Technology Shocks and Employment*

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Abstract

Recent empirical work has suggested that in response to a positive technology shock employment shows a *persistent decline*. This finding has raised doubts concerning the relevance of flexible prices as well as the quantitative significance of technology shocks as a source of aggregate fluctuations. We show that the standard, open economy, flexible price RBC model can match the negative conditional correlation between productivity and employment quite well if trade elasticities are sufficiently low. In addition, the model also has satisfactory overall empirical performance.

Keywords: Technological shocks, employment, open economy, flexible prices.
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Introduction

The real business cycle model (RBC) model assigns a critical role to aggregate variations in technology as the driving force behind macroeconomic fluctuations. One of its key implications is that technology shocks lead to procyclical movements in employment, productivity and real wages of the type observed in the data.

The ability of the RBC model to account for business cycles has been questioned on the basis of recent evidence concerning the *conditional* relationship between productivity and employment. Galí [1999] and more recently Galí and Rabanal [2004], and Basu, Fernald and Kimball [1998] (henceforth BFK) have identified technology shocks based on plausible identification schemes and have found that in response to a positive technology shock, labor productivity rises more than output while employment shows a *persistent decline*. Hence, the empirical correlation between employment and productivity as well as that between employment and output *conditional* on technology shocks is negative. This finding has raised *"...serious doubts not only about the relevance of the RBC model but more importantly about the quantitative significance of technology shocks as a source of aggregate fluctuations in industrialized economies..."* (Galí [2000]). Moreover, as the standard Keynesian model with imperfect competition and sticky prices seems capable of generating a short run decline in employment in response to a positive technology shock, this stylized fact has provided support for models with nominal frictions.

There have been three lines of response to the findings of Galí and BFK. The first is to dispute the ability of the particular identification schemes used to truly identify technology shocks (see Bils [1998]) and also Christiano, Eichenbaum and Vigfusson [2004] and Chari, Kehoe and McGrattan [2003]). However, Francis and Ramey [2001] examine whether Galí's extracted technology shocks behave like true technology shocks and conclude that this seems to be indeed the case.

The second response is more defensive and argues that the new Keynesian model is equally incapable of matching these stylized facts. Dotsey [1999] shows that a sufficiently procyclical monetary policy can induce a positive correlation between output and employment following a technology shock even under fixed prices.

The third response is to suggest plausible, flexible price models that can reproduce these stylized facts. It is easy to see what kind of modelling features are needed for this. In order to get a reduction in employment following a positive productivity shock, the increase in labor demand must be limited while the supply of labor must decrease. The latter effect can be accomplished either via a strong wealth effect and/or via an intertemporal substitution effect that favors future at the expense of current effort. Standard preferences with high risk aversion can make wealth effects large. Implementation lags in the adoption of new technology can make future productivity higher than current one, inducing a decrease in current labor supply (time–to–implement as in Hairault, Langot and Portier [1997], or time–to–plan as in Christiano and Todd [1996]). Implementation lags also work to restrain the increase in labor demand.

An alternative way of thinking about this is via aggregate demand and supply. If aggregate demand is sluggish in the short run then output will not expand much following a positive productivity shock. With more productive workers, fewer of them will be needed in order to produce any level of output. Sluggishness in investment can be brought about by capital adjustment costs, in consumption by habit persistence (Francis and Ramey [2001]) and in exports by low trade elasticities.

In this paper we argue that the open economy dimension can greatly enhance the *standard* flexible price model's ability to account for Galí's stylized facts. And that it does so without compromising the ability of the model to account for other dimensions of the business cycle. This is an important consideration because specifications that are less standard (*i.e.* require "extreme" parameter values) may succeed in matching the conditional correlations singled out by Galí and BFK but tend to perform poorly in many other respects. It is also worth noting, that trade openness may undermine the ability of the fixed price model to match these correlations because it adds a flexible component to domestic aggregate demand, exports (at least under flexible exchange rates).

The open, flexible price mechanism relies on the degree of substitution between domestic and foreign goods. A positive domestic supply shock may *reduce* domestic employment if domestic and foreign goods are not good substitutes. Indeed, low substitutability means that the domestic terms of trade must worsen significantly in order to clear the market. The reduction in the relative price of the domestic good then discourages output expansion. Therefore, higher productivity combined with a small output expansion translates into lower employment.

An alternative but equivalent way of describing this is to say that in an open economy, if short run international trade substitution is low, domestic output cannot expand much unless it is accompanied by a comparable expansion in foreign output. Foreign output expands because of the improvement in the foreign term of trade. However, in the absence of strong contemporaneous international correlation of supply shocks this expansion may not be sufficient to boost domestic employment.

We show that an RBC model that contains a combination of three elements matches the aforementioned conditional correlations quite well. These elements are trade openness, low trade elasticities and sluggish capital adjustment. Using the standard open economy parametrization employed in the literature (e.g. Backus, Kehoe and Kydland [1992]) but with lower trade elasticities (for instance, using the values suggested by Taylor [1993] or those implicit in the J–curve) we obtain negative, conditional comovement of output and employment. While the model does not generate enough unconditional volatility in employment (due to the lack of labor indivisibilities) its overall performance is satisfactory. The model implications for the response of the trade balance and the real exchange rate to an identified technological shock are also broadly consistent with those observed in the data. Based on this evidence we conclude that the observation of a negative conditional correlation between employment and output (or productivity and employment) does not justify the rejection of the RBC model, or more generally, a refusal to accept supply shocks as a major source of economic fluctuations.

Note that the multi–country world used here is not much different from a multi sector economy. Hence, rather than talking about multiple countries, one could instead talk about multiple sectors within a single country. As long as the products of different industries are not good substitutes (in either consumption or production) and significant sector specific supply shocks exist, then similar patterns are expected.[1] The main reason we are focusing on the multi–country specification is that we have much more information about international rather than intersectoral trade so that the model can be calibrated and evaluated more easily.

The rest of the paper is organized as follows. Section 1 reproduces and extend the empirical analysis of Galí to an open economy. Section 2 contains the description of the model. In section 3 we discuss the parametrization of the model. Section 4 reports and discusses the main findings.

1 The Empirical Evidence

This section reports evidence on the conditional relationship between productivity and the labor input as well as on the effects of identified technology shocks on open economy variables. The analysis follows closely Galí [1999].

We estimate a four variable VAR model which includes, besides labor productivity, x, and labor input, h, the real exchange rate, RER, and the trade balance, TB. We use U.S. quarterly data from 1970:1–2001:4. Hours per capita are taken from Prescott and Ueberfeldt [2003].

[1] King and Rebelo [2000] and Francis and Ramey [2001] have suggested that production complementarities may help the flexible price model account for Galí's stylized facts.

Labor productivity is constructed by dividing GDP (obtained from the NIPA) by total hours worked. The real exchange rate is computed according to the standard formula (an increase in this variable represents a US currency real depreciation):

$$\mathrm{REER}_t = \sum_{i \in I} \omega_i e_{i,t} \frac{\mathrm{CPI}_{i,t}}{\mathrm{CPI}_{\mathrm{US},t}}$$

where ω_i is the share of country $i's$ trade in total US trade, $e_{i,t}$ is the nominal exchange rate between the i–th country's currency and the US dollar and $\mathrm{CPI}_{i,t}$ is the consumption price index in country i. Both series are obtained from the IFS database. The set of countries consists of the main EU trading partners of the US: Belgium, France, Germany, Netherlands and the United Kingdom (they together account for more than 80% of EU trade with the US). The trade balance is constructed using data from the IMF's direction of trade statistics. It is computed as

$$TB_t = \frac{\sum_{i \in I} \mathrm{EXP}_{i,t}}{\sum_{i \in I} \mathrm{IMP}_{i,t}}$$

where EXP and IMP denote, respectively, US exports to and imports from country i denominated in US dollars. As TB_t was found to exhibit a strong seasonal component we seasonally adjusted it using the CENSUS X–12 procedure.

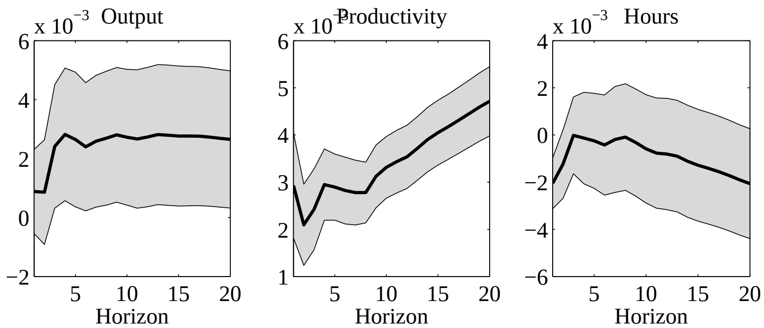
The VAR is run in the rate of growth of productivity, hours worked per capita, the log of the real exchange rate and the log of the trade balance index. The latter two series are found to be stationary. Regarding hours worked we follow Galí [1999] in using two alternative methods for rendering the data stationary: *(i)* hours were detrended using a linear trend and *(ii)* hours were taken in first difference. In both cases a likelihood ratio test suggested a model with 5 lags. As in Galí [1999] the technology shock is identified through the assumption that it is the only one that has a long run effect on labor productivity.

Figure (1) reports the impulse response functions of output, productivity and hours to a one standard deviation, positive technological shock. The shaded area corresponds to the 95% confidence interval, computed using a Monte Carlo method to sample from the estimated asymptotic distribution of the VAR coefficients and the covariance matrix. The results are similar to those obtained by Galí [1999].[2] In response to a one standard deviation positive shock to technology, labor productivity rises on impact by 0.4% when hours are used in the first difference form. The impact effect of the technology shock is about the same when hours are linearly detrended. Labor productivity eventually reaches a permanently higher level in the long run. Likewise, output experiences a permanent increase. As in Galí, the gap between the impact effects of the technology shock on labor productivity and output is reflected in

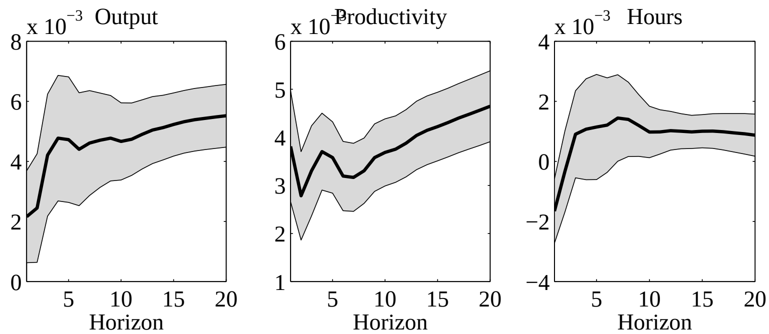
[2]We also run Galí's bivariate VAR model using the updated sample and found results similar to his.

Figure 1: Impulse Response to a Technology Shock

(a) Hours in difference



(b) Linearly detrended hours



Note: The shaded area is the 95% confidence interval, obtained by Monte Carlo simulation using 1000 draws.

Table 1: Correlation with productivity

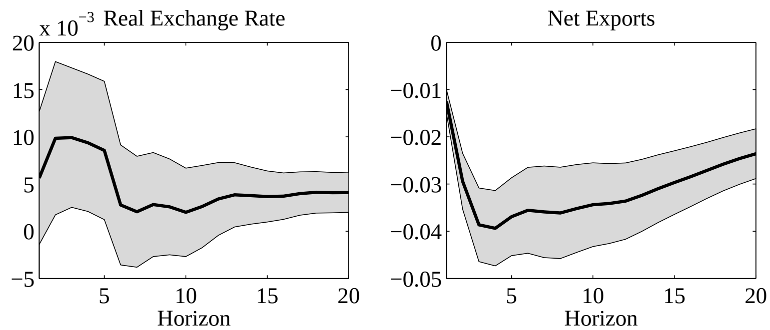
	ΔHours	REER	TB
	Difference		
Unconditional	-0.25**	-0.05	-0.02
	(0.08)	(0.08)	(0.07)
Techno.	-0.81**	0.33**	-0.27**
	(0.10)	(0.09)	(0.07)
Non–Techno.	-0.13**	-0.01	-0.00
	(0.07)	(0.01)	(0.01)
	Linearly Detrended		
Unconditional	-0.25	-0.05	-0.02
	(0.08)	(0.08)	(0.07)
Techno.	-0.70**	0.21*	-0.16**
	(0.13)	(0.11)	(0.08)
Non–Techno.	-0.12*	0.00	-0.01
	(0.06)	(0.02)	(0.01)

Note: Standard errors (obtained by Monte Carlo simulations using 1000 draws) into parenthesis. Significance is indicated by one asterisk (10–percent level) or two asterisks (5–percent level).

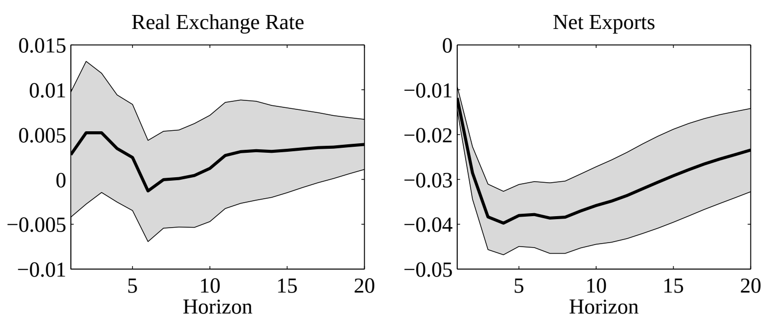
a persistent decrease in the labor input. This pattern obtains whether hours are in first difference or in deviations from a linear trend. A direct consequence of this result is that the conditional correlation between changes in labor productivity and changes in hours worked is negative. For instance, as reported in Table 1, the conditional correlation between changes in labor productivity and hours is -0.81 when hours are taken in differences, and -0.70 when they are linearly detrended. The unconditional correlation is weaker (-0.25). These results are in agreement with Galí's findings, suggesting that trade openness does not affect fundamentally the stylized facts.[3]

Figure 2: Impulse Response to a Technology Shock

(a) Hours in difference



(b) Linearly detrended hours



Note: The shaded area is the 95% confidence interval, obtained by Monte Carlo simulation using 1000 draws.

Figure 2 reports the impulse response functions of the real exchange rate and the trade balance following a one standard deviation, technological shock. The real exchange rate depreciates on impact (the US traded goods become less expensive) while the trade balance follows a J–curve type of path. Namely, it deteriorates in the short run and then reverses course going back to its initial steady state level of zero. There is a positive conditional —on the technology shock— correlation between the real exchange rate and changes in productivity

[3]However, as it will be emphasized below, openness may be play a crucial role in the interpretation of these stylized facts.

Table 2: Correlation with output

	ΔHours	REER	TB
	Difference		
Unconditional	0.62**	-0.19*	-0.20*
	(0.07)	(0.10)	(0.10)
Techno.	0.05	0.37**	-0.22**
	(0.19)	(0.14)	(0.09)
Non–Techno.	0.73**	-0.24**	-0.21**
	(0.04)	(0.04)	(0.02)
	Linearly Detrended		
Unconditional	0.62	-0.19	-0.20
Techno.	-0.12	0.40*	-0.33**
	(0.14)	(0.23)	(0.09)
Non–Techno.	0.79**	-0.31**	-0.28**
	(0.03)	(0.02)	(0.02)

Note: Standard errors (obtained by Monte Carlo simulations using 1000 draws) into parenthesis. Significance is indicated by one asterisk (10–percent level) or two asterisks (5–percent level).

(0.33 in the difference case, and 0.25 in the linear trend case) and a negative correlation between productivity and the trade balance (-0.27 in the difference case, and -0.16 in the linear trend case). Table 2 reports the correlations between —changes in— output and the real exchange rate and the trade balance. The unconditional correlation between output and the real exchange rate is slightly negative (-0.19 under either detrending method) whereas it is positive (about 0.40) when only technological shocks are taken into account. Most of the negative unconditional correlation is therefore due to other shocks. The pattern is different for the trade balance where both the conditional and unconditional correlation are negative.

2 The model

This section develops an open economy model with the goal of accounting for the stylized facts described in the previous section. The models consists of two large countries. Each country is populated by a large number of identical agents and specializes in the production of a distinct, traded good. Asset markets are complete and there are no impediments to international transactions. Labor is not mobile.

2.1 Domestic Household

Household preferences are characterized by the lifetime utility function:

$$\mathbb{E}_t \sum_{\tau=0}^{\infty} \beta^{\star\tau} U\left(C_{t+\tau}, \frac{M_{t+\tau}}{P_{t+\tau}}, \ell_{t+\tau}\right) \tag{1}$$

where $0 < \beta^\star < 1$ is a constant discount factor, C denotes the domestic consumption bundle, M/P is real balances and ℓ is the quantity of leisure enjoyed by the representative household. The utility function,$U\left(C, \frac{M}{P}, \ell\right) : \mathbb{R}_+ \times \mathbb{R}_+ \times [0,1] \longrightarrow \mathbb{R}$ is increasing and concave in its arguments.

The household is subject to the following time constraint

$$\ell_t + h_t = 1 \tag{2}$$

where h denotes hours worked. The total time endowment is normalized to unity.

The representative household faces a budget constraint of the form

$$\begin{aligned} \int P^b(s) B_{t+1}(s)\mathrm{d}s + M_t \quad &\leqslant \quad B_t + P_t z_t K_t + W_t h_t + \Pi_t \\ &\quad\quad +M_{t-1} + N_t - P_t(C_t + I_t + T_t) \end{aligned} \tag{3}$$

where $P^b(s)$ is the period t price of a contingent claim that pays one unit of the home currency in period $t+1$ if the particular state s occurs and 0 otherwise. $B_{t+1}(s)$ is the number of contingent claims owned by the domestic household at the beginning of period t; W_t is the nominal wage; P_t is the nominal price of the domestic final good; C_t is consumption and I_t is investment expenditure; K_t is the amount of physical capital owned by the household and leased to the firms at the real rental rate z_t. M_{t-1} is the amount of money that the household brings into period t, M_t is the end of period t money and N_t is a nominal lump-sum transfer received from the monetary authority; T_t is the real lump–sum taxes paid to the government and used to finance government consumption.

Capital accumulates according to the law of motion

$$K_{t+1} = \Phi\left(\frac{I_t}{K_t}\right) K_t + (1-\delta)K_t \tag{4}$$

where $\delta \in [0,1]$ denotes the rate of depreciation. The concave function $\Phi(.)$ reflects the presence of adjustment costs to investment. It is assumed to be twice differentiable and homogeneous of degree 0. Furthermore, without loss of generality, we impose two assumptions that guarantee the absence of adjustment costs in the steady state: $\Phi(\gamma+\delta-1) = \gamma+\delta-1$ and $\Phi'(\gamma+\delta-1) = 1$, where γ denotes the deterministic rate of growth of the economy. We will also assume that physical capital is not internationally mobile, that is, once it is in place it cannot be transported to the other country. Nonetheless, foreign goods can be indirectly used to augment the domestic capital stock through trade in intermediated goods.

The domestic household decides on its optimal plans by maximizing the utility function (1) subject to (2), (3) and (4).

It is useful for later purposes to report the labor supply decision

$$u_\ell(c_t, M_t/P_t, \ell_t) = \frac{W_t}{P_t} u_c(c_t, M_t/P_t, \ell_t)$$

where $u_x(\cdot)$ denotes the partial derivative of $u(\cdot)$ with respect to x. Note that the labor supply decision depends on the real wage expressed in terms of the domestic final (consumption) good, W_t/P_t.

The behavior of the foreign household is similar.[4]

2.1.1 Final goods sector

The economy consists of two sectors. One produces final goods that are not traded. The other produces intermediate goods that are internationally traded.

The domestic final good, Y, is produced by combining domestic (X^d) and foreign (X^f) intermediate goods. Final good production at home is described by

$$Y_t = \left(\omega^{1-\rho} X_t^{d\rho} + (1-\omega)^{1-\rho} X_t^{f\rho}\right)^{\frac{1}{\rho}} \tag{5}$$

where $\omega \in (0,1)$ and $\rho \in (-\infty, 1)$. X^d and X^f are themselves combinations of the domestic and foreign intermediate goods according to

$$X_t^d = \left(\int_0^1 X_t^d(i)^\theta \mathrm{d}i\right)^{\frac{1}{\theta}} \text{ and } X_t^f = \left(\int_0^1 X_t^f(i)^\theta \mathrm{d}i\right)^{\frac{1}{\theta}} \tag{6}$$

where $\theta \in (-\infty, 1)$. Note that ρ determines the elasticity of substitution between the foreign and the domestic bundle of goods, while θ determines the elasticity of substitution between the goods in the domestic and foreign bundles. The producers of the final goods behave competitively and determine their demand for each intermediate good $X_t^d(i)$ and $X_t^f(i)$,

[4] Note, however, that since contingent claims are denominated in terms of the domestic currency, the foreign household's budget constraint takes the form

$$\int P^b(s) \frac{B_{t+1}^\star(s)}{e_t} + M_t^\star \leqslant B_t^\star + M_{t-1}^\star + N_t^\star + \Pi_t^\star + P_t^\star W_t^\star h_t^\star + P_t^\star z_t^\star K_t^\star - P_t^\star(C_t^\star + I_t^\star + T_t^\star)$$

where a $\star$ denotes the foreign economy and e_t is the nominal exchange rate.

$i \in (0,1)$ by maximizing the static profit equation

$$\max_{\{X_t^d(i), X_t^f(i)\}_{i\in(0,1)}} P_t Y_t - \int_0^1 P_{xt}(i) X_t^d(i) \mathrm{d}i - \int_0^1 e_t P_{xt}^\star(i) X_t^f(i) \mathrm{d}i \tag{7}$$

subject to (6), where $P_{xt}(i)$ and $P_{xt}^\star(i)$ denote the price of each domestic and foreign intermediate good respectively, denominated in terms of the currency of the *seller*. e_t is the nominal exchange rate. This yields demand functions of the form:

$$X_t^d(i) = \left(\frac{P_{xt}(i)}{P_{xt}}\right)^{\frac{1}{\theta-1}} \left(\frac{P_{xt}}{P_t}\right)^{\frac{1}{\rho-1}} \omega Y_t \tag{8}$$

and

$$X_t^f(i) = \left(\frac{e_t P_{xt}^\star(i)}{e_t P_{xt}^\star}\right)^{\frac{1}{\theta-1}} \left(\frac{e_t P_{xt}^\star}{P_t}\right)^{\frac{1}{\rho-1}} (1-\omega) Y_t \tag{9}$$

and the following general price indexes

$$P_{xt} = \left(\int_0^1 P_{xt}(i)^{\frac{\theta}{\theta-1}} \mathrm{d}i\right)^{\frac{\theta-1}{\theta}}, \; P_{xt}^\star = \left(\int_0^1 P_{xt}^\star(i)^{\frac{\theta}{\theta-1}} \mathrm{d}i\right)^{\frac{\theta-1}{\theta}} \tag{10}$$

$$P_t = \left(\omega P_{xt}^{\frac{\rho}{\rho-1}} + (1-\omega)(e_t P_{xt}^\star)^{\frac{\rho}{\rho-1}}\right)^{\frac{\rho-1}{\rho}} \tag{11}$$

The final good can be used for domestic private and public consumption as well as for investment purposes.

The behavior of the foreign final goods producers is similar.[5]

2.1.2 Intermediate goods producers

Each intermediate firm i, $i \in (0,1)$, produces an intermediate good by means of capital and labor according to a constant returns–to–scale technology, represented by the production function

$$X_t(i) \geqslant A_t K_t(i)^\alpha (\Gamma_t h_t(i))^{1-\alpha} \text{ with } \alpha \in (0,1) \tag{12}$$

where $K_t(i)$ and $h_t(i)$ respectively denote the physical capital and the labor input used by firm i in the production process[6]. Γ_t represents Harrod neutral, deterministic, technical progress evolving according to $\Gamma_t = \gamma \Gamma_{t-1}$, where $\gamma \geq 1$ is the deterministic rate of growth.

[5] Note that the general price index in the foreign economy is

$$P_t^\star = \left((1-\omega)\left(\frac{P_{xt}}{e_t}\right)^{\frac{\rho}{\rho-1}} + \omega P_{xt}^{\star\,\frac{\rho}{\rho-1}}\right)^{\frac{\rho-1}{\rho}}$$

[6] We have also experimented with a version that allows for variable capital utilization. This modification does not matter for the ability of the model to match the conditional correlation of output and employment.

A_t is an exogenous stationary stochastic technological shock, whose properties will be defined later. Assuming that each firm i operates under perfect competition in the input markets, the firm determines its production plan so as to minimize its total cost

$$\min_{\{K_t(i),h_t(i)\}} W_t h_t(i) + P_t z_t K_t(i)$$

subject to (12). This yields to the following expression for total costs:

$$P_t \mathcal{C}_{mt} X_t(i)$$

where the real marginal cost, $\mathcal{C}_{mt}$, is given by $\frac{(W_t/P_t)^{1-\alpha} z_t^\alpha}{\chi A_t \Gamma_t^{1-\alpha}}$ with $\chi = \alpha^\alpha (1-\alpha)^{1-\alpha}$

Intermediate goods producers are monopolistically competitive, and therefore set prices for the good they produce, maximizing profits taking the form of the demand into account[7]. Price setting is similar in the foreign economy. Note that in this case, the labor demand decision of the firm writes

$$\theta(1-\alpha)\frac{X_t(i)}{h_t(i)} = \frac{W_t}{P_{xt}}$$

It is worth noting that the labor decision of the intermediate firm does not depend on the real wage expressed in terms of the final good but rather in terms of the intermediate good. Hence, the relevant price for labor demand is different from that for labor supply. This feature will prove very important for the ability of the flexible price version of the model to match the facts reported above. In particular, the labor market equilibrium is described by

$$\frac{U_\ell(C_t, M_t/P_t, \ell_t)}{U_c(C_t, M_t/P_t, \ell_t)} = \theta(1-\alpha)\frac{X_t(i)}{h_t(i)} \times \frac{P_{xt}}{P_t} \tag{13}$$

so, unlike the closed economy version of the model, the labor market equilibrium includes a terms of trade effect, which is critical for our results.

2.1.3 The monetary authorities

The behavior of the monetary authorities is similar to that[8] postulated by Galí [1999]. Namely, the supply of money evolves according to the rule:

$$M_t = g_{mt} M_{t-1}$$

where $g_{mt} > 1$ is the gross rate of growth of nominal balances, which is assumed to follow an exogenous stochastic process. A similar process is assumed in the foreign country.

[7]We assume imperfect competition so that the firms can have price setting behaviour in the sticky price version of the model we solve.

[8]While the monetary policy rule does not matter under flexible prices, it can make a big difference under fixed prices. Dotsey [1999] shows that a sufficiently procyclical monetary policy can induce a positive correlation between output and employment following a technology shock.

2.1.4 The government

The government finances government expenditure on the domestic final good using lump sum taxes. The stationary component of government expenditures is assumed to follow an exogenous stochastic process, whose properties will be defined later.

3 Calibration

The model is calibrated using post–WWII data for the US and Europe[9]. In setting the parameters, we draw heavily on previous calibration exercises by Backus, Kehoe and Kydland [1995], Cooley and Prescott [1995], Chari et al. [2003], Collard and Dellas [2002]. The parameters are reported in Table 3.

As far as preferences are concerned, the instantaneous utility function takes the following form.

$$U\left(C_t, \frac{M_t}{P_t}, \ell_t\right) = \frac{1}{1-\sigma}\left[\left(\left(C_t^{\eta} + \zeta \frac{M_t}{P_t}^{\eta}\right)^{\frac{\nu}{\eta}} \ell_t^{1-\nu}\right)^{1-\sigma} - 1\right]$$

The parameter ruling the elasticity of substitution between consumption and real balances, η, and the weight assigned to real balances are borrowed from Chari et al. [2003] who estimated it from the money demand function. They find an interest rate elasticity of money demand of -0.39 implying that $\eta = -1.5641$ and the estimated weight assigned to money in preferences implies that $\zeta = 0.0638$. σ is set to 2.5 in our study. We also ran the model assuming different values for σ. The results are qualitatively the same, therefore we retained this value which is widely used in the literature. ν is set such that the model generates a total fraction of time devoted to market activities of 31%. Finally the household is assumed to discount the future at a 4% annual rate, implying $\beta = 0.988$.

The rate of growth of the economy, γ, is calibrated such that the model reproduces the US rate of growth of real per capita output and the rate of population growth, respectively equal to 0.012 and 0.0156 on an annual basis. θ is set such that markups in the economy are 20%. α, the elasticity of the production function to physical capital is set such that the labor share in the economy is 2/3, which corresponds to the average labor share other the period. The technology shocks are specified as follows[10] $a_t = \log(A_t/A)$ and $a_t^{\star} = \log(A_t^{\star}/A^{\star})$ are assumed

[9]Europe consists of the five countries that are the main trade partners of the US: Belgium, France, Germany, the Netherlands and the UK. We also considered France and Germany separately. This pair actually represents a more favorable environment for the flexible price model because it contains very open economies and the estimated trade elasticities for Germany are close to zero.

[10]While technology in Galí is an I(1) process, an I(1) specification cannot be used in an open economy, except under quite uninteresting circumstances. The reason is that if technology in each country follows a

Table 3: Calibration

Utility		
Discount factor	β	0.9880
Relative risk aversion	σ	2.5000
CES weight in utility function	ν	0.3301
Parameter of CES in utility function	η	-1.5641
Weight of money in the utility function	ζ	0.0638
Import share	$1-\omega$	0.1000
Elasticity of substitution	$1/(\rho-1)$	-0.5,-1.5
Technology		
Rate of growth	γ	1.0069
Depreciation rate	δ	0.0250
Labor share	wh/py	0.6400
Markup parameter	θ	0.8000
Capital adjustements costs (marginal elasticity)	φ	-0.1690
Shocks		
Persistence of technology shock	ρ_a	0.9060
Spillover of technology shock	$\rho_a^\star$	0.0880
Standard deviation of technology shock	σ_a	0.0085
Correlation between foreign and domestic shocks	ψ	0.2580
Persistence of government spending shock	ρ_g	0.9700
Volatility of government spending shock	σ_g	0.0200
Money supply gross rate of growth	μ	1.0166
Persistence of money supply shock	ρ_m	0.4900
Volatility of money supply shock	σ_m	0.0090

to follow a stationary VAR(1) process of the form

$$\begin{pmatrix} a_t \\ a_t^\star \end{pmatrix} = \begin{pmatrix} \rho_a & \rho_a^\star \\ \rho_a^\star & \rho_a \end{pmatrix} \begin{pmatrix} a_{t-1} \\ a_{t-1}^\star \end{pmatrix} + \begin{pmatrix} \varepsilon_{a,t} \\ \varepsilon_{a,t}^\star \end{pmatrix}$$

with $|\rho_a + \rho_a^\star| < 1$ and $|\rho_a - \rho_a^\star| < 1$ for the sake of stationarity and

$$\begin{pmatrix} \varepsilon_{a,t} \\ \varepsilon_{a,t}^\star \end{pmatrix} \rightsquigarrow \mathcal{N}\left(\begin{pmatrix} 0 \\ 0 \end{pmatrix}, \sigma_a^2 \begin{pmatrix} 1 & \psi \\ \psi & 1 \end{pmatrix} \right)$$

We follow Backus et al. [1995] and set $\rho_a = 0.906$, $\rho_a^\star = 0.088$, $\sigma_a = 0.0085$ and $\psi = 0.258$.

The government spending shock is assumed to follow an AR(1) process

$$\log(g_t) = \rho_g \log(g_{t-1}) + (1 - \rho_g)\log(\overline{g}) + \varepsilon_{g,t}$$

with $|\rho_g| < 1$ and $\varepsilon_{g,t} \rightsquigarrow \mathcal{N}(0, \sigma_g^2)$. ρ_g and σ_g are set at their empirical counterpart, namely, $\rho_g = 0.97$ and $\sigma_g = 0.02$.

Likewise, the money supply shock is assumed to follow an AR(1) process

$$\log(g_{mt}) = \rho_m \log(g_{mt-1}) + (1 - \rho_m)\log(\overline{g}_m) + \varepsilon_{m,t}$$

with $|\rho_m| < 1$ and $\varepsilon_{m,t} \rightsquigarrow \mathcal{N}(0, \sigma_m^2)$. ρ_m is set to 0.49, while $\sigma_g = 0.009$. The nominal growth of the economy, $\overline{g}_m$, is set equal to 6.8% per year.

ω, the parameter representing the weight of domestic intermediate goods in the final good bundle is set so as to match the import share. Note that in our model economy, the whole world consists of only two countries so that bilateral and total trade coincide. We have used a –common– import share of 10%, [11] implying a value of 0.90 for ω. ρ is related to the elasticity of substitution between domestic and foreign intermediate goods in the final good bundle and also determines the price elasticity of the import demand function. We consider two alternative values for ρ. The first one, $\rho = 1/3$ (labeled henceforth the high elasticity case) corresponds to the value commonly used in the RBC literature (see e.g. Backus et al. [1995], Chari et al. [2003]). It implies an elasticity of substitution of 1.5 in the Armington aggregator, as reported in Whalley [1985]. There actually exist no consensus on this parameter and the literature reports a wide range of values for trade elasticities. In a recent study, Hooper, Johnson and Marquez [2000] estimate trade elasticities for the G7 countries. Their results suggest that the price channel plays a weak role in the determination

specific random walk then it leads with probability one to a situation where one of the two economies becomes infinitely large relative to the other one. This can be prevented only if the shocks are perfectly correlated across countries or if preferences are logarithmic so that the ratio of incomes of the two countries is constant. In both cases the real exchange rate is left unaffected by a technology shock which is highly counterfactual.

[11] We have also carried out the analysis with a higher import share (20%). With this value the results are even more favorable to the flexible price, low elasticity model. See 3 below.

of imports and exports. They report long–run trade elasticities of 0.3 for the US, and a corresponding short–run elasticity of 0.6. The reported values for the other G7 countries range between 0 and 0.6. Earlier studies by Houthakker and Magee [1969] and Marquez [1990] also suggest trade elasticities between 0 and 1. In his study, Taylor [1993] estimates an import demand equation for the US and finds a short–run trade elasticity of 0.22 and a long–run trade elasticity of 0.39. All these estimates are consistent with the trade elasticity pessimism view that emerged originally in the 40s in the context of the Marshall–Lerner conditions but has remained the dominant view among trade economists since. We set ρ such that the trade elasticity is close to the upper bound of these estimates. We assume that $\rho = -1$, implying a trade elasticity of 0.5.[12]

We finally have to set the parameters characterizing the capital accumulation process. We first set the depreciation rate, δ, at 0.025, which amounts to a 10% annual depreciation of physical capital. Since capital adjustment costs are assumed to be zero in steady state, we cannot determine the benchmark value for the capital adjustment cost parameter, $\varphi \equiv (i/k)\Phi''(i/k)/\Phi'(i/k)$ by using long–run averages. We therefore set φ such that the model reproduces the relative standard deviation of HP–filtered investment (σ_i/σ_y) in the model with a low trade elasticity. This led us to a value of -0.169.

For comparative purposes, we have also solved a fixed price version of the model. Price stickiness is modeled with Calvo price setting. The probability of price resetting in that version of the model model was set equal to 0.25, which amounts to assume that —on average— firm reset their price every year.

4 The results

This section reports the results. We first evaluate the ability of the model to account for the basic stylized facts reported in Section 1. We then assess its ability to account for a broader set of stylized facts reported in the international business cycle literature.

4.1 Dynamic Properties

In the flexible price economy, the impact effect of a technology shock on employment depends mostly on three parameters: The marginal elasticity of capital with regard to investment (the capital adjustment cost parameter), the trade elasticity and the degree of openness. The first parameter is important because it determines the degree to which investment — and hence

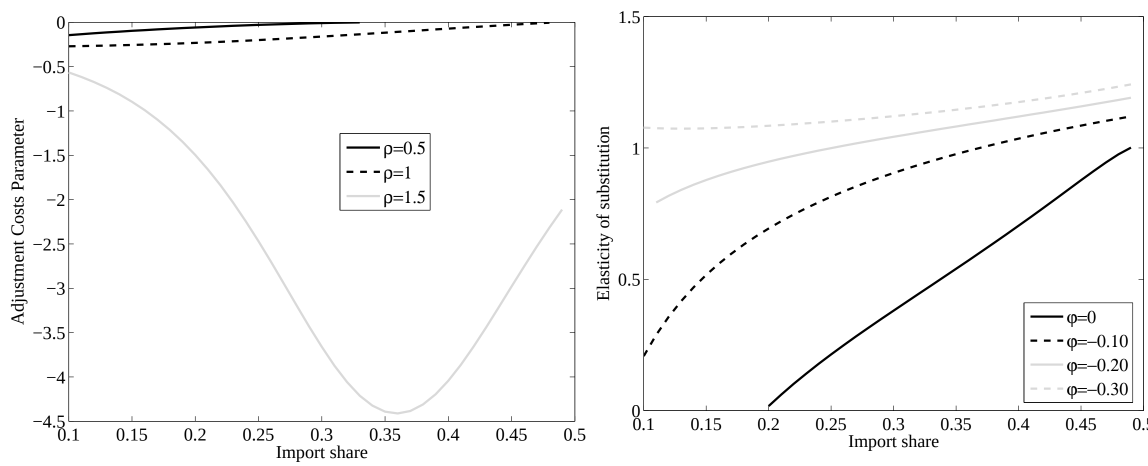
[12]Using the lower value suggested by Taylor strengthens the ability of the RBC model to match the conditional correlation of employment and output.

aggregate demand — responds to a technological shock. With a small increase in aggregate demand, a given capital stock and improved technology, labor may have to decrease[13]

The second parameter can also play a crucial role. When domestic and foreign goods are not good substitutes, a positive supply shock deteriorates the terms of trade for the economy that experiences the shock. The reduction in the relative price of the domestic good discourages output expansion. Therefore, as the mild expansion in output is accompanied with a higher level of total factor productivity, and because capital is predetermined, less labor may be needed. Hours worked can drop. Moreover, the greater the degree of trade openness (the larger the import share) the larger the potential role of this mechanism.

This intuition is summarized in Figure 3, which reports the loci of points for which the contemporaneous response of employment to a technology shock is zero ($dh/dA = 0$) as a function of these parameters. Points below a curve correspond to $dh/dA < 0$. We report two

Figure 3: Loci of $dh/dA = 0$



Note: Points below a curve corresponds to $dh/dA < 0$.

combinations. The first one, depicted in the left hand side panel, plots the size of adjustment costs required to get a negative response of hours worked for a given level of the elasticity of substitution between foreign and domestic goods. The figure makes it clear that when foreign and domestic goods are substitutable, the level of capital adjustment costs required to get a negative response of hours is very high. In the case of an import share of 10%, a value of $\varphi = -0.6$ is needed which is much higher than that assumed in the benchmark calibration (-0.169). When goods are highly substitutable, the terms of trade are less responsive to shocks, and hence they cannot act as a major barrier to output expansion. Therefore, a drop in hours can only occur when demand is very unresponsive, which is achieved by having

[13] An alternative way of limiting changes in aggregate demand is by using habit persistence.

very large capital adjustment costs. Since the volatility of the terms of trade is decreasing in the degree of openness, the required capital adjustment costs tend to increase (φ becomes more negative) as the import share increases.[14] An unsatisfactory implication of such a high level of capital adjustment costs is that the model generates a relative standard deviation of investment that is close to zero. Conversely, when the trade elasticity is low, say 0.5, then the required level of capital adjustment costs is low (-0.145) and consistent with that in the data (at least as far as investment volatility is concerned).

The second panel in the right hand side of the figure plots again the combination of the elasticity of substitution between foreign and domestic goods, the degree of openness and the capital adjustment costs parameter that is required for a negative response of hours to a positive technological shock. Again, points below a curve correspond to $dh/dA < 0$. The figure suggests that such a response is not too difficult to get if it is costly to adjust capital, domestic and foreign goods are not good substitutes and the degree of openness is sufficiently — but not unrealistically — high. As expected, a low degree of substitutability can support a negative response of hours even when capital adjustment costs are mild. The figure also illustrates that when capital adjustment costs are large enough — i.e. when aggregate demand is less responsive — a negative response of hours worked may obtain even in situations where foreign and domestic goods are good substitutes. Note however that, as discussed above, this obtains at the price of having excessively smooth investment.

Table 4 and Figure 4–6 report the impact and dynamic effects of technological shocks[15] in the flexible economies under the two alternative values of the trade elasticity: High, -1.5 and low -0.5. The signs of the impact effects and the dynamics of the main macroeconomic variables are as predicted by theory.

The main difference across the two trade elasticity values regards the response of hours. It is negative when the elasticity is low and positive when it is high.[16] In Figure 5, we compare the model predicted IRFs of output, hours and productivity to their empirical counterparts. The shaded area corresponds to the 95% confidence interval.[17]

The middle panel of the figure shows that the model with a low trade elasticity can statistically account for the empirical IRF of hours with regard of a technology shock. The theoretical

[14] Note that beyond a certain threshold, the phenomenon reverses.

[15] Figures reporting the impulse response functions to the other shocks are reproduced in the appendix.

[16] Under the same calibration, a sticky price version of the model with Calvo type contracts gives a negative and considerably larger effect: -1.26 as compared to -0.06 in the flexible price case. However, it also predicts negative response of output to a technology shock. The complete results from the sticky price version are available from the authors.

[17] The empirical IRFs are obtained from the VAR specification with linearly detrended hours worked. This avoids the criticism of Christiano et al. [2004] that hours should not be differenced.

Table 4: Elasticities (Flexible Prices, Low Elasticity)

	ϵ_a	$\epsilon_a^\star$	ϵ_g	$\epsilon_g^\star$	ϵ_m	$\epsilon_m^\star$
			Low Elasticity Case			
Y	0.971	-0.045	0.162	-0.026	-0.024	0.001
h	-0.019	-0.074	0.158	0.012	-0.027	-0.001
W	0.875	0.144	-0.013	-0.021	0.006	-0.000
π	-0.953	-0.072	0.112	0.030	1.820	-0.001
e	0.148	-0.148	-0.070	0.070	1.818	-1.818
RER	1.030	-1.030	-0.151	0.151	-0.003	0.003
ToT	1.287	-1.287	-0.189	0.189	-0.004	0.004
TB	-0.143	0.143	0.358	-0.358	-0.021	0.021
			High Elasticity Case			
Y	0.903	0.023	0.166	-0.030	-0.023	0.001
h	0.099	-0.192	0.137	0.033	-0.027	-0.001
W	0.882	0.136	-0.014	-0.020	0.006	-0.000
π	-0.865	-0.160	0.100	0.041	1.820	-0.001
e	0.077	-0.077	-0.050	0.050	1.818	-1.818
RER	0.783	-0.783	-0.109	0.109	-0.003	0.003
ToT	0.979	-0.979	-0.137	0.137	-0.003	0.003
TB	-1.762	1.762	0.566	-0.566	-0.016	0.016

Note: ϵ_j, $j = a, m, g$ denote respectively the supply, money and fiscal shock respectively. A star denotes the foreign country. e, RER, ToT and TB respectively denote the nominal exchange rate, the real exchange rate, the terms of trade and the trade balance.

Figure 4: IRF to a positive technological shock: Domestic Variables

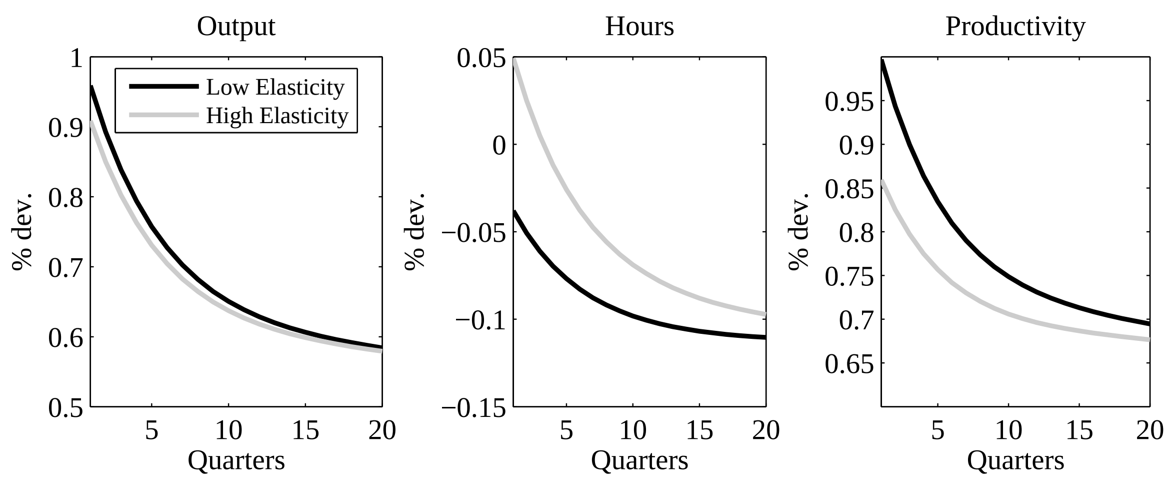
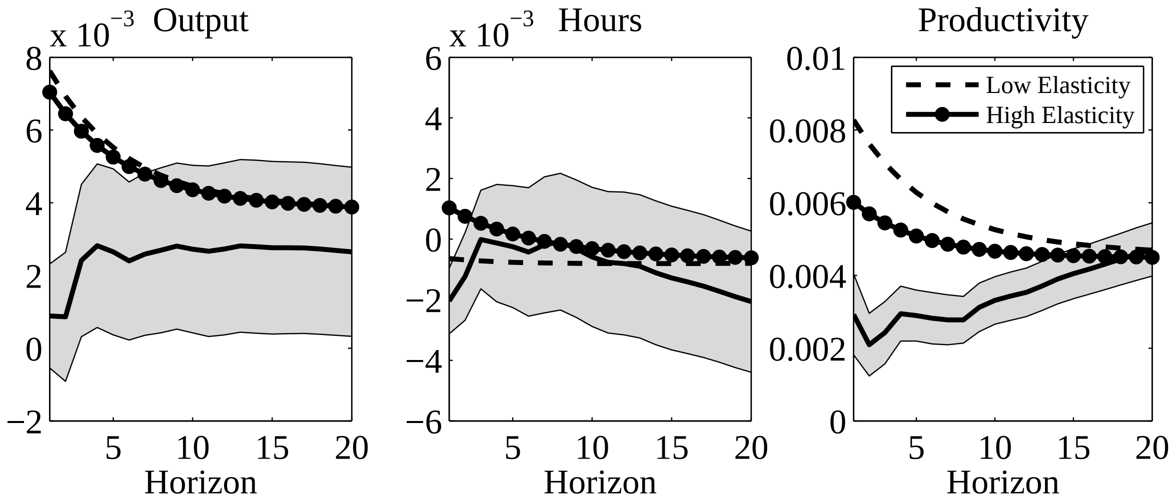


Figure 5: Impulse Response Function to a 1 s.d. technological shock



IRF lies within the 95% confidence interval. However, output is excessively responsive, as the impact effect of the technological shock is above the upper limit of the confidence interval. As a result, the model fails to statistically account for the very short–run dynamics of labor productivity.

Turning to correlations one is struck by how well the low trade elasticity version of the flexible price model performs in terms of conditional correlations. In Table 5, we report the correlation between changes in hours and changes in productivity, both unconditional and conditional. The low trade elasticity version of the model generates an unconditional correlation of -0.10, when the data indicate that this correlation is -0.25. Likewise, the correlation conditional on technology shocks is -0.42 in the model while that in the data is about -0.70 or -0.81, depending on the way hours worked are made stationary. The model also does a good job in accounting for the correlation conditional on the other shocks. It is slightly negative in the data (about -0.1) while the model generates zero correlation. In this respect, a sticky price version of the model would outperform *qualitatively* the flexible price version, but it would do much worse quantitatively as it generates a correlation of -0.96. Note also that because the model fails to account for the hump–shaped pattern of actual output it cannot generate the low conditional correlation between changes in hours and changes in output observed (0.05 or -0.12 in the data versus -0.34 in the model).[18]

We now turn to the behavior of the real exchange rate and the trade balance (see Figure 6). As shown by Backus et al. [1992], the properties of the open economy variables are quite sensitive to the size of the trade elasticity. Our model is quite similar to theirs, so it has

[18]The sticky price version of the model gives a positive conditional correlation of 0.11.

Table 5: Conditional Correlations

	Corr($\cdot, \Delta y/h$)			Corr($\cdot, \Delta y$)		
	Δh	RER	NX	Δh	RER	NX
			Flexible, low elasticity			
All	-0.094	0.110	0.035	0.279	0.081	0.075
Techno.	-0.415	0.153	0.013	-0.340	0.156	0.022
Other	0.029	-0.154	0.150	0.971	-0.152	0.149
			Flexible, high elasticity			
All	0.048	0.060	-0.013	0.436	0.072	-0.008
Techno.	0.042	0.106	-0.093	0.261	0.149	-0.129
Other	0.189	-0.177	0.174	0.914	-0.153	0.151

similar properties. In particular, we face the trade off noted by Backus et al. [1992]: A lower elasticity of substitution between foreign and domestic goods amplifies the response of the nominal and real exchange rates and of the terms of trade, but dampens that of the trade balance. We see that in the low trade elasticity, the impact effect of a positive technology shock on the real exchange rate is 30% larger than that in the high trade elasticity (1.03 versus 0.78). But the impact effect of a unit, positive, technology shock on the trade balance is only -0.14 in the low trade case as compared with -1.77 in the high trade elasticity case. The intuition for these findings is that offered by Backus et al. [1992]. Hence, this model (as well as its sticky price version) does not escape the *price anomaly*.

As shown in Figure 7, the model has no difficulty accounting for the dynamics of the real exchange rate following a positive technological shock, irrespective of the value of the trade elasticity. The IRF generated by the model lies within the 95% confidence band. But it is less successful in capturing the short–run dynamics of the trade balance. In particular, while it does a good qualitative job (it predicts a worsening of the trade balance) it cannot generate a large enough response on impact. Note that the high trade elasticity version of the model does better in this regard.[19]

These findings also show up in the correlation coefficients. The model cannot fully account for the conditional correlation between the real exchange rate and changes in productivity. This correlation is about 0.33 in the data but 0.15 in the model. It is, however, worth noting that the low trade elasticity version of the model outperforms the high trade elasticity version, where the correlation is even lower (0.10). Likewise the correlation between the real exchange rate and changes in output is underestimated by the model (0.16 versus 0.40 in the data).

[19]The sticky price version of the model fails too to account for the dynamics of trade balance since it also exhibits the price anomaly.

Figure 6: IRF to a positive technological shock: International variables

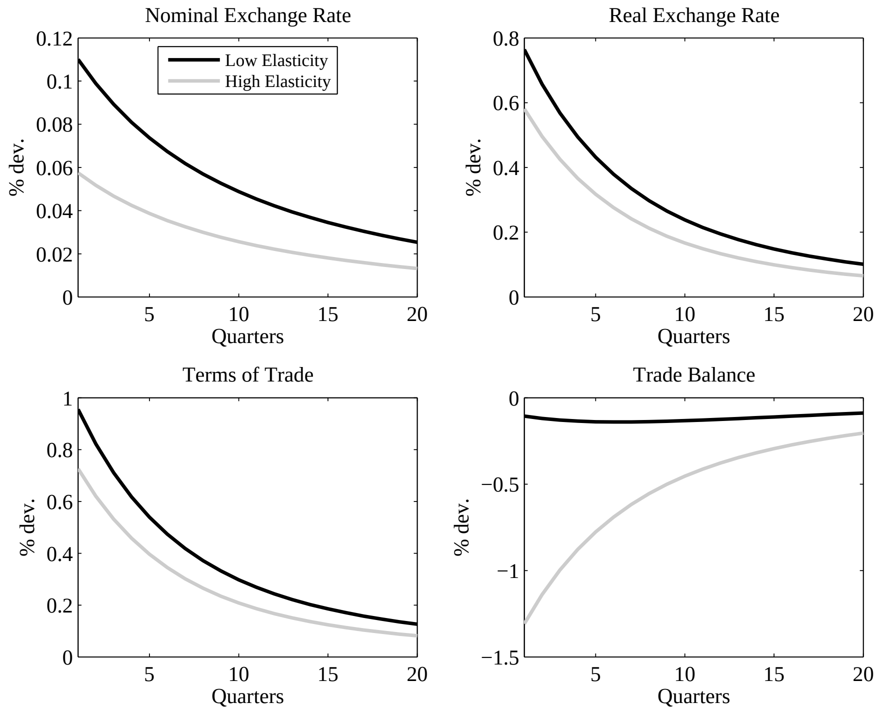
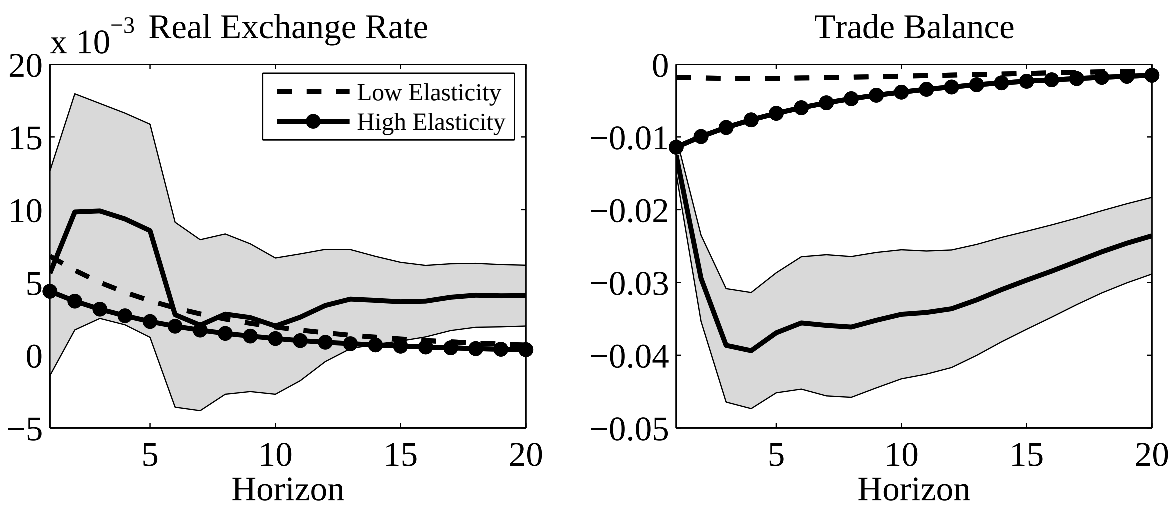


Figure 7: Impulse Response Function to a 1 s.d. technological shock



The same difficulties obtain regarding the trade balance. The conditional correlation is all versions of the model is about zero while that in the data is -0.2. [20]

4.2 Business Cycle Properties

The previous section has demonstrated that the standard, flexible price model can reproduce the negative conditional correlation between hours and productivity as long as one is prepared to accept low trade elasticities. It also showed that it has good qualitative properties as far as the real exchange rate and to a lesser extend the trade balance are concerned. Following a technology shock, both of them move in the right direction. In this section we investigate whether this success carries a cost in terms of overall model fit. In particular, we examine its ability to account for the broader set of stylized fact typically considered in the literature. In contrast to the previous section, and in order to adhere to the common practice in the international business cycle literature we consider moments of HP–filtered series.

Tables 6 and 7 report the findings. Note that all standard deviations — except that of output — are expressed in relative terms (with regard to that of output). No clear, overall winner emerges from the comparison of the low elasticity, flexible price model with the two standard models in the literature, the high elasticity flexible and fixed price models. The model with a low trade elasticity tends to under–predict the standard deviation of hours worked, while it generates too much volatility in labor productivity and too low a correlation between hours and output. Note however that, as in the standard literature, using a indivisible labor specification for preferences would greatly enhance the ability of the model to account for these facts. For instance, with indivisible labor, the relative standard deviation of hours worked would rise to 0.55, that of productivity to 0.92 and the correlation between hours and output would double. The fixed price version gives a correlation of 0.88 but it overestimates the relative standard deviation of hours and also fails to account for the positive correlation between output and productivity (-0.33).

Interestingly, the low elasticity, flexible price model produces a good match concerning the volatility of the terms of trade and of the real exchange rate, although it under–predicts the volatilities. This finding is encouraging for the empirical relevance of this model, as the terms of trade is the key price variable in an open economy. For instance, the (relative) volatility of the real exchange rate is about 1 in the low trade elasticity version of the model while it only amounts to 2/3 in the high elasticity case. Likewise the volatility of terms of trade is 50% greater in the low trade elasticity version of the model that in the high elasticity case. These

[20] The conditional correlations between the real exchange rate and changes in productivity and output in the sticky price version of the model are -0.01 and 0.10 respectively. And -0.21 and -0.13 for the trade balance.

Table 6: Second order moments

	Data		Flexible prices (Low elasticity)		Flexible prices (High elasticity)		Fixed prices (High elasticity)	
	Std.	Corr(·,y)	Std.	Corr(·,y)	Std.	Corr(·,y)	Std.	Corr(·,y)
Y	1.62	1.00	1.04	1.00	1.00	1.00	1.93	1.00
C	0.83	0.87	0.93	0.78	0.95	0.79	0.74	0.92
I	2.73	0.94	2.73	0.84	2.51	0.83	3.61	0.95
h	0.90	0.89	0.36	0.17	0.39	0.36	1.39	0.88
y/h	0.46	0.44	1.01	0.93	0.93	0.92	0.69	-0.33
π	0.35	0.38	1.67	-0.16	1.71	-0.14	0.46	0.82
Open economy dimension								
e	4.54	0.07	2.90	0.02	3.00	0.01	1.54	0.33
RER	4.08	0.07	1.01	0.35	0.67	0.29	0.49	0.47
ToT	–	–	1.68	0.35	1.12	0.29	0.81	0.47
NX	5.20	-0.36	1.19	0.25	2.28	-0.05	1.21	-0.20

Note: All standard deviations (except output) are relative to the standard deviation of output. The moments are derived from HP–filtered data. e is the real exchange rate, RER is the real exchange rate and ToT denotes the terms of trade (import price/export price). NX is a measure of the trade balance computed as the log of the ratio of exports to imports. The variables are from the OECD quarterly National Accounts, and the sample runs from 1970:1 to 1999:3.

findings are actually well known and already documented by Backus et al. [1995]. A lower trade elasticity, by constraining the response of quantities triggers a large response of prices to various shocks. This therefore improves the ability of the model to account for the volatility of prices. But this comes at the price of a lower volatility of net exports. For instance, the volatility of the trade balance in the low elasticity flexible price model is half of that in the high elasticity version. In other words, and as already mentioned in the IRF analysis, the model is not immune to the price anomaly. Note however that the sticky price version of the model would not improve much the predictions of the model along these dimensions as the price anomaly is not related to the presence of nominal rigidities at the aggregate level. In fact the sticky price model would do an even poorer job in terms of volatility, as the relative standard deviation of the real exchange rate is only about 0.5 and that of the terms of trade is only 0.8, while the volatility of trade balance is much lower than the flexible price model although the sticky price version uses a high trade elasticity. Hence, although the model possesses some weaknesses, these weaknesses are shared with the whole existing literature.

A similar conclusion emerges from the evaluation of the models in terms of cross country correlations. All versions exhibit the quantity anomaly (they predict higher correlations for consumption than for output), but the model with fixed price less so. This finding is common to much of the literature, and unless the model is modified to allow for less international risk

Table 7: Cross-Country Correlations

	Data	Flexible prices (Low elasticity)	Flexible prices (High elasticity)	Fixed prices (High elasticity)
y,y*	0.61	0.22	0.31	0.32
c,c*	0.43	0.77	0.82	0.41
h,h*	0.39	0.37	0.28	0.20
rer,nx	0.16	-0.50	-0.90	-0.83

sharing or the existence of non–traded goods, the flexible price model cannot account for this stylized facts. The strength of the low trade elasticity, flexible price model is found in its better matching of the cross–country correlation in hours worked. Note also that all models fail to account for the positive, although weak, correlation between net exports and the real exchange rate (another widespread weakness in the literature). The flexible price, low elasticity model does relatively better regarding this fact but still not well enough.

Summary and conclusions

The empirical evidence indicates that in response to an –empirically identified– positive technology shock, labor productivity rises more than output while employment shows a persistent decline. Technology shocks are almost synonymous with the RBC model, yet the standard RBC model does not seem capable of accounting for this important stylized fact. This finding has led many to doubt not only the relevance of the RBC model but also the plausibility of models that assign a big role to technology shocks as a source of aggregate fluctuations. Moreover, as the standard Keynesian model with imperfect competition and sticky prices typically generates a short run decline in employment in response to a positive technology shock, this stylized fact has provided support for models with nominal frictions.

In this paper we have argued that the standard RBC model can plausibly generate a negative, conditional correlation between productivity and employment if the model allows for international trade. If trade elasticities fall below unity — a quite realistic case — then the flexible price model can match this correlation satisfactorily. Moreover, under these circumstances, it can also broadly account for the observed response of the trade balance and the real exchange rate to a technological shock.

Our conclusion is that it may be premature to claim that there is unreconcilable contradiction between the observation of a countercyclical employment response to a supply shock and the belief that prices are flexible and supply shocks are a major source of macroeconomic fluctuations. It must be acknowledged, though, that there exists at present no model (with fixed or flexible prices) that can fully account for the empirical patterns discussed in section 1 (the Galí facts as well as their open economy extensions) and also for the stylized facts presented in section 4. The present paper has identified and highlighted the limits of existing models and may thus offer the basis for building models with better properties.

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A IRF to a Domestic Fiscal Shock

Figure 8: Domestic Variables

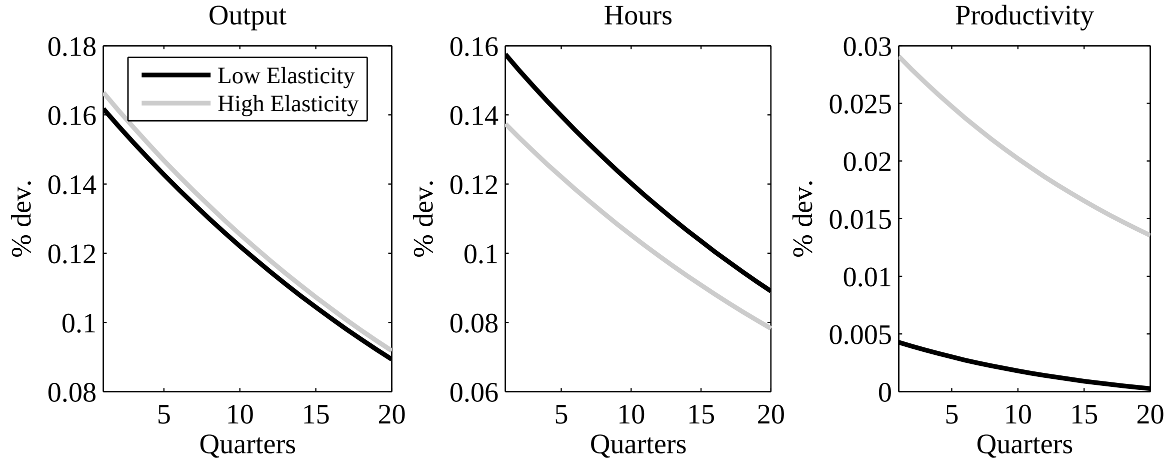
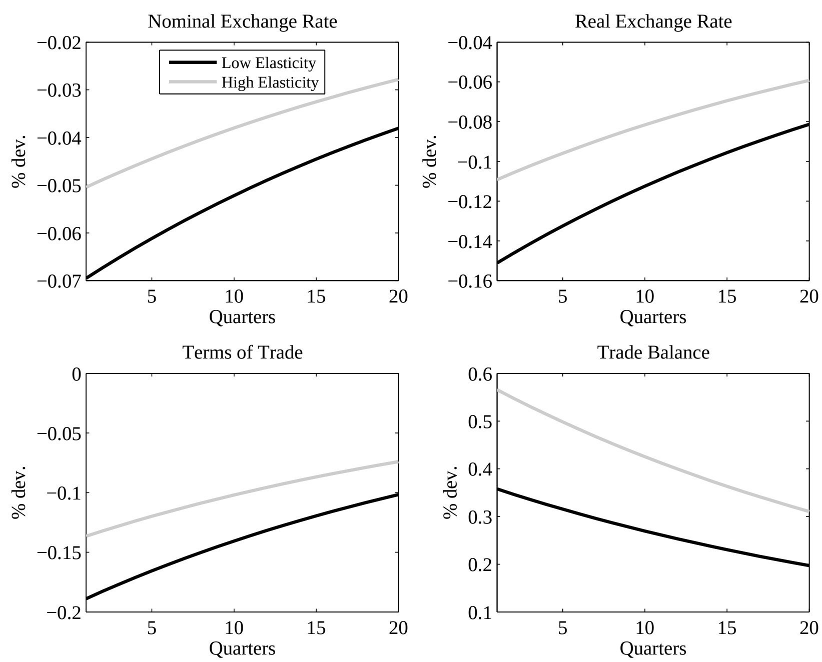


Figure 9: International Variables



B IRF to a Domestic Money Supply Shock

Figure 10: Domestic Variables

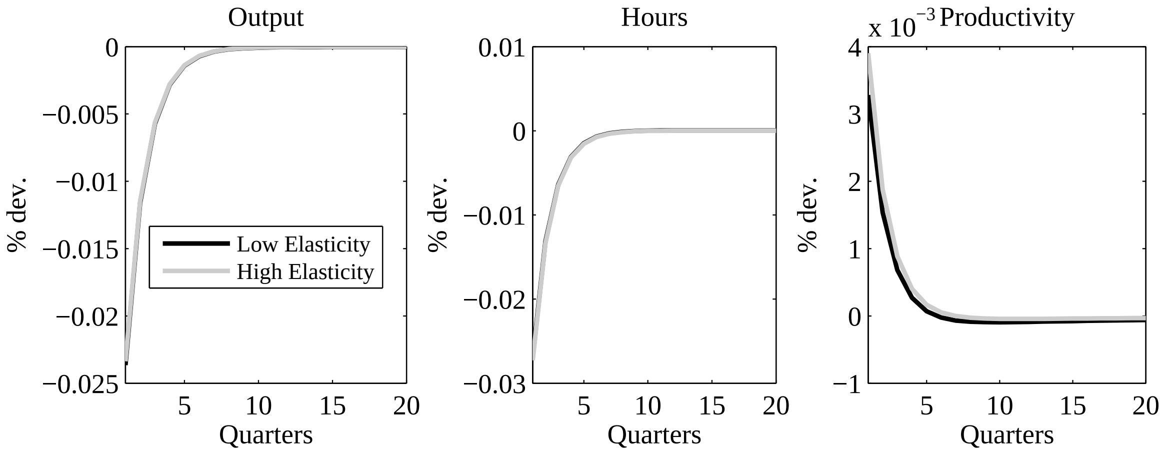


Figure 11: International Variables