

Steady state In the steady state, $x_t = x$, $\forall x$. We focus on a symmetric steady state and assume $c^* = c$ so as to get $s = q = 1$. Furthermore, assuming $\tau = (1-\theta)^{-1}$, such that the tax rate is chosen to eliminate distortions emerging from the existence of monopoly power, the steady state is characterized by,

$$r = \beta^{-1},\ y = c = a^{\frac{1+\psi}{\psi+\sigma}},\ n = a^{\frac{1-\sigma}{\psi+\sigma}}.$$

Log-linearization We log-linearize the model around the steady state. A hat denotes the log-deviation of a variable from its steady state. The log-linearized equilibrium conditions are given in Table 1.

Monetary policy The model is closed by assuming that monetary policy is conducted through a standard Taylor-type nominal interest rate rule

$$\widehat{r}_t = \varphi_\pi \widehat{\pi}_{c,t}.$$

Table 1. The log-linearized model

Euler equation and risk sharing
$\sigma E_t\left\{\widehat{c}_{t+1}\right\}-\sigma\widehat{c}_t=\widehat{r}_t-E_t\left\{\widehat{\pi}_{t+1}+\alpha\Delta\widehat{s}_{t+1}\right\}$
$\sigma\left(\widehat{c}_t-\widehat{c}_t^*\right)=(1-\alpha)\widehat{s}_t$
NK Phillips curves
$\widehat{\pi}_t=\beta E_t\left\{\widehat{\pi}_{t+1}\right\}+\frac{(1-\eta\beta)(1-\eta)}{\eta}\left(\psi\widehat{n}_t+\sigma\widehat{c}_t-\widehat{a}_t+\alpha\widehat{s}_t+\gamma\widehat{\rho}_t\right)$
$\widehat{\pi}_t^*=\beta E_t\left\{\widehat{\pi}_{t+1}^*\right\}+\frac{(1-\eta\beta)(1-\eta)}{\eta}\left(\psi\widehat{n}_t^*+\sigma\widehat{c}_t^*-\widehat{a}_t^*\right)$
Consumption goods market clearing
$\widehat{y}_t=\widehat{c}_t+\sigma^{-1}\alpha\left(\sigma\mu+(1-\alpha)(\sigma\mu-1)\right)\widehat{s}_t$
$\widehat{y}_t^*=\widehat{c}_t^*$
Intermediate goods market clearing
$\widehat{a}_t+\widehat{n}_t=(1-\gamma)\widehat{y}_t+\gamma\widehat{y}_t^*+\phi\gamma\left(1+(1-\gamma)\right)\widehat{\rho}_t$
$\widehat{a}_t^*+\widehat{n}_t^*=\widehat{y}_t^*$
Terms of trade and exchange rates
$\widehat{\rho}_t=(1-\alpha)\widehat{s}_t+\psi\left(\widehat{n}_t^*-\widehat{n}_t\right)+\sigma\left(\widehat{c}_t^*-\widehat{c}_t\right)-\left(\widehat{a}_t^*-\widehat{a}_t\right)$
$\widehat{q}_t=(1-\alpha)\widehat{s}_t$
$\Delta\widehat{s}_t=\Delta\widehat{\varepsilon}_t+\widehat{\pi}_t^*-\widehat{\pi}_t$
$E_t\left\{\Delta\widehat{\varepsilon}_{t+1}\right\}=\widehat{r}_t^*-\widehat{r}_t$
Exogenous shocks
$\widehat{a}_{t+1}=\rho_a\widehat{a}_t+\xi_{a,t+1}$
$\widehat{a}_{t+1}^*=\rho_{a^*}\widehat{a}_t^*+\xi_{a^*,t+1}$

We also check the robustness of our results in the case where the central bank strictly targets the PPI inflation rate, i.e.

$$\widehat{r}_t=\varphi_\pi\widehat{\pi}_t.$$

In the foreign economy, as $p_{c,t}^*=p_t^*$, monetary policy is just

$$\widehat{r}_t^*=\varphi_\pi\widehat{\pi}_t^*$$

Parameterization The model is quarterly. We assume $\beta=0.99$, implying an annual steady state real interest rate of 4%. We adopt a log-utility function in consumption by setting $\sigma=1$. Consistently with Galí & Monacelli (2005), the parameter governing the disutility of labour (ψ) is set to 3, implying that labour supply elasticity is 1/3. In accordance with aggregate estimates, we set the elasticity of substitution between domestic and foreign goods in the consumption bundle to $\mu=1.5$ (see Backus, Kehoe & Kydland (1993)). This value is fairly standard and aims at matching the volatility of the trade balance. It is worth emphasizing that we depart from the case where the domestic economy is fully insulated from foreign shocks, namely the case where $\sigma=\mu=1$. In the intermediate sector production function, we assume that $\phi=1$ in the benchmark case but conduct a full sensitivity analysis to variations in the value of this parameter. Under all versions of the model, we keep the

Table 2. Parameters value

Discount factor	$\beta = 0.99$
Risk aversion	$\sigma = 1$
Elasticity of labour supply	$\frac{1}{\psi} = \frac{1}{3}$
Total trade openness	$\alpha + \gamma = 0.3$
Intermediate goods trade openness	$\gamma \in [0, 0.3]$
Consumption goods trade openness	Adjusted
Elasticity of substitution of intermediate goods	$\phi = 1$
Elasticity of substitution of consumption goods	$\mu = 1.5$
Duration of price contracts	$\frac{1}{1-\eta} = 4$
Reaction of monetary policy to inflation	$\varphi_\pi = 1.5$
Persistence of domestic productivity shocks	$\rho_a = 0.47$
Persistence of foreign productivity shocks	$\rho_{a^*} = 0.75$
Standard deviation of domestic productivity shocks	$\sigma(\xi_a) = 1.05\%$
Persistence of domestic productivity shocks	$\sigma(\xi_{a^*}) = 0.45\%$

share of imports in total production equal to 0.3. As a consequence, when production is not internationalized, $\alpha = 0.3$. When we account for intermediate goods trade – when γ is positive, we adjust α to keep the share of total imports in output constant. In our baseline model with internationalized production, we assume that half of the imports are intermediate goods imports, i.e. $\alpha = \gamma = 0.15$. We set the price rigidity parameter to $\eta = 0.75$ implying that the average duration of prices of is 4 quarters. Concerning the monetary policy rules, the elasticity of the nominal interest rate to the inflation rate is set to $\varphi_\pi = 1.5$ (see Clarida et al. (2001)). Finally, we fit an first-order autoregressive process on (model consistent) TFP measures for the US and for New-Zealand using quarterly data between 1992Q01 and 2008Q04.[6] The estimated persistence of TFP is $\rho_a = 0.47$ for New-Zealand and $\rho_{a^*} = 0.75$ for the US, while the standard errors and cross-country correlation of residuals, which we interpret as shocks, are $\sigma(\xi_a) = 0.0105$, $\sigma(\xi_{a^*}) = 0.0045$, and $corr(\xi_a, \xi_{a^*}) = 0.0041 \simeq 0$. We use these values to feed our model with exogenous shocks. Table 2 summarizes the value of parameters used in the rest of the paper.

5 Impulse Response Functions

In this section, we analyze the dynamic response of our model economy to domestic and foreign technology shocks. We report the Impulse Response Functions (IRFs) of the model in the benchmark case ($\gamma = 0$) and with trade in intermediate goods ($\gamma = 0.15$). To assess

[6] Data from the Bureau of Economic Analysis.

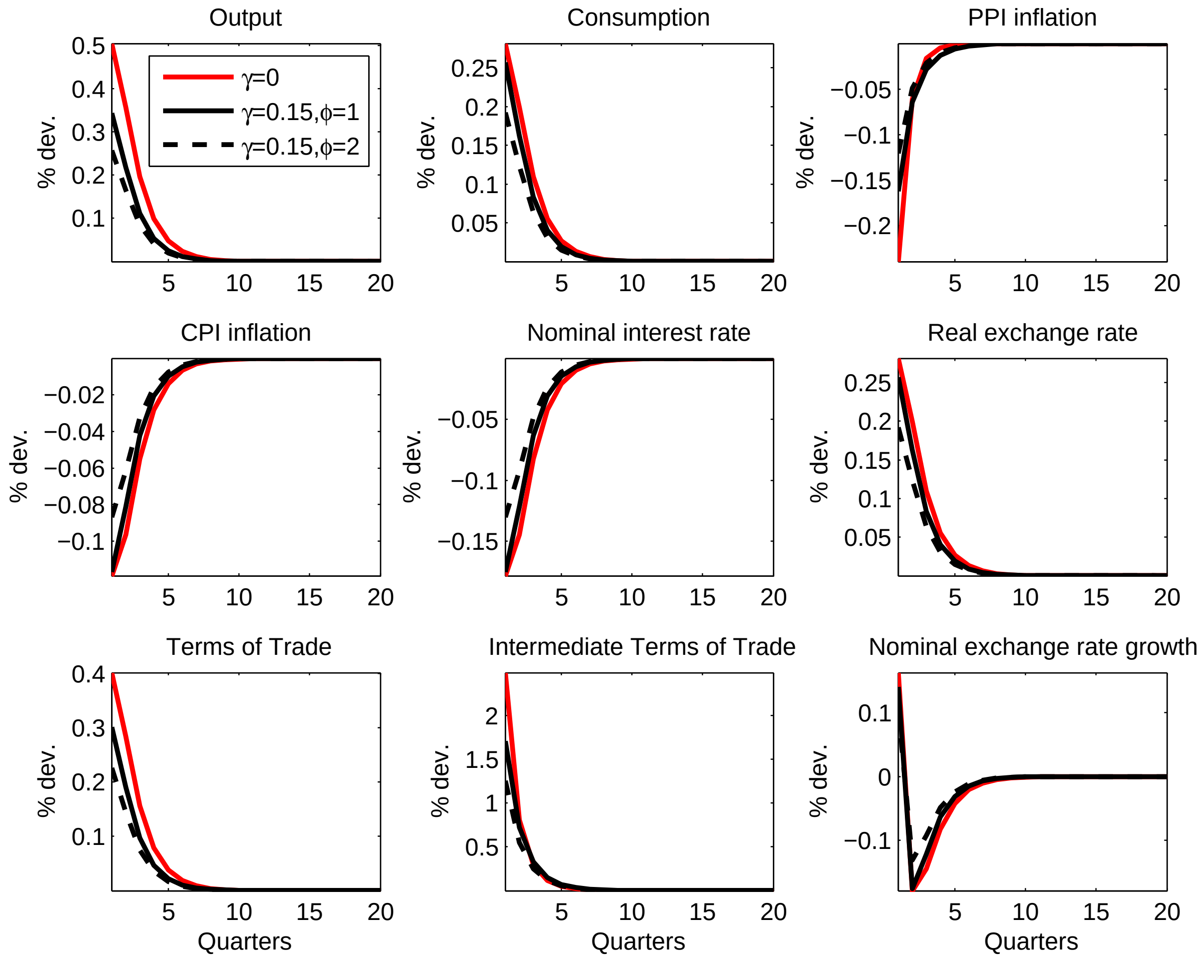

Figure 1: Impulses responses to a domestic technology shock

the role of elasticity of substitution in the production function, we also present the impulses responses when the elasticity of substitution between intermediate goods, ϕ, equals 2 [7].

Domestic productivity shock Figure 1 displays the IRFs of key variables to a unit domestic productivity shock.

In all cases, the qualitative impulse responses are similar. A positive technology shock is associated with an increase in output and consumption alongside a fall in inflation. The nominal interest rate falls in order to support the increase in output and consumption. The

[7] The tables on business cycle properties in the next sections provides results under various calibration of the elasticity of substitution between domestic and imported intermediate good

fall in the interest rate yields a depreciation of the nominal exchange rate, which, combined with the drop of domestic PPI inflation, implies a significant real depreciation.

The responses differ, however, quantitatively. The impulse responses are lower in magnitude when we allow for intermediate goods trade. The drop is the size of the response is increasing with the elasticity of substitution. When $\gamma = 0$, the effect of productivity shocks in inflation are governed by their effects on the marginal cost of consumption goods producers. The fall in real marginal cost yields a decrease in the PPI inflation rate. When $\gamma > 0$, beside the direct marginal cost effect, our model displays an additional channel through which inflation dynamics are affected, originated from the depreciation of the nominal exchange rate. The deterioration of the terms of trade in the intermediate goods sector (ρ_t increases) makes the foreign intermediate goods more costly to acquire from the perspective of domestic firms. Hence, the fall in marginal cost is balanced by more expensive foreign intermediate goods. The lower reaction of marginal cost reduces the size of adjustment in inflation and in all other variables. This second round effect is absent in most New Keynesian models. For instance, in response to the same technology shock the boost in output under internationalized production is half of the increase without internationalized production.

Foreign productivity shock Figure 2 displays the IRFs of key variables to a unit foreign productivity shock.

After a foreign productivity shock, domestic output and consumption increase while both producer price inflation and consumer price inflation fall persistently. The perfect risk sharing requires that real exchange rate appreciates after a favorable foreign productivity shock.

As in the case of domestic productivity shock, the dynamic responses of real and nominal variables are qualitatively similar whether we allow intermediate goods trade or not. However, contrary to a domestic productivity shock, under internationalized production, the dynamic response of domestic variables is magnified in the case of a foreign productivity shock. In particular the response of domestic output on impact is almost three times larger.

The reason for this result is that, when $\gamma > 0$, fluctuations of the intermediate goods terms of trade now trigger intermediate goods trade flows and affect the real marginal cost of

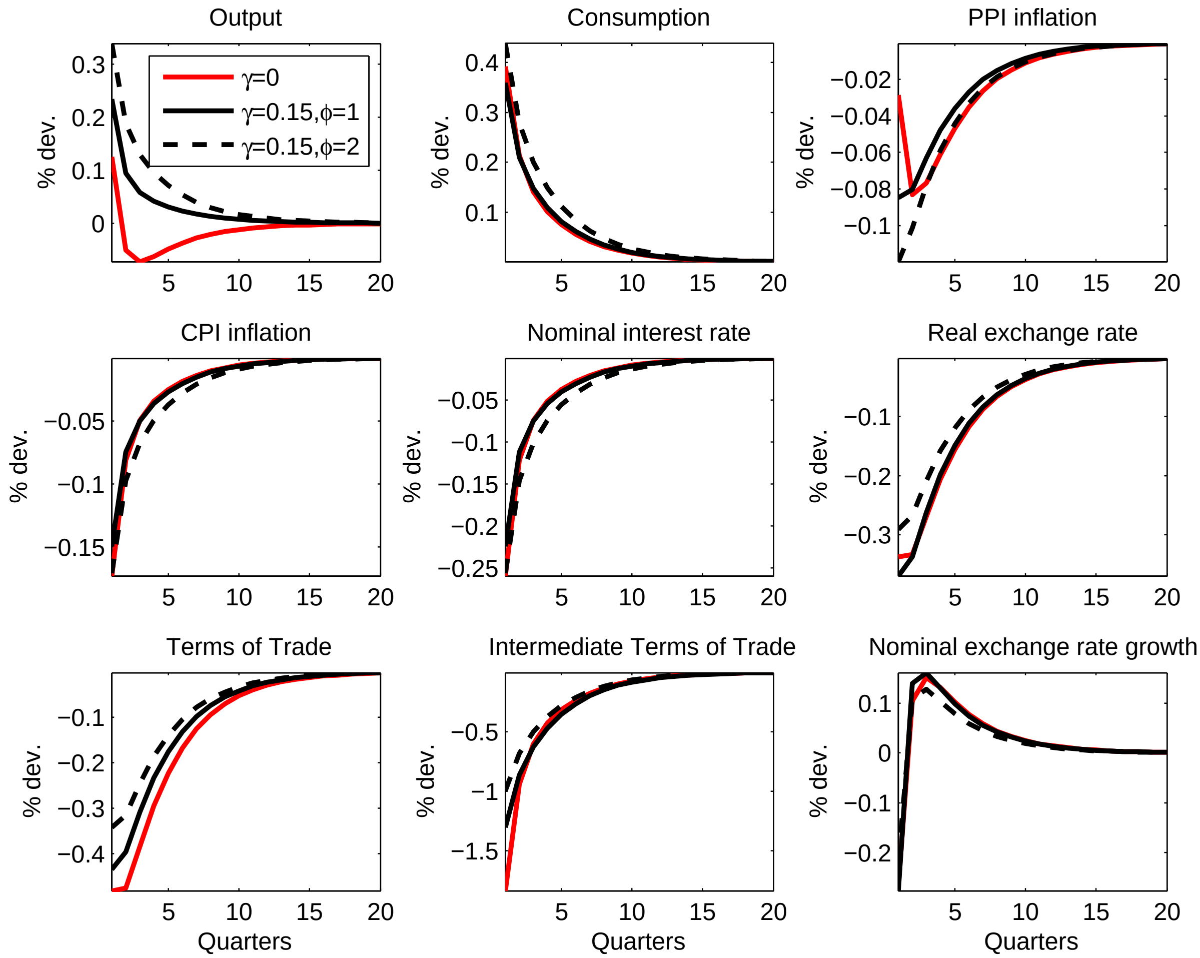

Figure 2: Impulses responses to a foreign technology shock

domestic consumption goods producers. The increase in the intermediate goods terms of trade decreases the competitiveness of domestic intermediate goods producers and makes it less costly for domestic final goods producers to buy intermediate goods from the rest of the world. The first point results in a decrease in intermediate goods exports, requiring a decrease in the domestic real wage. The second point makes the domestic producer use foreign intermediate goods more intensively. The magnitude of this effect is determined by the elasticity of substitution ϕ, since higher values of ϕ implies a higher expenditure switching toward foreign intermediate inputs.

Table 3. Cyclical Properties: Standard Deviations (%)

A – CB reacting to CPI inflation					
	$\gamma = 0$	$\gamma = 0.15$			
		$\phi = 0.5$	$\phi = 1$	$\phi = 1.5$	$\phi = 2$
Output	0.70	0.54	0.46	0.42	0.39
Consumption	0.44	0.43	0.40	0.38	0.37
PPI inflation	0.27	0.23	0.20	0.18	0.16
CPI inflation	0.20	0.20	0.18	0.16	0.15
Nominal interest rate	0.30	0.30	0.27	0.25	0.23
Real exchange rate	0.48	0.52	0.44	0.38	0.34
Cons. goods ToT	0.68	0.61	0.52	0.45	0.40
Inter. goods ToT	2.94	2.59	2.15	1.83	1.60
Nominal Depr.	0.36	0.39	0.33	0.29	0.25
B – CB reacting to PPI inflation					
	$\gamma = 0$	$\gamma = 0.15$			
		$\phi = 0.5$	$\phi = 1$	$\phi = 1.5$	$\phi = 2$
Output	0.75	0.55	0.46	0.41	0.39
Consumption	0.46	0.44	0.39	0.37	0.37
PPI inflation	0.31	0.25	0.21	0.19	0.17
CPI inflation	0.28	0.23	0.19	0.17	0.16
Nominal interest rate	0.46	0.37	0.32	0.28	0.25
Real exchange rate	0.52	0.53	0.45	0.39	0.34
Cons. goods ToT	0.74	0.62	0.53	0.45	0.40
Inter. goods ToT	2.65	2.55	2.13	1.82	1.60
Nominal Depr.	0.60	0.50	0.42	0.36	0.32

Hence, allowing for an additional trade channel impacting the marginal production cost of final goods may significantly alter both the qualitative and quantitative implications of a small open economy model after domestic and foreign shocks.

6 Business cycles properties

This section investigates the cyclical properties of the model and compares them with the case where $\gamma = 0$. For robustness motives, we report these cyclical properties for different values of the elasticity of substitution between domestic and foreign intermediate goods, ϕ. We also report the results when the central bank reacts to the PPI inflation rate instead of the CPI. Table 3 reports the volatility of several key variables for these alternative scenarios. When $\gamma = 0.15$, the volatility of all the variables are lower than the case where trade solely occurs at the consumption goods level. The most significant decreases are in output and terms of trade measures where their volatility is halved. The decrease in the volatility of PPI inflation is larger than the decrease in CPI inflation and as monetary policy reacts to the

Table 4. Share of foreign shocks in variance decomposition (%)

A – CB reacting to CPI inflation					
	$\gamma = 0$	$\gamma = 0.15$			
		$\phi = 0.5$	$\phi = 1$	$\phi = 1.5$	$\phi = 2$
Output	1.4	1.7	6.7	15.0	25.2
Consumption	24.8	15.2	28.7	42.1	53.7
PPI inflation	6.3	5.3	11.8	19.9	28.7
CPI inflation	21.7	12.0	21.4	31.7	41.5
Nominal interest rate	21.7	12.0	21.4	31.7	41.5
Real exchange rate	35.0	40.6	42.6	44.1	45.2
Cons. goods ToT	35.0	40.6	42.6	44.1	45.2
Inter. goods ToT	11.7	13.7	14.7	15.4	16.0
Nominal Depr.	23.4	28.0	29.6	30.9	31.9
B – CB reacting to PPI inflation					
	$\gamma = 0$	$\gamma = 0.15$			
		$\phi = 0.5$	$\phi = 1$	$\phi = 1.5$	$\phi = 2$
Output	0.3	0.6	5.1	13.3	23.8
Consumption	17.9	13.0	26.7	40.7	52.9
PPI inflation	0.5	1.7	5.8	12.0	19.6
CPI inflation	12.7	7.4	13.8	21.8	30.7
Nominal interest rate	0.5	1.7	5.8	12.0	19.6
Real exchange rate	34.2	40.7	42.8	44.3	45.5
Cons. goods ToT	34.2	40.7	42.8	44.3	45.5
Inter. goods ToT	10.5	13.4	14.5	15.3	15.9
Nominal Depr.	22.8	28.1	29.9	31.2	32.3

latter, the volatility of the interest rate is also lowered (panel A). The fact that model predicts a reduction of the overall volatility although the response of variables to foreign shocks are magnified when $\gamma > 0$ suggests that the effects of domestic shocks dominate. In the case where the central bank reacts to PPI inflation (panel B), the reduction in the macroeconomic volatility is slightly more pronounced, confirming the robustness of this result to alternative monetary policy specifications. The intuition behind is the following. The impact of trade in intermediate goods bears mostly on the marginal production cost, and therefore translates to the PPI inflation rate. If the central bank reacts to PPI inflation, the effect of intermediate trade is fully transmitted to other key variables, such as consumption or output, while it is slightly attenuated when the central bank reacts to CPI inflation. PPI inflation targeting thus magnifies the effects of trade in intermediate goods on macroeconomic volatility.

We now turn to the analysis of the share of foreign productivity shock in the variance decomposition of domestic variables. Table 4 displays the share of foreign productivity shock in the variance decomposition of domestic variables for alternative calibrations of the model.

The standard model (panel A) implies that only 1.4% of output fluctuations and about 6.3% of domestic PPI inflation fluctuations are due to foreign productivity shocks. For other domestic variables the share of foreign shock lies around 20%, while it is 11.7% and 35% for intermediate goods terms of trade and the real exchange rate. When $\gamma = 0.15$, the share of foreign shocks in the variance decomposition increases with the elasticity of substitution between foreign and domestic inputs. The more intermediate inputs are substitutable, the more firms respond to changes in intermediate inputs prices. Table 4 shows that the increase in the share of variance explained by foreign shocks reaches several orders of magnitude for most variables. For example, when $\phi = 2$, the variability due to the foreign shock is 18 times larger for output and 4.5 times larger for PPI inflation. For consumption and CPI inflation the share almost doubles while it slightly increases for other variables measuring the relative price level between the small open economy and the rest of the world. Interestingly, in the absence of intermediate trade, the share of variance is much smaller when the central bank targets the PPI inflation rate (panel B). Indeed, when the central bank targets the CPI inflation rate, it incorporates some of the fluctuations of consumption goods terms of trade, more affected by external shocks, to other variables such as inflation, the nominal interest rate,consumption and output. On the contrary, the fluctuations of terms of trade are not incorporated when the central bank targets the PPI inflation rate. However, trade in intermediate goods increases significantly the share of variance explained by foreign shocks, almost in the same proportions as when the central bank targets the CPI inflation rate. These results suggest that considering trade linkages at the production level is important to account for the substantial role of foreign shocks in the business cycles of small open economies.

Finally, our model encompasses the model of McCallum & Nelson (2000) as a special case. Indeed, when $\gamma = 0.3$ ($\alpha = 0$) and $\phi = 1$, all trade occurs at the intermediate goods level and the production function is a Cobb-Douglas in foreign and domestic goods. McCallum & Nelson (2000) argue that the standard New Keynesian model is unable to deliver the low exchange rate pass-through observed in the data, defined as the correlation between nominal exchange rate depreciation and CPI inflation. Table 5 reports the pass-through at different time horizons under alternative calibrations and monetary policy specifications. The contemporaneous correlation between inflation and exchange rate depreciation is much lower

Table 5. Exchange rate pass-through ($\pi_t^c, \Delta e_{t-k}$)

A – CB reacting to CPI inflation

	$\gamma = 0$	$\gamma = 0.15$				$\gamma = 0.3$			
k		$\phi = 0.5$	$\phi = 1$	$\phi = 1.5$	$\phi = 2$	$\phi = 0.5$	$\phi = 1$	$\phi = 1.5$	$\phi = 2$
0	0.20	0.13	0.13	0.12	0.11	-0.03	-0.05	-0.06	-0.07
1	0.01	-0.01	-0.01	-0.01	-0.02	-0.02	-0.03	-0.04	-0.05
2	-0.02	-0.02	-0.02	-0.02	-0.02	-0.01	-0.02	-0.03	-0.03
3	-0.01	-0.01	-0.01	-0.01	-0.02	-0.01	-0.02	-0.02	-0.02
4	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	-0.02	-0.02

B – CB reacting to PPI inflation

	$\gamma = 0$	$\gamma = 0.15$				$\gamma = 0.3$			
k		$\phi = 0.5$	$\phi = 1$	$\phi = 1.5$	$\phi = 2$	$\phi = 0.5$	$\phi = 1$	$\phi = 1.5$	$\phi = 2$
0	0.61	0.30	0.29	0.27	0.24	-0.03	-0.05	-0.06	-0.07
1	-0.01	-0.01	-0.02	-0.02	-0.03	-0.02	-0.03	-0.04	-0.05
2	-0.00	-0.01	-0.01	-0.02	-0.02	-0.01	-0.02	-0.03	-0.03
3	-0.00	-0.00	-0.01	-0.01	-0.01	-0.01	-0.02	-0.02	-0.02
4	0.00	-0.00	-0.00	-0.01	-0.01	-0.01	-0.01	-0.02	-0.02

in the presence of intermediate goods trade. The pass-through is further lowered with higher values of ϕ and the share of intermediate inputs in total imports. Again, these results are even more self-evident when the central bank targets the PPI inflation rate.

7 Conclusion

In this paper, we show that assuming trade in intermediate goods, or equivalently internationalized production, in an otherwise standard New Keynesian small open economy model has important consequences for business cycle dynamics. We document an additional channel through which external shocks and exchange rate fluctuations impact the economy, denoted as the "cost channel". This channel exists because changes in relative prices or in the nominal exchange rate affect trade of intermediate goods and the marginal production cost of consumption goods producers through the price of imported inputs. We show that this additional channel reduces the overall fluctuations of domestic variables while it results in a dramatic increase in the share of foreign shocks in the variance decomposition of domestic variables. We also show that taking into account intermediate inputs trade can bring the standard model in line with the empirical evidence with regards to the exchange rate pass-through.

Future research may explore to which extent taking into account intermediate goods trade can improve the empirical fit of an estimated small open economy model .

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A Figures and Tables for robustness

In this section, we present robustness of our model to our choice of monetary policy rule and to the calibration of elasticity of substitution between domestic and imported consumption goods.

First, Galí & Monacelli (2005) show that under certain restrictions on parameter value, a monetary policy based on producer price inflation targeting is the closest rule to optimal policy. Figure 3-4 present impulse responses of our model under PPI inflation targeting (while business cycles moments are reported in the paper).

Second, the calibration of elasticity of substitution is controversial in open economy macro models. While micro studies find a value higher than unity, most estimates based on macroeconomic models suggest a value lower than unity. Therefore we report the robustness of our result by setting μ to 1 as in Galí & Monacelli (2005) and 0.5, respectively.

A.1 PPI inflation targeting

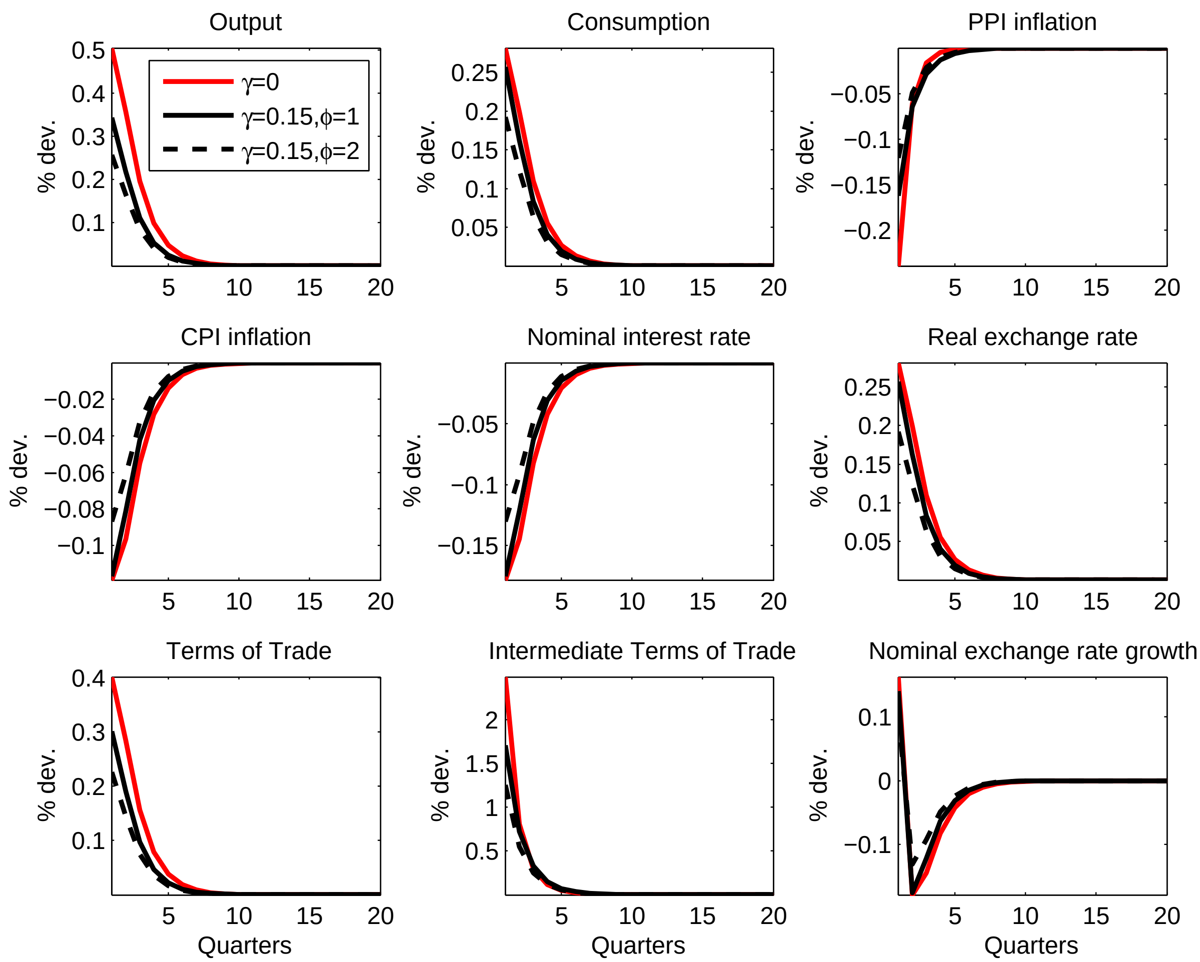

Figure 3: Impulses responses to a domestic technology shock (PPI inflation targeting)

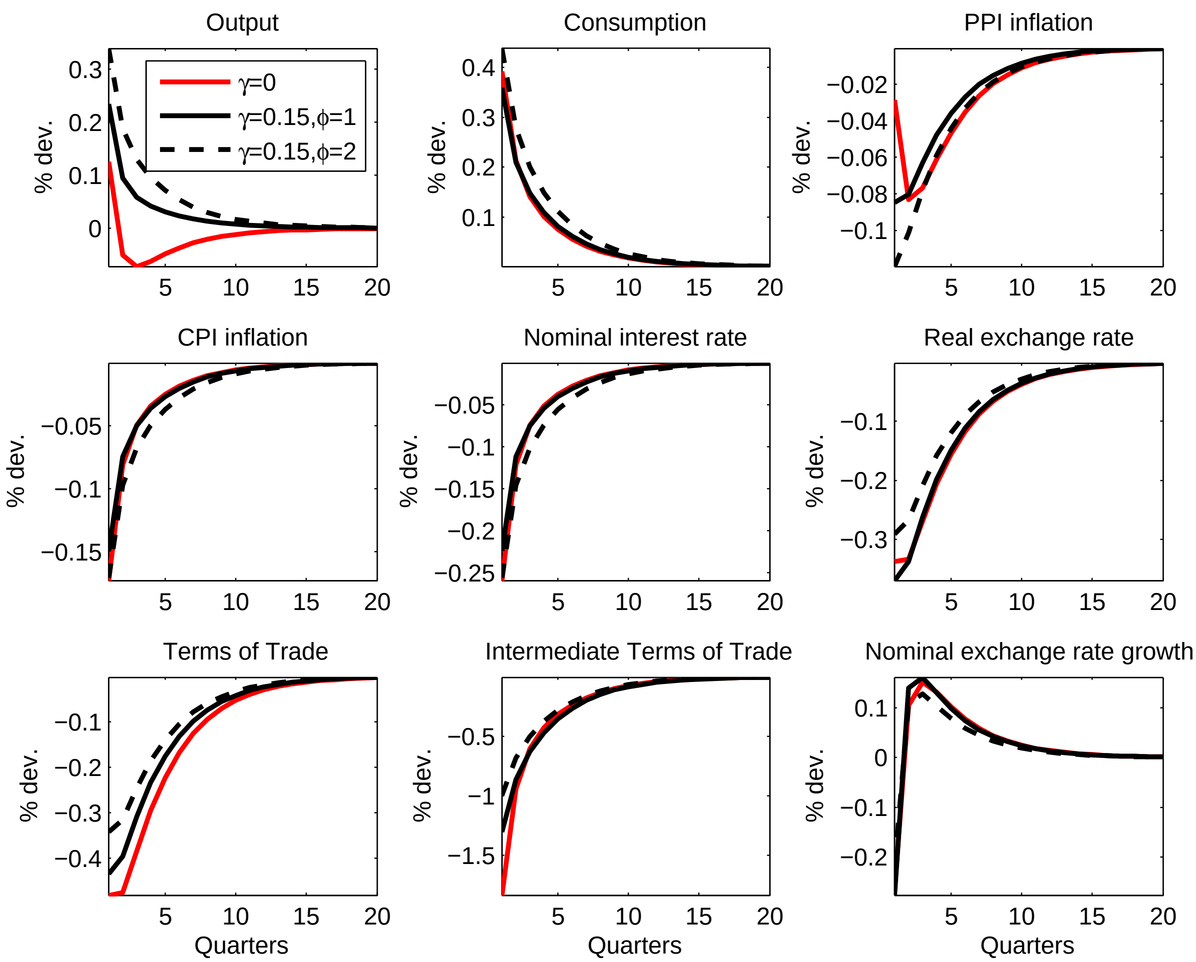

Figure 4: Impulse responses to a foreign productivity shock (PPI inflation targeting)

A.2 Robustness to the values of elasticity of substitution

A.2.1 $\mu = 1$

Table 6. Cyclical Properties: Standard Deviations (%) ($\mu = 1$)

	$\gamma = 0$	$\gamma = 0.15$			
		$\phi = 0.5$	$\phi = 1$	$\phi = 1.5$	$\phi = 2$
Output	0.62	0.50	0.43	0.39	0.37
Consumption	0.47	0.44	0.40	0.38	0.37
PPI inflation	0.29	0.24	0.20	0.18	0.17
CPI inflation	0.21	0.21	0.18	0.16	0.16
Nominal interest rate	0.31	0.31	0.27	0.25	0.23
Real exchange rate	0.54	0.55	0.46	0.40	0.35
Cons. goods ToT	0.77	0.64	0.54	0.47	0.41
Inter. goods ToT	3.20	2.69	2.21	1.88	1.64
Nominal Depr.	0.40	0.41	0.35	0.30	0.26

Table 7. Share of foreign shocks in variance decomposition (%) ($\mu = 1$)

	$\gamma = 0$	$\gamma = 0.15$			
		$\phi = 0.5$	$\phi = 1$	$\phi = 1.5$	$\phi = 2$
Output	2.0	3.6	11.5	22.5	34.5
Consumption	15.3	11.5	24.5	38.3	50.6
PPI inflation	3.7	3.9	9.7	17.5	26.3
CPI inflation	16.1	9.8	18.8	29.0	39.1
Nominal interest rate	16.1	9.8	18.8	29.0	39.1
Real exchange rate	36.6	41.6	43.5	45.0	46.0
Cons. goods ToT	36.6	41.6	43.5	45.0	46.0
Inter. goods ToT	12.4	14.2	15.1	15.9	16.4
Nominal Depr.	24.7	28.8	30.4	31.6	32.6

Table 8. Exchange rate pass-through ($\pi_t^c, \Delta e_{t-k}$) ($\mu = 1$)

	$\gamma = 0$	$\gamma = 0.15$			
k		$\phi = 0.5$	$\phi = 1$	$\phi = 1.5$	$\phi = 2$
0	0.23	0.14	0.14	0.13	0.12
1	0.01	-0.01	-0.01	-0.01	-0.01
2	-0.02	-0.02	-0.02	-0.02	-0.02
3	-0.01	-0.01	-0.01	-0.01	-0.02
4	-0.01	-0.01	-0.01	-0.01	-0.01

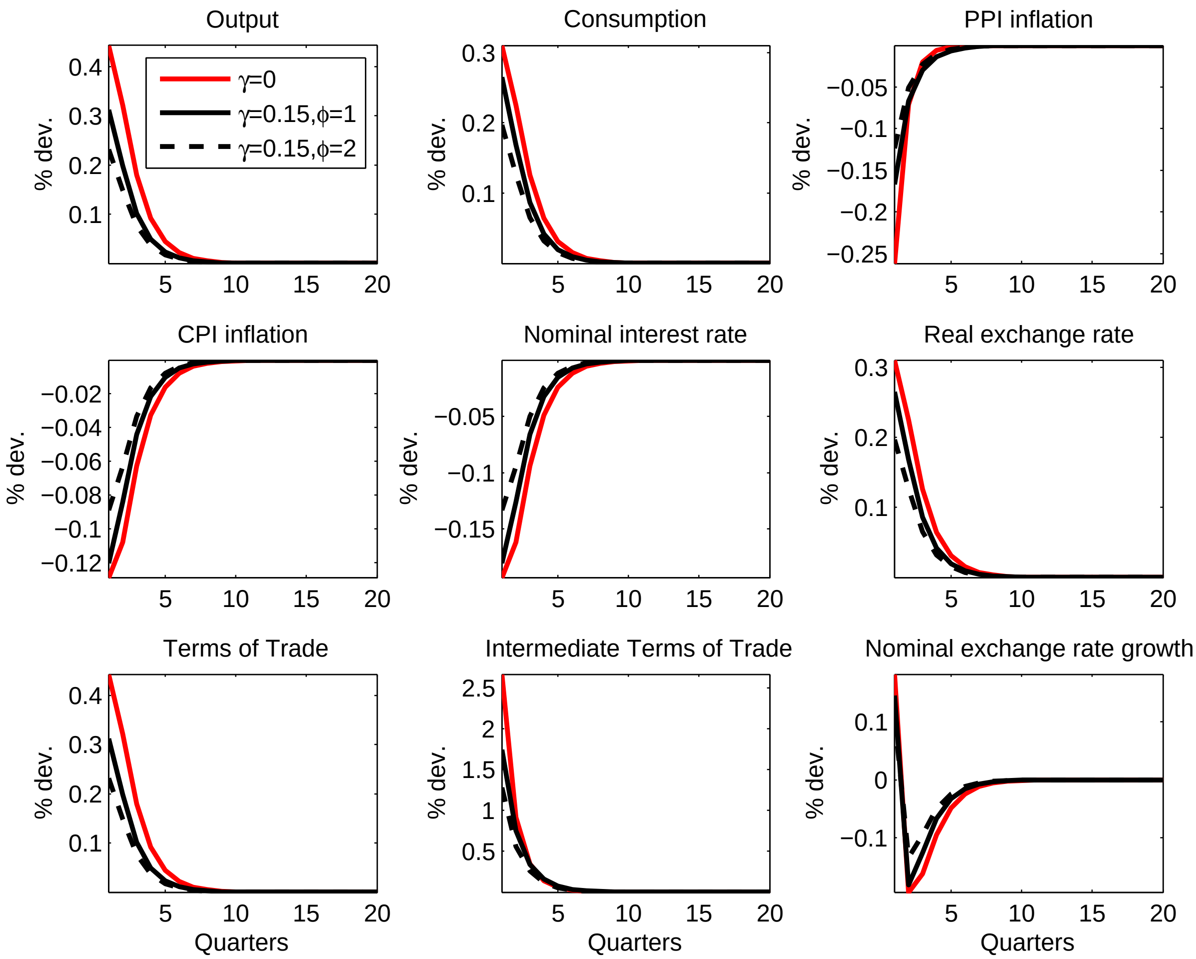

Figure 5: Impulse responses to a domestic technology shock ($\mu = 1$)

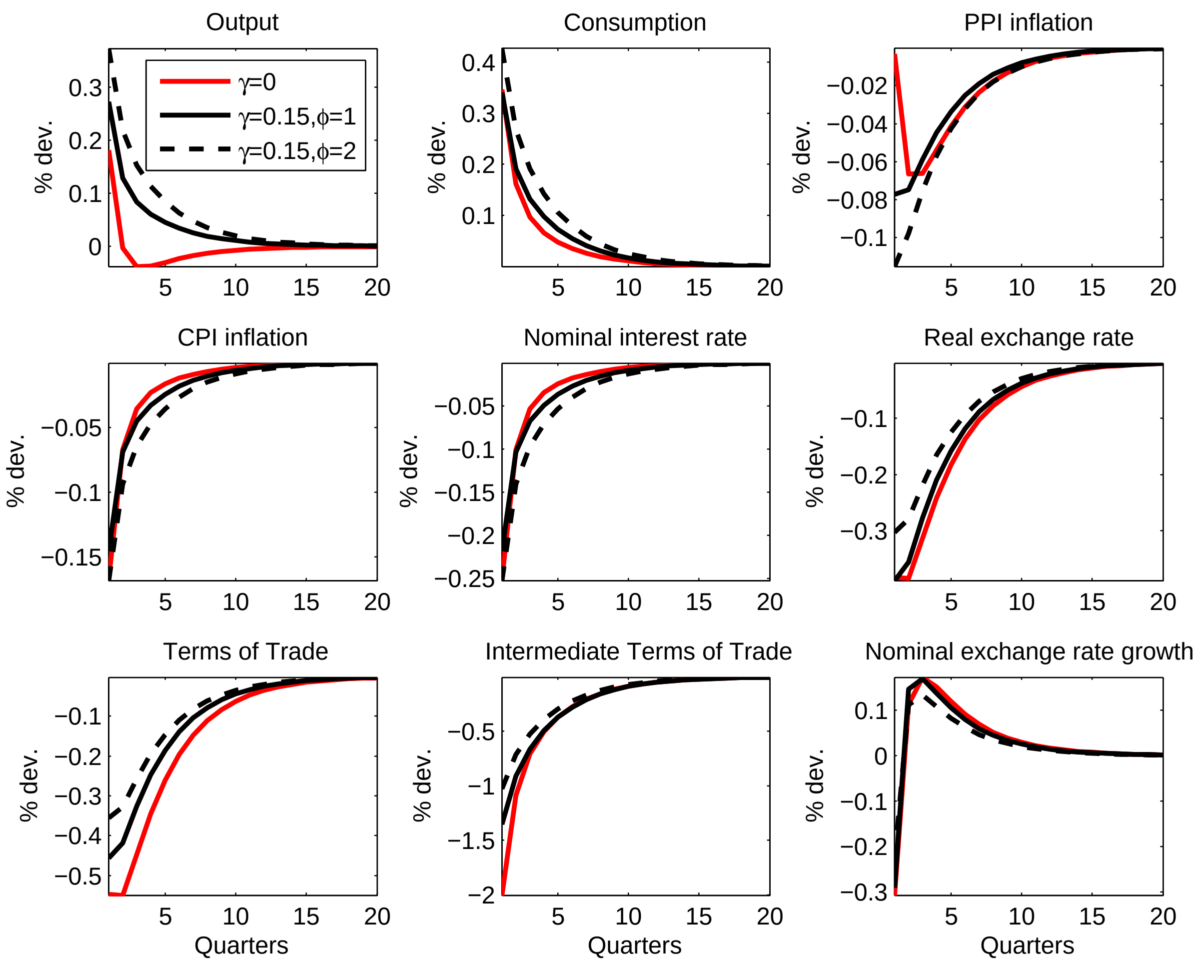

Figure 6: Impulse responses to a foreign technology shock ($\mu = 1$)

A.2.2 $\mu = 0.5$

Table 9. Cyclical Properties: Standard Deviations (%) ($\mu = 0.5$)

	$\gamma = 0$	$\gamma = 0.15$			
		$\phi = 0.5$	$\phi = 1$	$\phi = 1.5$	$\phi = 2$
Output	0.53	0.46	0.40	0.38	0.36
Consumption	0.51	0.45	0.40	0.38	0.36
PPI inflation	0.32	0.25	0.21	0.18	0.17
CPI inflation	0.23	0.21	0.18	0.17	0.16
Nominal interest rate	0.34	0.32	0.28	0.25	0.23
Real exchange rate	0.62	0.57	0.48	0.41	0.36
Cons. goods ToT	0.89	0.68	0.57	0.49	0.43
Inter. goods ToT	3.51	2.79	2.29	1.94	1.68
Nominal Depr.	0.45	0.43	0.36	0.31	0.27

Table 10. Share of foreign shocks in variance decomposition (%) ($\mu = 0.5$)

	$\gamma = 0$	$\gamma = 0.15$			
		$\phi = 0.5$	$\phi = 1$	$\phi = 1.5$	$\phi = 2$
Output	4.9	7.4	19.1	33.0	46.0
Consumption	7.1	8.1	20.3	34.3	47.3
PPI inflation	2.0	2.6	7.7	15.1	23.9
CPI inflation	11.1	7.8	16.3	26.3	36.6
Nominal interest rate	11.1	7.8	16.3	26.3	36.6
Real exchange rate	38.8	42.8	44.6	45.9	46.9
Cons. goods ToT	38.8	42.8	44.6	45.9	46.9
Inter. goods ToT	13.3	14.7	15.7	16.4	16.9
Nominal Depr.	26.5	29.8	31.3	32.5	33.4

Table 11. Exchange rate pass-through ($\pi_t^c, \Delta e_{t-k}$) ($\mu = 0.5$)

	$\gamma = 0$	$\gamma = 0.15$			
k		$\phi = 0.5$	$\phi = 1$	$\phi = 1.5$	$\phi = 2$
0	0.26	0.15	0.15	0.14	0.13
1	0.03	-0.01	-0.01	-0.01	-0.01
2	-0.01	-0.02	-0.02	-0.02	-0.02
3	-0.01	-0.01	-0.01	-0.01	-0.02
4	-0.01	-0.01	-0.01	-0.01	-0.01

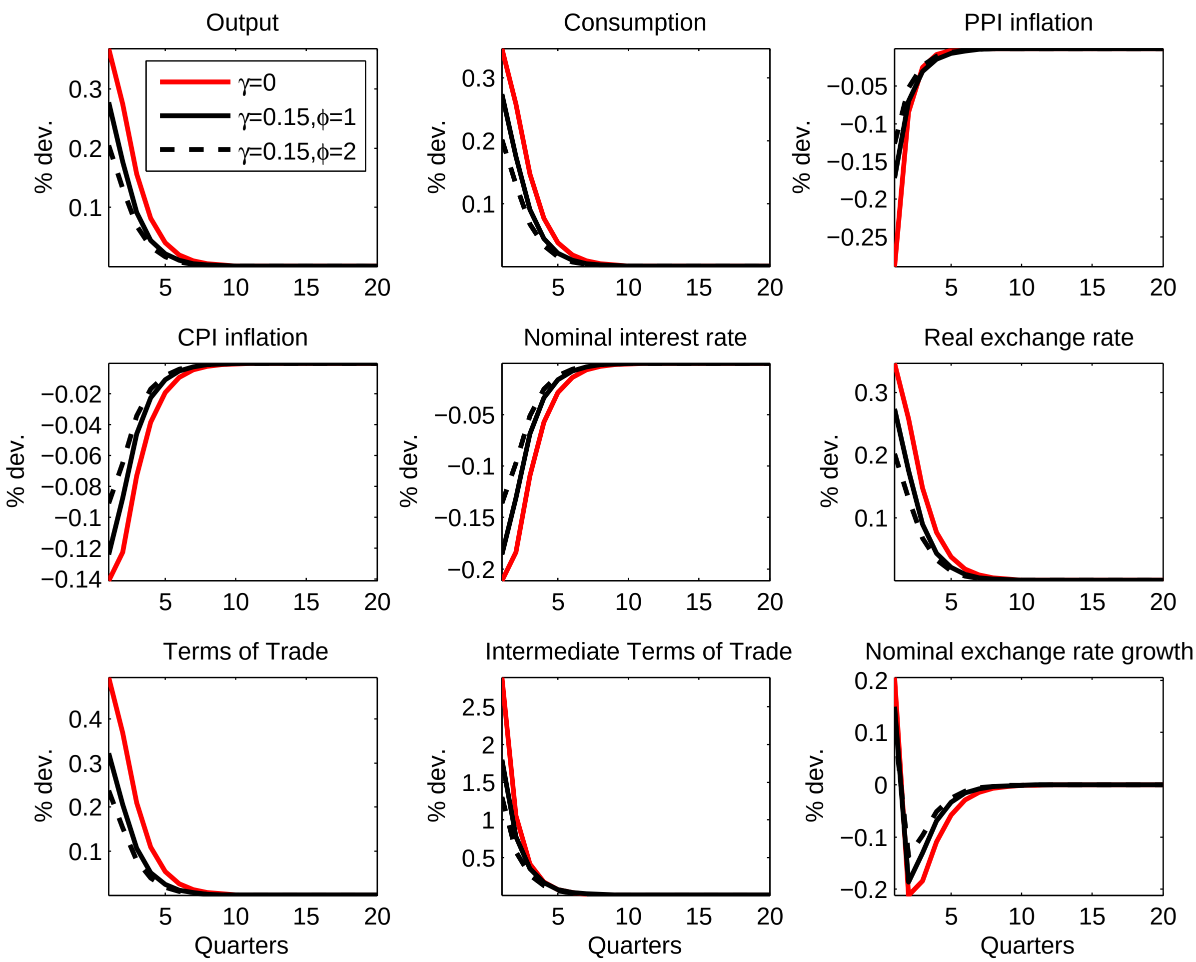

Figure 7: Impulse responses to a domestic technology shock ($\mu = 0.5$)

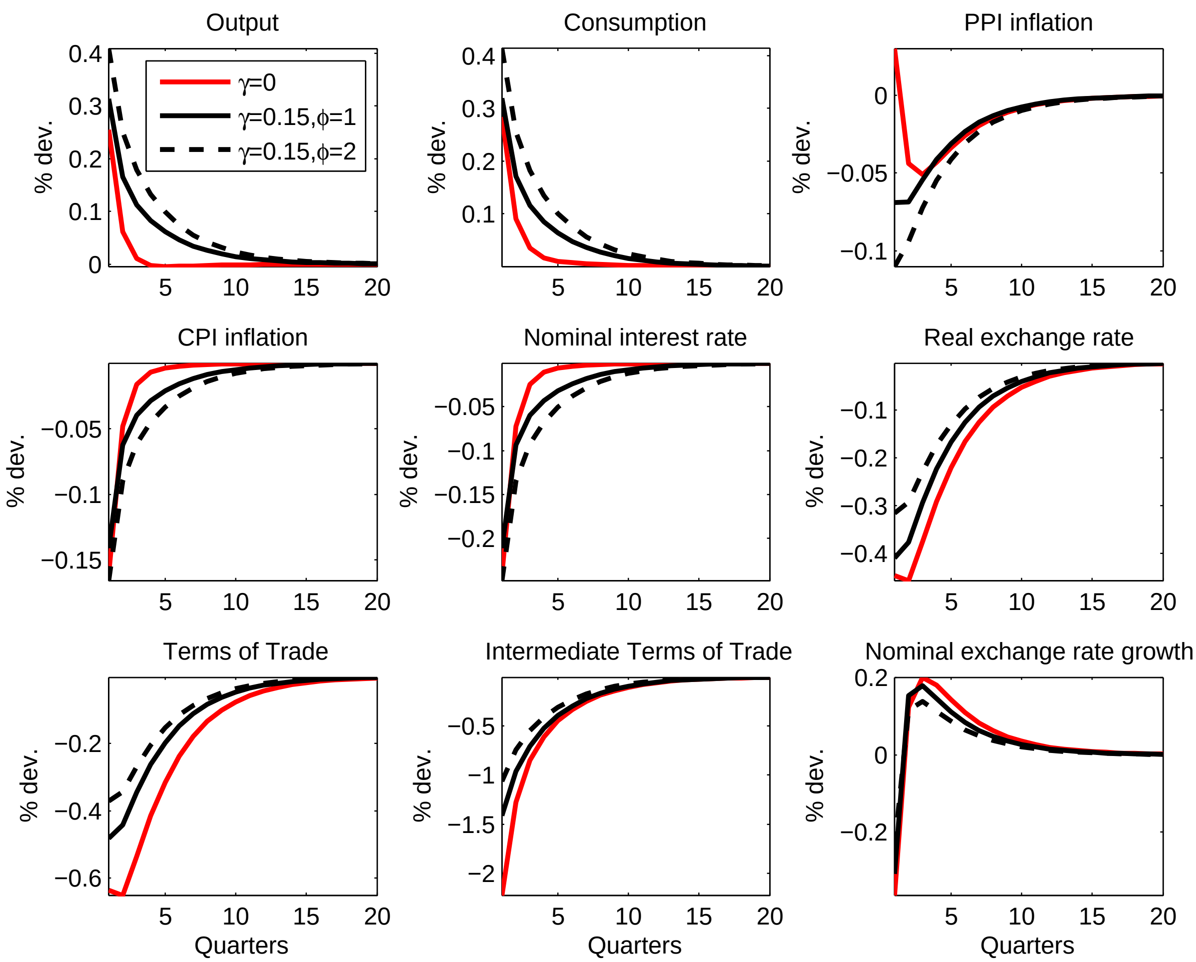

Figure 8: Impulses responses to a foreign technology shock ($\mu = 0.5$)