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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 the RBC model 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 easily match the negative conditional correlation between productivity and employment quite well if domestic and foreign goods are not good substitutes in the short run. The computed variance-decompositions also suggest that there is no empirical inconsistency between matching this correlation and accepting that technology shocks are the main source of variation in output while demand shocks are the main source of variation in employment. Moreover, using a low rather than a high degree of substitution does not worsen model performance along any other dimensions.

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JEL Class: E32, E24.

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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 to account for business cycles has been questioned on the basis of recent evidence concerning the *conditional* relationship between productivity and employment. Gali, 1999, and Basu, Fernald and Kimball, 1999 (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.. (Gali, 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 Gali and BFK. The first is to dispute the ability of the particular identification schemes used to truly identify technology shocks(Bils, 1998). However, Francis and Ramey, 2001, examine whether Gali'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, Hairault and Portier, 1995, or time-to plan, Christiano and Todd, 1998). Implementation lags also work to restraint the increase in labor demand.

An alternative way of thinking about this is via aggregate demand and supply. If aggregate demand is inelastic 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. Inelasticity 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 Gali's stylized facts. And that it does so without compromising the ability of the model to account for many 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 Gali 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. Low substitutability means that the domestic terms of trade must worsen significantly. The reduction in the relative price of the domestic good discourages output expansion. 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 parameterization 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 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 represents an improvement relative to the high elasticity of substitution case commonly used in the literature. The fixed price model can match the sign of the correlations independent of the degree of substitutability but it under-predicts significantly the conditional correlation between productivity and employment.

From these findings we draw the conclusion that the empirical, conditional correlation of employment and output (or productivity and employment) does not necessarily pose problems for the RBC model, or more generally, for supply shocks. This conclusion is reinforced by the fact that the computed variance–decompositions indicate that output fluctuations are driven by supply shocks while employment is driven by demand shocks. Hence, there is no empirical inconsistency between matching this correlation and at the same time claiming that technology shocks are the main source of variation in output.

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 contains the description of the fixed and flexible price economies. In section 2 we report the main findings.

1 The model

1.1 Flexible prices

The world 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.

1.1.1 Domestic Household

Household preferences are characterized by the lifetime utility function:[2]

$$\sum_{\tau=0}^{\infty}\sum_{s^{t+\tau}} \beta^{\star t}\pi\left(s^{t+\tau}|s^t\right) U\left(C(s^{t+\tau}), \frac{M(s^{t+\tau})}{P(s^{t+\tau})}, \ell(s^{t+\tau})\right) \tag{1}$$

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

$$\ell(s^t) + h(s^t) = 1 \tag{2}$$

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

The representative household faces a budget constraint of the form

$$\sum_{s^{t+1}} P^b\left(s^{t+1}|s^t\right) B(s^{t+1}) + M(s^t) \quad \leq \quad B(s^t) + P(s^t)z(s^t)K(s^{t-1}) + P(s^t)W(s^t)h(s^t) + \Pi(s^t)$$

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

[2]$E_t(.)$ denotes mathematical conditional expectations. Expectations are conditional on information available at the beginning of period t.

$$+M(s^{t-1})+N(s^t)-P(s^t)(C(s^t)+I(s^t)+T(s^t)) \quad (3)$$

where $P^b\left(s^{t+1}|s^t\right)$ is the period t price of a contingent claim that delivers one unit of the final good in period $t+1$; $B(s^t)$ is the number of contingent claims owned by the domestic household at the beginning of period t; W is the real wage; P is the nominal price of the domestic final good; C is consumption and I is investment expenditure; K is the amount of physical capital owned by the household and leased to the firms at the real rental rate z. $M(s^{t-1})$ is the amount of money that the household brings into period t, $M(s^t)$ is the end of period t money and N is a nominal lump-sum transfer received from the monetary authority; $T(s^t)$ is the lump-sum taxes paid to the government and used to finance government consumption.

Capital accumulates according to the law of motion

$$K(s^t)=\Phi\left(\frac{I(s^t)}{K(s^{t-1})}\right)K(s^{t-1})+(1-\delta)K(s^{t-1}) \quad (4)$$

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, we impose two assumptions that guarantee the absence of adjustment costs in the steady state: $\Phi(\gamma+\delta-1)=\gamma+\delta-1$ and $\Phi'(\gamma+\delta-1)=1$.

The behavior of the foreign household is similar.[3]

1.1.2 Final 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

$$Y(s^t)=\left(\omega^{\frac{1}{1-\rho}}X^d(s^t)^\rho+(1-\omega)^{\frac{1}{1-\rho}}X^f(s^t)^\rho\right)^{\frac{1}{\rho}} \quad (5)$$

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

$$\sum_{s^{t+1}}P^b\left(s^{t+1}|s^t\right)\frac{B^\star(s^{t+1})}{e_t}+M^\star(s^t) \leq B^\star(s^t)+M^\star(s^{t-1})+N^\star(s^t)+\Pi^\star(s^t)+P^\star(s^t)W^\star(s^t)h^\star(s^t)$$
$$+P^\star(s^t)z^\star(s^t)K^\star(s^{t-1})-P^\star(s^t)(C^\star(s^t)+I^\star(s^t))-T^\star(s^t)$$

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

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

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

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 goods in the domestic and foreign bundles. The producers of the final goods behave competitively and determine their demand for each intermediate good $X^d(i,s^t)$ and $X^f(i,s^t)$, $i \in (0,1)$ by maximizing the static profit equation

$$\max_{\{X^d(i,s^t),X^f(i,s^t)\}_{i\in(0,1)}} P(s^t)Y(s^t) - \int_0^1 P_x(i,s^t)X^d(i,s^t)\mathrm{d}i - \int_0^1 e(s^t)P_x^\star(i,s^t)X^f(i,s^t)\mathrm{d}i \tag{7}$$

subject to (6), where $P_x(i,s^t)$ and $P_x^\star(i,s^t)$ denote the price of each domestic and foreign intermediate good respectively, denominated in terms of the currency of the *seller*. This yields demand functions of the form:

$$X^d(i,s^t) = \left(\frac{P_x(i,s^t)}{P_x(s^t)}\right)^{\frac{1}{\theta-1}} \left(\frac{P_x(s^t)}{P(s^t)}\right)^{\frac{1}{\rho-1}} \omega Y(s^t) \tag{8}$$

and

$$X^f(i,s^t) = \left(\frac{e(s^t)P_x^\star(i,s^t)}{e(s^t)P_x^\star(s^t)}\right)^{\frac{1}{\theta-1}} \left(\frac{e(s^t)P_x^\star(s^t)}{P(s^t)}\right)^{\frac{1}{\rho-1}} (1-\omega)Y(s^t) \tag{9}$$

and the following general price indexes

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

$$P(s^t) = \left(\omega P_x(s^t)^{\frac{\rho}{\rho-1}} + (1-\omega)(e(s^t)P_x^\star(s^t))^{\frac{\rho}{\rho-1}}\right)^{\frac{\rho-1}{\rho}} \tag{11}$$

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

The behavior of the foreign final goods producers is similar.[4]

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

$$P^\star(s^t) = \left((1-\omega)\left(\frac{P_x(s^t)}{e(s^t)}\right)^{\frac{\rho}{\rho-1}} + \omega P_x^\star(s^t)^{\frac{\rho}{\rho-1}}\right)^{\frac{\rho-1}{\rho}}$$

1.1.3 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

$$X(i,s^t) \geqslant A_t K(i,s^t)^{\alpha}(\Gamma_t h(i,s^t))^{1-\alpha} \text{ with } \alpha \in (0,1) \tag{12}$$

where $K(i,s^t)$ and $h(i,s^t)$ respectively denote the physical capital and the labor input used by firm i in the production process[5]. 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. 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

$$\min_{\{K_t(i),h_t(i)\}} P(s^t)W(s^t)h(i,s^t) + P(s^t)z(s^t)K(i,s^t)$$

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

$$P(s^t)\mathcal{C}_m(s^t)X(i,s^t)$$

where the real marginal cost, $\mathcal{C}_m$, is given by $\frac{W(s^t)^{1-\alpha}z(s^t)^{\alpha}}{\chi A_t \Gamma_t^{1-\alpha}}$ with $\chi = \alpha^{\alpha}(1-\alpha)^{1-\alpha}$

Intermediate goods producers are monopolistically competitive, and therefore set prices for the good they produce. Price setting is similar in the foreign economy.

1.1.4 The monetary authorities

The behavior of the monetary authorities is similar to that[6] postulated by Gali, 1999. Namely, the supply of money evolves according to the rule:

$$M(s^t) = g_{mt}M(s^{t-1})$$

[5]We have also experimented with a version that allows for variable capital utilization. Such a version does not affect the ability of the model to match the conditional correlation of output and employment, so we have decided to abstract from it.

[6]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.

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.

1.1.5 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.

1.1.6 The equilibrium

We now turn to the description of the equilibrium of the economy. Recall that capital is perfectly mobile across countries while labor is not.

Definition 1 *An equilibrium of this economy is a sequence of prices* $\{\mathcal{P}(s^t)\}_{t=0}^{\infty} = \{W(s^t),$ $W^\star(s^t), z(s^t), z^\star(s^t), P(s^t), P^\star(s^t), P_x(s^t), P_x^\star(s^t), \widetilde{P}_x(s^t), \widetilde{P}_x^\star(s^t), e(s^t), R(s^t), R^\star(s^t)\}_{t=0}^{\infty}$ *and a sequence of quantities* $\{\mathcal{Q}(s^t)\}_{t=0}^{\infty} = \{\{\mathcal{Q}^H(s^t)\}_{t=0}^{\infty}, \{\mathcal{Q}^F(s^t)\}_{t=0}^{\infty}\}$ *with* $\{\mathcal{Q}^H(s^t)\}_{t=0}^{\infty} = \{C(s^t),$ $C^\star(s^t), I(s^t), I^\star(s^t), B(s^{t+1}), B^\star(s^{t+1}), K(s^t), K^\star(s^t), h(s^t), h^\star(s^t)^\star, M_{t+1}, M_{t+1}^\star, G(s^t), G^\star(s^t)\}_{t=0}^{\infty}$ *and* $\{\mathcal{Q}^F(s^t)\}_{t=0}^{\infty} = \{Y(s^t), Y(s^t)^\star, X(i,s^t), X^\star(i,s^t), X^d(i,s^t), X^{d\star}(i,s^t), X^f(i,s^t), X^{f\star}(i,s^t),$ $K(i,s^t), K^\star(i,s^t),\ h(i,s^t), h^\star(i,s^t); i \in (0,1)\}_{t=0}^{\infty}$ *such that:*

(i) given a sequence of prices $\{\mathcal{P}_t\}_{t=0}^{\infty}$ *and a sequence of shocks,* $\{\mathcal{Q}_t^H\}_{t=0}^{\infty}$ *is a solution to the representative household's problem;*

(ii) given a sequence of prices $\{\mathcal{P}_t\}_{t=0}^{\infty}$ *and a sequence of shocks,* $\{\mathcal{Q}_t^F\}_{t=0}^{\infty}$ *is a solution to the representative firms' problem;*

(iii) given a sequence of quantities $\{\mathcal{Q}_t\}_{t=0}^{\infty}$ *and a sequence of shocks,* $\{\mathcal{P}_t\}_{t=0}^{\infty}$ *clears the markets*

$$Y(s^t) = C(s^t) + I(s^t) + G(s^t) \tag{13}$$

$$Y^\star(s^t) = C^\star(s^t) + I^\star(s^t) + G^\star(s^t) \tag{14}$$

$$\int_0^1 X(i,s^t)di = \int_0^1 X^d(i,s^t) + X^{d\star}(i,s^t)di \tag{15}$$

$$
\begin{aligned}
\int_0^1 X^\star(i,s^t)\,di &= \int_0^1 X^f(i,s^t) + X^{f\star}(i,s^t)\,di && (16)\\
h(s^t) &= \int_0^1 h(i,s^t)\,di && (17)\\
h^\star(s^t) &= \int_0^1 h^\star(i,s^t)\,di && (18)\\
K(s^{t-1}) &= \int_0^1 K(i,s^t)\,di && (19)\\
K^\star(s^{t-1}) &= \int_0^1 K^\star(i,s^t)\,di && (20)\\
B(s^t) + \frac{B^\star(s^t)}{e(s^t)} &= 0 && (21)\\
P(s^t)G(s^t) &= T(s^t) && (22)\\
P^\star(s^t)G^\star(s^t) &= T^\star(s^t) && (23)
\end{aligned}
$$

and the money markets.

1.2 Fixed prices

We now describe an economy with sluggish prices. The reason for considering such an economy is that we do not know if and how well such a model matches the conditional correlations as well as other stylized facts.

The model differs from that described above only concerning the degree of price flexibility. Following Calvo, 1983, we assume that firms set their prices for a stochastic number of periods. In each and every period, a firm either gets the chance to adjust its price (an event occurring with probability q) or it does not. If it does not, it charges the price selected during the last time it set prices. We assume that the predetermined prices incorporate a nominal indexation term Ξ_t, that is, the nominal price in period t is $P_x(i,s^t) = \Xi_t p_x(i,s^t)$ where $p_x(i,s^t)$ is the deflated fixed price. A firm i sets its price in period t in order to maximize its discounted profit flow:

$$
\max_{p_x(i,s^t)} \widetilde{\Pi}_x(i,s^t) + \sum_{\tau=1}^{\infty}\sum_{s^{t+\tau}} P^b(s^{t+\tau}|s^t)(1-q)^{\tau-1}\left(q\widetilde{\Pi}_x(i,s^{t+\tau}) + (1-q)\Pi_x(i,s^{t+\tau})\right)
$$

subject to the total demand it faces:

$$
X(i,s^t) = \left(\frac{P_x(i,s^t)}{P_x(s^t)}\right)^{\frac{1}{\theta-1}} \left(X^d(s^t) + X^{d\star}(s^t)\right)
$$

and where $\Pi_x(i, s^{t+\tau}) = (\Xi_{t+\tau} p_x(i, s^t) - P(s^{t+\tau})\mathcal{C}_m(s^{t+\tau}))X(i, s^{t+\tau})$ is the profit attained when the price is maintained, while $\widetilde{\Pi}_x(i, s^{t+\tau}) = (\widetilde{p}_x(i, s^{t+\tau}) - P(s^{t+\tau})\mathcal{C}_m(s^{t+\tau}))X(i, s^{t+\tau})$ is the profit attained when the price is reset. This yields the price setting behavior

$$\widetilde{p}_{x,t}(i) = \frac{1}{\theta} \frac{\sum_{\tau=0}^{\infty} \sum_{s^{t+\tau}} P^b(s^{t+\tau}|s^t)(1-q)^{\tau} \Xi_{t+\tau}^{\frac{1}{\theta-1}} P(s^{t+\tau}) P_x(s^{t+\tau})^{\frac{1}{\theta-1}} \mathcal{C}_m(s^{t+\tau}) X(s^{t+\tau})}{\sum_{\tau=0}^{\infty} \sum_{s^{t+\tau}} P^b(s^{t+\tau}|s^t)(1-q)^{\tau} \Xi_{t+\tau}^{\frac{\theta}{\theta-1}} P_x(s^{t+\tau})^{\frac{1}{\theta-1}} X(s^{t+\tau})} \tag{24}$$

Since the price setting is independent of any firm specific characteristic, all firms that reset their prices will choose the same price.

In each period, a fraction q of contracts ends, so there are $q(1-q)$ contracts surviving from period $t-1$, and therefore $q(1-q)^j$ from period $t-j$. Hence, the aggregate intermediate price index is given by

$$P_x(s^t) = \left(\sum_{i=0}^{\infty} q(1-q)^i \left(\Xi_{t-i} \widetilde{p}_x(s^{t-i}) \right)^{\frac{\theta}{\theta-1}} \right)^{\frac{\theta-1}{\theta}} \tag{25}$$

2 Calibration

We consider the US and Europe[7]. In setting the parameters, we draw heavily on Backus et al., 1995, Cooley and Prescott, 1995, Chari et al., 2000 and Collard and Dellas, 2002. The parameters are reported in table 1. ω is set such that the import share in the economy is 20%. The rate of growth of the economy, γ, is calibrated such that the model reproduces the rate of growth of real per capita output and the rate of population growth, respectively equal to 0.012 in the US and 0.0156 in Europe on an annual basis. The nominal growth of the economy is set equal to 6.8% per year. δ is set equal to 0.025. The elasticity of the marginal adjustment cost, φ was set to -0.17. 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 0.6. For the fixed price economy, we set q, the probability of price resetting to 0.25.

[7] We have also considered France and Germany. This pair 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.

The instantaneous utility function takes the form

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

ν is set such that the model generates a total fraction of time devoted to market activities of 31%. σ is set to 2.5, η and ζ are borrowed from Chari et al., 2000. Finally, β, the discount factor is set equal to 0.988.

The technology shocks are specified as follows. $a_t = \log(A_t/A)$ and $a_t^\star = \log(A_t^\star/A^\star)$ are assumed 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

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

Following Backus et al., 1995, we 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 is set to 0.97, while $\sigma_g = 0.02$.

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 $\sigma_g = 0.009$.

We consider two alternative values for ρ. The first value, $\rho = 1/3$ generates an elasticity of substitution between foreign and domestic goods in the Armington aggregator of -1.5. This is the value used by Backus et al., 1992, 1995. The second value, $\rho = -1$ gives an elasticity of -0.5 which is close to the value of -0.39 suggested[8] by Taylor, 1993.

[8] The lower value suggested by Taylor enhances the ability of the RBC model to match the conditional correlation of employment and output.

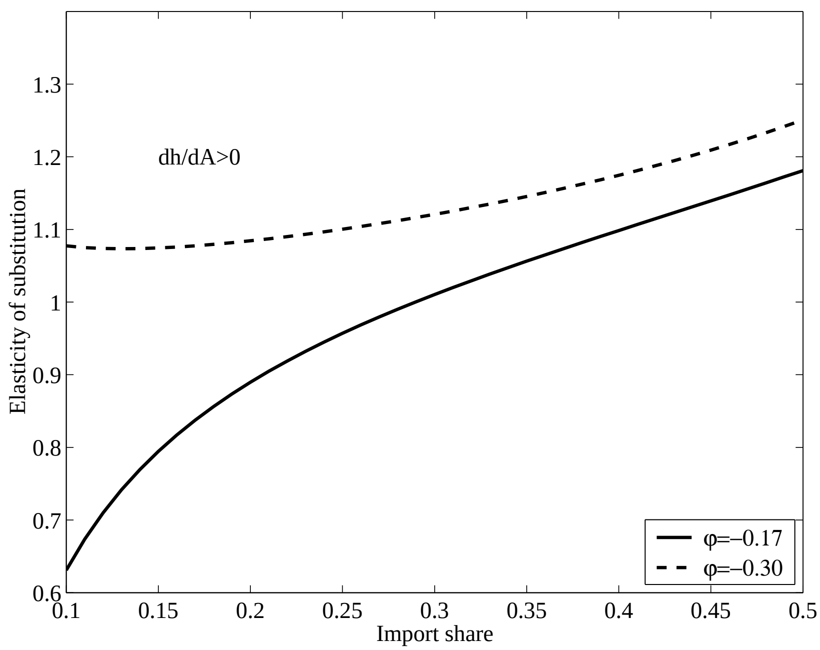
Table 1: Calibration

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	$1-\omega$	0.2000
Technology		
Rate of growth	γ	1.0069
Depreciation rate	δ	0.0250
Labor share	wh/py	0.6400
Markup parameter	θ	0.8000
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
Probality of price resetting	q	0.2500

3 The results

In the flexible price economy, the impact effect of a technology shock on employment depends much on three parameters: The trade elasticity, the degree of openness and the capital adjustment cost. The last parameter is important because it determines the degree to which investment -and hence aggregate demand- responds to a technological shock. A smaller response requires a larger change in the terms of trade and hence stronger trade effects. Graph 2 shows 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 $dh/dA < 0$. The graph suggests that the negative response of employment to a positive technology shock does not in principle create any problems for the flexible price model as long as there exist capital adjustment costs, domestic and foreign goods are not good substitutes and the degree of openness is sufficiently — but not unrealistically — high. As expected, high capital adjustment costs are sufficient for $dh/dA < 0$, independent of open economy considerations.

Figure 1: Flexible prices: Loci of $dh/dA = 0$



Tables 2–4 and figures 2-4 report the impact and dynamic effects in the flexible and fixed

price economies under the two alternative values of the trade elasticity: High, -1.5 and low -0.5. The value of the elasticity does not matter much for the fixed price model, so for the sake of space we only report the high elasticity case. We summarize the main patterns below.

First, while the *flexible* price model requires low trade elasticities and trade openness in order to generate an immediate reduction in employment in response to a positive, domestic technology shock (table 3), the *fixed* price model's ability to accomplish this does not depend much on open economy elements. Nevertheless, the former model produces a more persistent decline in employment (figure 3) and a higher conditional correlation of output and employment and productivity and employment (table 7) than the latter. As a matter of fact, under flexible prices and low elasticity, the predicted correlation for the conditional correlation of productivity and employment is much closer to that estimated by Gali, 1999. The inability of the fixed price model to reproduce the observed correlation is due to the fact that it generates a short lived reduction in employment (see figure 4).

Second, the signs of the impact effects of all the shocks on the main macroeconomic variables are as predicted by theory.

Third, neither model performs completely satisfactorily as far as a broader set of stylized facts is concerned. The flexible price model tends to under–predict the volatility of employment and of the real exchange rate while over-predicting that of inflation (table 5). The fixed price model tends to exaggerate volatility in investment, the real wage and inflation (but to a smaller degree than the flexible price model) while under–predicting the volatility of consumption and international, relative prices. Interestingly, the low elasticity, flexible price model produces the best match concerning the volatility of the terms of trade and of the real exchange rate. 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. Nonetheless, all of the models (and in particular, the flexible price ones) fail to capture the stylized fact that international consumption *correlations* are low and smaller than the correlations of outputs (table 6). An additional weakness of the flexible price versions is that they produce an unconditional correlation of employment and output that, while positive, is low. They also generate countercyclical inflation. Finally, all of the models under-predict persistence (table 8).

Fourth, the variance decompositions for the low elasticity, flexible price model (table 10) reveal an interesting property. Namely, while productivity shocks account for the bulk of fluctuations in output, fiscal shocks account for the bulk of fluctuations in employment. This suggest that that there is no empirical inconsistency between having technology shocks account for most of the variation in output while at the same time generating a negative conditional correlation between productivity and employment and a positive unconditional correlation between output and hours.

Before concluding this section let us briefly comment on the role played by the other parameters of the model. The parameters whose values have some quantitative influence on the conditional correlation between employment and output, are: The intertemporal elasticity of substitution, the mark up and the depreciation rate. In general, the ability of the flexible price model to match the conditional correlation between employment and output is enhanced by smaller intertemporal substitution and higher values for the markup and the depreciation rate. Labor indivisibility and variable capital utilization, on the other hand, are of no consequence.

Summary and conclusions

Recent 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 questioned the view that the standard RBC model cannot plausibly generate a negative, conditional correlation between productivity and employment. What is needed in order for the RBC model to account for this pattern is international trade. If trade elasticities fall below unity — a quite realistic case — then the flexible price model can match this correlation quite well (even better than the standard fixed price model). Moreover, this improvement in performance does *not* come at the cost of sacrificing goodness of fit along any other dimensions relative to the high elasticity case. On the contrary, the flexible price—low trade elasticity RBC model generates better results regarding the behavior of is key variable, the terms of trade (also in relationship to the fixed price model).

Our conclusion is that, as suggested by the computed variance–decompositions, there is no empirical inconsistency between accepting that technology shocks account for most of the variation in output while at the same time generating countercyclical employment conditional on supply shocks.

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Table 2: Elasticities (Flexible prices, high elasticity)

	ϵ_a	$\epsilon_a^\star$	ϵ_m	$\epsilon_m^\star$	ϵ_g	$\epsilon_g^\star$
Y	0.786	0.140	-0.048	0.002	0.179	-0.043
h	0.103	-0.196	-0.054	-0.004	0.119	0.051
W	0.802	0.217	0.013	-0.001	-0.007	-0.027
π	-0.761	-0.264	2.674	-0.002	0.082	0.060
$eP^\star/P$	0.532	-0.532	-0.006	0.006	-0.049	0.049
$eP_x^\star/P_x$	0.887	-0.887	-0.011	0.011	-0.082	0.082

Note: $\epsilon_j j = a, m, g$ is the supply, money and fiscal shock respectively. A star denotes the foreign country.

Table 3: Elasticities (Flexible prices, low elasticity)

	ϵ_a	$\epsilon_a^\star$	ϵ_m	$\epsilon_m^\star$	ϵ_g	$\epsilon_g^\star$
Y	0.852	0.074	-0.049	0.003	0.179	-0.043
h	-0.103	0.010	-0.052	-0.006	0.141	0.029
W	0.744	0.275	0.013	-0.002	-0.001	-0.033
π	-0.864	-0.160	2.675	-0.003	0.089	0.052
$eP^\star/P$	0.830	-0.830	-0.010	0.010	-0.081	0.081
$eP_x^\star/P_x$	1.384	-1.384	-0.016	0.016	-0.135	0.135

Note: $\epsilon_j j = a, m, g$ is the supply, money and fiscal shock respectively. A star denotes the foreign country.

Table 4: Elasticities (Fixed prices, high elasticity)

	ϵ_a	$\epsilon_a^\star$	ϵ_m	$\epsilon_m^\star$	ϵ_g	$\epsilon_g^\star$
Y	0.406	0.386	1.213	0.242	0.229	-0.024
h	-0.565	0.305	1.785	0.034	0.193	0.063
W	-0.144	0.401	1.903	0.161	0.094	0.014
π	-0.198	-0.093	1.913	-0.177	0.021	0.021
$eP^\star/P$	0.183	-0.183	0.511	-0.511	-0.029	0.029
$eP_x^\star/P_x$	0.305	-0.305	0.852	-0.852	-0.049	0.049

Note: $\epsilon_j j = a, m, g$ is the supply, money and fiscal shock respectively. A star denotes the foreign country.

Table 5: Standard deviations (relative to output)

	Data	Flexible prices		Fixed prices	
		High	Low	High	Low
c	0.83	0.97	0.96	0.69	0.67
i	2.73	2.25	2.45	3.81	3.87
h	1.15	0.38	0.36	1.16	1.05
w	0.44	0.95	0.89	1.23	1.15
π	0.35	2.52	2.44	1.02	1.02
rer	2.31	0.69	1.04	0.47	0.58
tot	1.71	1.15	1.74	0.78	0.96

Note: The moments are derived from HP–filtered data. rer is the real exchange rate and tot denotes the terms of trade (import price/export price). The variables are from the OECD quarterly National Accounts, and the sample runs from 1970:1 to 1999:3.

Table 6: Correlations

	Data	Flexible prices		Fixed prices	
		High	Low	High	Low
c, y	0.87	0.80	0.80	0.92	0.92
i, y	0.94	0.84	0.85	0.93	0.93
h, y	0.94	0.33	0.11	0.79	0.78
w, y	-0.40	0.88	0.88	0.90	0.90
π, y	0.38	-0.12	-0.13	0.50	0.48
rer, y	-0.23	0.30	0.36	0.36	0.32
tot, y	-0.23	0.30	0.36	0.36	0.32
$y, y^\star$	0.61	0.34	0.25	0.50	0.53
$c, c^\star$	0.43	0.82	0.76	0.47	0.59

Note: The moments are derived from HP–filtered data. *rer* is the real exchange rate and *tot* denotes the terms of trade (import price/export price). The variables are from the OECD quarterly National Accounts, and the sample runs from 1970:1 to 1999:3. Foreign variables are for EU15 members.

Table 7: Conditional Correlations

	Flexible prices		Fixed prices	
	High	Low	High	Low
y, h	0.58	-0.98	0.19	0.05
$y/h, h$	0.52	-0.99	-0.42	-0.54

Table 8: Autocorrelations

	Data	Flexible prices		Fixed prices	
		High	Low	High	Low
y	0.87	0.68	0.67	0.62	0.63
c	0.88	0.69	0.69	0.59	0.61
i	0.90	0.65	0.65	0.66	0.66
h	0.88	0.65	0.66	0.49	0.51
w	0.81	0.69	0.69	0.53	0.55
π	0.57	-0.17	-0.17	-0.14	-0.14
rer	0.81	0.63	0.63	0.54	0.59
tot	0.83	0.63	0.63	0.54	0.59

Note: The moments are derived from HP–filtered data. *rer* is the real exchange rate and *tot* denotes the terms of trade (import price/export price). The variables are from the OECD quarterly National Accounts, and the sample runs from 1970:1 to 1999:3.

Table 9: Variance decomposition (Flexible prices, high elasticity)

k	ϵ_c	ϵ_a	$\epsilon_a^\star$	ϵ_m	$\epsilon_m^\star$	ϵ_g	$\epsilon_g^\star$
Output							
1	24.99	51.82	1.64	0.29	0.00	20.10	1.17
4	27.56	46.18	4.84	0.10	0.00	20.13	1.18
8	29.69	40.75	9.15	0.06	0.00	19.22	1.14
20	32.88	33.57	17.03	0.03	0.00	15.55	0.95
40	35.32	30.91	21.77	0.01	0.00	11.28	0.71
Hours worked							
1	1.66	5.84	21.19	2.40	0.01	58.32	10.58
4	2.32	3.14	17.99	0.94	0.00	63.95	11.65
8	3.22	1.93	15.17	0.55	0.00	66.88	12.25
20	6.01	3.20	12.39	0.29	0.00	65.88	12.22
40	10.49	6.70	13.11	0.20	0.00	58.53	10.98

Table 10: Variance decomposition (Flexible prices, low elasticity)

k	ϵ_c	ϵ_a	$\epsilon_a^\star$	ϵ_m	$\epsilon_m^\star$	ϵ_g	$\epsilon_g^\star$
Output							
1	23.18	56.47	0.42	0.28	0.00	18.58	1.07
4	26.22	50.49	2.99	0.10	0.00	19.08	1.11
8	28.75	44.34	7.22	0.06	0.00	18.55	1.09
20	32.40	35.69	15.70	0.03	0.00	15.26	0.92
40	35.04	32.17	20.94	0.01	0.00	11.14	0.69
Hours worked							
1	1.75	6.15	0.06	2.32	0.03	86.11	3.58
4	2.25	6.53	0.03	0.84	0.01	86.61	3.73
8	2.96	6.99	0.17	0.46	0.01	85.56	3.85
20	5.36	8.46	1.37	0.24	0.00	80.60	3.96
40	9.43	10.87	4.25	0.16	0.00	71.50	3.79

Table 11: Variance decomposition (Fixed prices, high elasticity)

k	ϵ_c	ϵ_a	$\epsilon_a^\star$	ϵ_m	$\epsilon_m^\star$	ϵ_g	$\epsilon_g^\star$
			Output				
1	6.74	5.08	4.61	68.67	2.73	12.05	0.13
4	18.79	18.02	9.71	39.85	1.72	11.43	0.48
8	27.12	25.05	14.69	22.13	1.02	9.30	0.68
20	34.58	27.94	22.11	8.65	0.43	5.58	0.69
40	37.72	28.52	25.87	4.06	0.21	3.08	0.52
			Hours worked				
1	0.42	5.74	1.67	86.59	0.03	5.02	0.53
4	0.88	4.01	2.75	84.65	0.02	6.98	0.71
8	2.91	5.19	3.99	78.30	0.03	8.70	0.87
20	6.63	7.62	6.22	67.27	0.03	11.08	1.15
40	8.51	8.69	7.46	61.39	0.04	12.53	1.39

Figure 2: Impulse responses (Flexible prices, high elasticity)

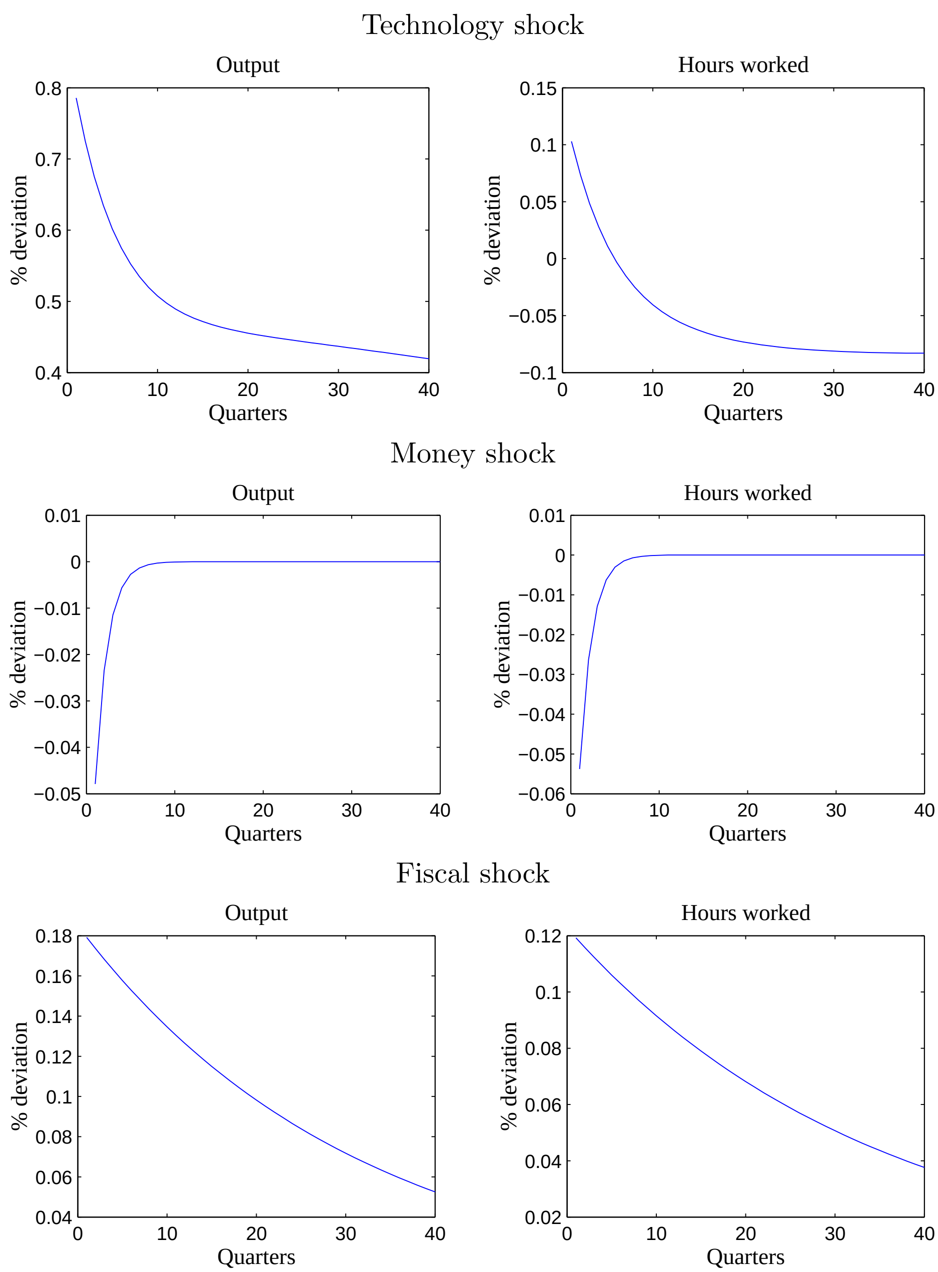

Figure 3: Impulse responses (Flexible prices, low elasticity)

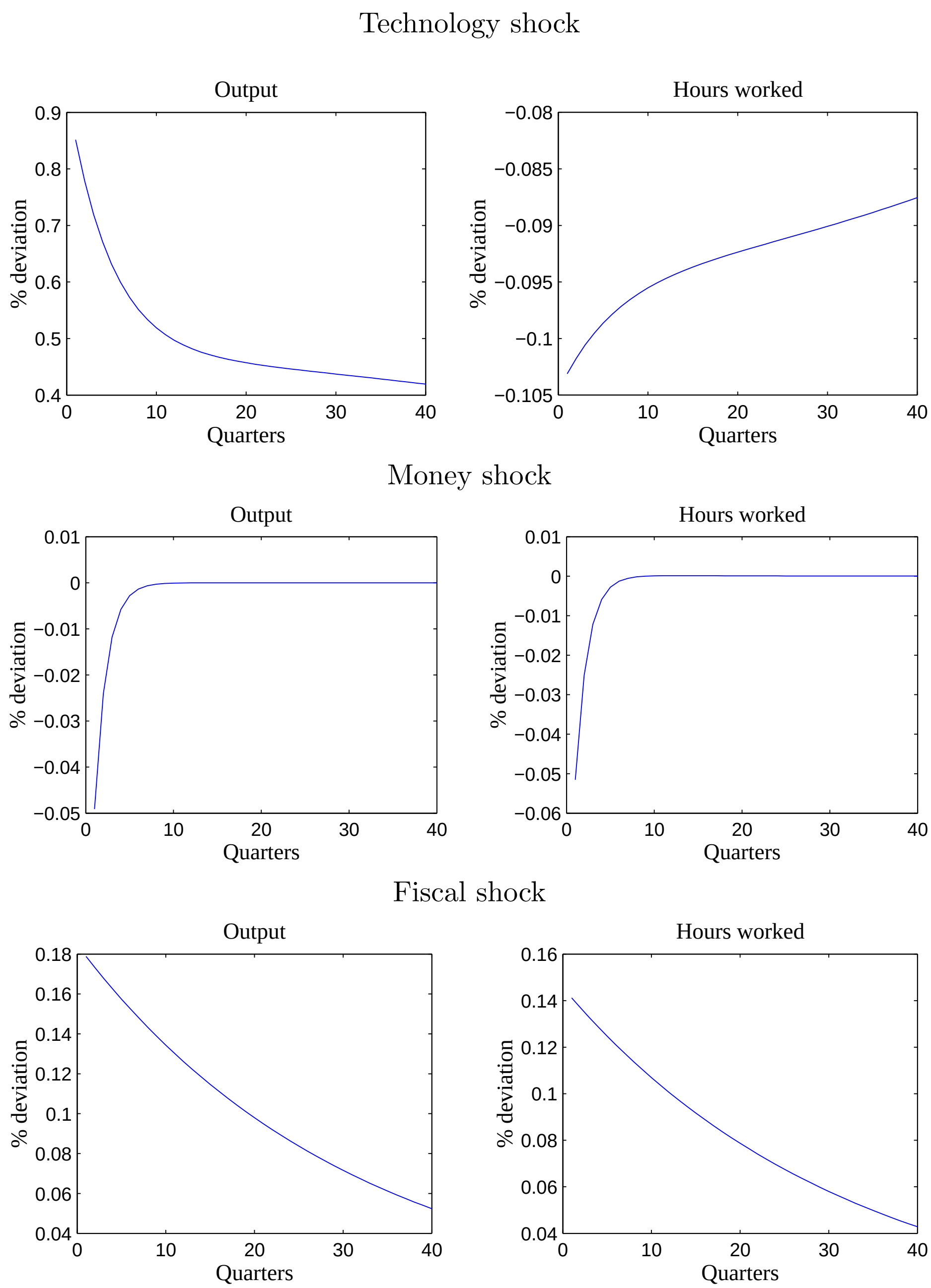

Figure 4: Impulse responses (Fixed prices, high elasticity)