Money, New-Keynesian Macroeconomics and the Business Cycle

Jean-Olivier Hairault* and Franck Portier†‡

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Abstract

We show in this paper that the typical modern business cycle can not be reduced to the real business cycles archetype. A monopolistic competition model with price adjustment costs, affected by technological *and* monetary shocks, better mimics the economic fluctuations in two countries with very different cyclical properties, namely France and the United States. In our model, monetary shocks are *necessary* to reproduce the standard deviation of output, the money-output correlation, the labor productivity-worked hours relative standard deviation, the labor productivity-worked hours correlation and the mark-up-output correlation. With two independant shocks, one real, more specifically defined than the Solow residual, and one nominal, the model gives an answer to these empirical puzzles, which were left unexplained by traditionnal *RBC* models.

Keywords: Imperfect Competition - New-Keynesian Macroeconomics - Nominal rigidities - Monetary Shocks - Real Business Cycles

Introduction

Two main competing approaches of the business cycle arose in the eighties: the Real Business Cycles theory and the New-Keynesian Macroeconomics. Following the seminal papers of Kydland and Prescott [1982], Long and Plosser [1983] and King, Plosser, and Rebelo [1988], *RBC* theorists consider economic fluctuations as the optimal responses of economic agents to exogeneous real shocks. The aim of these first models was to explain macroeconomic fluctuations only with technological shocks; demand shocks were unnecessary and nominal shocks were *de facto* absent from these purely real models. Hénin [1989] noticed some attempts to introduce money in such a flex-price competitive framework: the King and Plosser [1984] model introduces financial intermediation and get some insight on the (inside) money-output correlation when technology shocks occur. Nevertheless, the outside money-output link is missing and no quantitative validation of the model is proposed. Outside money shocks are introduced in a cash-in-advance economy by Cooley and Hansen [1989] (constraint on consumption) and Hairault and Portier [1991a] (constraint on consumption and investment) or in a model with money in the utility function by Hairault and Portier [1991b]. These models do not provide a good description of the money-output correlation

*Paris IX, C.E.B.I. and M.A.D. Paris I.

†CREST-ENSAE and M.A.D. Paris I.

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and are not able to reproduce the shape and level of the real variables impulse responses to monetary shocks for a realistic calibration. King [1990] obtains the *triangular shape* of the monetary business cycle in a staggered contracts model where money is introduced *via* a quantitative equation. Nevertheless, this quantitative equation has no microeconomic foundations in the model and no simulated moments are computed. Ambler and Phaneuf [1991] also use staggered contracts in a reduced- form model which provides good approximation of monetary impulse responses, but without explicit microfoundations.

Furthermore, the *RBC* literature initiated a validation method based upon the ability of the model to mimic some macroeconomic stylized facts by stochastic simulations.

On the other hand, the New-Keynesian macroeconomy[1] expanded microfounded macroeconomic models with Keynesian features such as underemployment equilibria, coordination failures, market power, real and nominal rigidities and the importance of nominal shocks in the business cycle.

A first attempt to reconciliate the *RBC* techniques with these new Keynesian developments relies on the introduction of real rigidities on the labour market, *via* efficency wages (Danthine and Donaldson [1990a]), risk sharing contracts (Danthine and Donaldson [1990b]) or labour hoarding (Burnside, Eichenbaum, and Rebelo [1990], Fairise and Langot [1992]). Nominal rigidities through wage contracts are introduced by Cho [1990a] and Cho and Cooley [1990]. In an other direction, Rotemberg and Woodford [1989] proposed an oligopolistic competition model with Keynesian features.

Following Kiyotaki [1985], Blanchard and Kiyotaki [1987] and Benassy [1987], the monopolistic competition framework has been widely used to introduce nominal rigidities (staggered contrats or menu costs) and to emphasize the role of demand shocks, and particularly monetary shocks[2].

We propose in this paper a dynamic monopolistic competition model with nominal rigidities and money in the utility function. As Danthine and Donaldson [1991] pointed out the difficulty of a single model to give an accurate description of both US and European fluctuations, we evaluate the ability of our model to mimic two very different business cycles features, namely the French and US ones.

This model allows us to study the effect of monetary shocks in this theoretical framework and with the validation methods of *RBC* theorists[3]. We will show that the presence of monetary shocks sharply modifies the behaviour of the model. With two independant shocks, one real, which cannot be measured by the Solow residual in that framework[4], and one nominal, the model gives an answer to five empirical puzzles, which were unexplained by traditionnal *RBC* models, on French data as well as on US data:

- the level of output standard deviation
- the money-output and inflation-output correlation
- the labor productivity-worked hours correlation
- the labor productivity-worked hours relative standard deviation
- the mark-up-output correlation

[1] This expression was first used by Parkin [1986], and then popularized by Gordon [1990] and Mankiw and Romer [1991].

[2] See Blanchard [1990] survey for the Handbook of Monetary Economics: *"Why Does Money Affect Output?"*.

[3] Rotemberg and Woodford [1989] compared their theoretical impulse responses to a military expenditures shock to estimated impulses responses on US data.

[4] Hall [1989] demonstrated that the Solow residual is *contaminated* by demand shocks in imperfectly competitive models and Evans [1992] showed that the Solow residual is Granger-caused by demand shocks on US data.

The ability of our model to reproduce these stylized facts, both for the French and US economy, must be underlined, as their cyclical behaviours are far different. Our model may be considered as a synthesis between the *RBC* model and the New-Keynesian approach to macroeconomics.

The first section of the paper presents the model and its approximated resolution around its stationary steady state. The second section illustrates its qualitative and quantitative cyclical properties on US and French data.

1 The Model

In that section, we present a dynamic extension of the Blanchard and Kiyotaki [1987] model of monopolistic competition with explicit intertemporal household behaviour and solve it around its stationary steady state.

1.1 A Monopolistic Competition Model with Money in the Utility Function

We describe representative household and firms behaviour, and solve the symetrical monopolistic competition equilibrium of that economy.

1.1.1 Technology et Preferences

The economy is composed of h identical households indexed by i and n firms indexed by j. Firm j is the only firm that produces Y_j units of good j. All firms have access to the same constant returns to scale production function:

$$Y_{j,t} \leq A_t K_{j,t}^{\alpha} H_{j,t}^{1-\alpha} \tag{1}$$

where $K_{j,t}$ is the capital stock used by firm j and $H_{j,t}$ the quantity of labour input. A_t follows the stochastic process:

$$\log(A_t) = \rho_A \log(A_{t-1}) + (1-\rho_A)\log(\overline{A}) + \varepsilon_{A,t} \tag{2}$$

where the $\varepsilon_{A,t}$ are *i.i.d.* stochastic variables following a normal law $\mathcal{N}(0, \sigma_A^2)$, and where $\rho_A < 1$. The total factor productivity A_t is a technological shock common to all firms of the economy, and we assume that A_t is observed at the beginning of period t.

Households are identical, and their preferences are given by the utility function U_0 which represents the expectation of the discounted sum of instantaneous utility flows u, conditionnally to the information available at date $t = 0$:

$$\begin{aligned} U_0 &= E_0\left[\sum_{t=0}^{\infty} \beta^t u(C_{i,t}, \frac{M_{i,t}}{P_t}, L_{i,t})\right] && (3) \\ &= E_0\left[\sum_{t=0}^{\infty} \beta^t \left(\frac{1}{a}\left(C_{i,t}^{\frac{\sigma-1}{\sigma}} + \gamma_2\left(\frac{M_{i,t}}{P_t}\right)^{\frac{\sigma-1}{\sigma}}\right)^{\frac{\sigma}{\sigma-1}a} + \gamma_1 v(L_{i,t})\right)\right] \end{aligned}$$

where $\beta \in]0,1[$, $\gamma_1 > 0$ and $\gamma_2 > 0$. $C_{i,t}$ is a *CES* basket of the different goods produced in the economy:

$$C_{i,t} = \left(\sum_{j=1}^{n} C_{i,j,t}^{\frac{1}{1+\gamma}}\right)^{1+\gamma} \tag{4}$$

where $\frac{1+\gamma}{\gamma}$ is the elasticity of substitution between the different goods. We can define a price index P_t:

$$P_t = \left(\frac{1}{n} \sum_{j=1}^{n} P_{j,t}^{\frac{-1}{\gamma}} \right)^{-\gamma} \tag{5}$$

which verifies by construction the equation:

$$P_t C_{i,t} = \sum_{j=1}^{n} P_{j,t} C_{i,j,t} \tag{6}$$

$\frac{M_{i,t}}{P_t}$ represents the real balances of the household at the beginning of period t. The utility of real balances relies on the transaction services allowed by money, as in a *Cash in Advance* model.

Each household is endowed with one unit of time at each period, and allocates it between leisure $L_{i,t}$ and worked hours $H_{i,t}$:

$$H_{i,t} + L_{i,t} \leq 1$$

The constant elasticity of substitution between real balances and the consumption basket is given by σ, and $\frac{1}{1-a}$ is the intertemporal elasticity of substitution of the basket composed of the consumption index and the real balances.

Each household accumulates capital and rents it to firms. Capital is a composite good, given as a CES index of the different produced goods. To simplify the computation of the demand function adressed to firm j, we assume that the investment index has the same structure than the consumption one. The accumulation technology is then given by the following equation:

$$\begin{aligned} K_{i,t+1} &= (1-\delta)K_{i,t} + \left(\sum_{j=1}^{n} I_{i,j,t}^{\frac{1}{1+\gamma}} \right)^{1+\gamma} \\ &= (1-\delta)K_{i,t} + I_{i,t} \end{aligned}$$

where $I_{i,t}$ is the investment index. One unit of each consumption good at period t is necessary to get one unit of capital at period $t+1$; the existing capital depreciates at constant rate δ.

1.1.2 The Money Supply

The money supply is specified as in Cooley and Hansen [1989]: the aggregate stock of money M_t grows at rate $(g_t - 1)$:

$$M_{t+1} = g_t M_t \tag{7}$$

The rate g_t has a mean $\overline{g}$ and follows the stochastic process:

$$\log(g_t) = \rho_g \log(g_{t-1}) + (1-\rho_g)\log(\overline{g}) + \varepsilon_{g,t} \tag{8}$$

Monetary shocks $\varepsilon_{g,t}$ are *i.i.d.* stochastic variables following a $\mathcal{N}(0, \sigma_g^2)$, and where $\rho_g < 1$. We assume that g_t is observed at the beginning of period t, and then all the money created at period t is distributed to households:

$$(g_t - 1)M_t = \sum_{i=1}^{h} N_{i,t} \tag{9}$$

1.1.3 The Optimal Composition of the Consumption and Investment Index

The optimal choice of the consumption and investment index composition can be viewed as a static choice. For given levels of consumption and investment $C_{i,t}$ and $I_{i,t}$ [5], household i maximises respectively these index by choosing $C_{i,j,t}$ et $I_{i,j,t}$ for all j, taking as given prices $P_{j,t}$. The solving of these two programs gives the following consumption and investment demands of household i to firm j:

$$C_{i,j,t} = P_{j,t}^{-\frac{1+\gamma}{\gamma}} P_t^{\frac{1+\gamma}{\gamma}} \frac{C_{i,t}}{n} \tag{10}$$

$$I_{i,j,t} = P_{j,t}^{-\frac{1+\gamma}{\gamma}} P_t^{\frac{1+\gamma}{\gamma}} \frac{I_{i,t}}{n} \tag{11}$$

1.1.4 The Intertemporal Behaviour of the Household

Each household enters in period t with a predetermined level of capital $K_{i,t}$ and a predetermined level of money $M_{i,t}$. In period t, the household receives a lump sum monetary transfert $N_{i,t}$, its wage income, the remuneration of its capital and a constant share $v_{i,j}$ of real profits $\Pi_{j,t}$ of each firm j. It chooses its level of consumption, its supply of labour and the quantity of capital $K_{i,t+1}$ and money $M_{i,t+1}$ it will transfer next period. If we call w_t the real wage and z_t the capital gross rental rate[6], the budget constraint of household i is given by:

$$\begin{aligned} P_t K_{i,t+1} + M_{i,t+1} \leq\ & P_t(1-\delta+z_t)K_{i,t} + M_{i,t} \\ & + N_{i,t} + P_t w_t H_{i,t} + P_t \sum_{j=1}^{n} (v_{i,j}\Pi_{j,t}) - P_t C_{i,t} \end{aligned} \tag{12}$$

Given $K_{i,0}$,$M_{i,0}$,g_0, A_0, household i chooses $(C_{i,t},\ H_{i,t},\ M_{i,t+1},\ K_{i,t+1})$, $t \in [0, +\infty[$ that maximise the expectation of the discounted sum of its utility flows, with respect to the budget constraint (12) at each period t. The problem can then be written in a recursive way and its optimal solution verifies the Bellman equation:

$$V_i\left(K_{i,t}, M_{i,t}, \mathcal{I}_{i,t}\right) = \max_{C_{i,t}, L_{i,t}, K_{i,t+1}, M_{i,t+1}} \left\{ u\left(C_{i,t}, \frac{M_{i,t}}{P_t}, L_{i,t}\right) + \beta E_t\left[V_i\left(K_{i,t+1}, M_{i,t+1}, \mathcal{I}_{i,t+1}\right)\right] \right\}$$

with respect to the budget constraint (12). Let $\Lambda_{i,t}$ be the Lagrange multiplier of the budget constraint and $\mathcal{I}_{i,t}$ the informational set of household i at period t: $\mathcal{I}_{i,t} = \{g_t, A_t, \{P_{j,t}\}_{j=1}^{n}, w_t, z_t\}$. We solve this problem to get the first order conditions of the household program. We also impose the transversality conditions:

$$\lim_{\tau \to +\infty} E_t\left[\beta^{t+\tau} K_{i,t+\tau+1} \frac{\partial V_{i,t+\tau+1}}{\partial K_{i,t+\tau+1}}\right] = 0 \tag{13}$$

$$\lim_{\tau \to +\infty} E_t\left[\beta^{t+\tau} M_{i,t+\tau+1} \frac{\partial V_{i,t+\tau+1}}{\partial M_{i,t+\tau+1}}\right] = 0 \tag{14}$$

[5] These levels will be chosen later by solving an intertemporal problem.

[6] The interest rate is then given by $r_t = z_t - \delta$.

1.1.5 Price Adjustment Costs and the Behaviour of Firms

We adopt in this model a monopolistic market structure *à la* Blanchard and Kiyotaki [1987][7]. As the elasticity of substitution between the different goods entering in the utility function is not infinite, each firm has a monopoly power on its market. As this elasticity is strictly positive, each firm cares of its price level relatively to the aggregate price level. We assume that the number of firms n is large enough to ensure that each firm has a negligible effect on aggregate variables. Firms play a Nash game on the good market, and each one chooses its price, its labour and capital demands, knowing its good demand function and taking aggregate demand and aggregate price level as given. Without any other assumption, the firm problem is essentially a static one.

We then introduce prices adjustment costs, which refers to different theoretical models (search costs for instance) and are often modelised as menu costs in the *New-Keynesian* literature. To get a simple solution to the firm problem, we assume that these costs are quadratic[8]. We also assume that these costs are null at the steady state. As we will show later that prices grow at rate $\overline{g}$ at the steady state, the real adjustment cost at period t for firm j is given by:

$$\mathcal{CA}_{j,t} = \frac{\phi}{2}\left(\frac{P_{j,t}}{P_{j,t-1}} - \overline{g}\right)^2 \tag{15}$$

where ϕ is the adjustment costs scale parameter. To preserve a simple closing of the model, we assume that these real costs $\mathcal{CA}_{j,t}$ are paid by the firm throught the purchase of a *CES* basket of all the produced goods of the economy, with the same elasticity of substitution than the consumption and investment basket. The optimal composition of this basket is identical to (10) and (11), and the demand of good j' from firm j is given by:

$$\mathcal{CA}_{j,j',t} = P_{j',t}^{-\frac{1+\gamma}{\gamma}} P_t^{\frac{1+\gamma}{\gamma}} \mathcal{CA}_{j,t} \tag{16}$$

The problem of firm j is then dynamic, and it maximises the expectation of the discounted sum $V_{j,0}$ of its profit flows, conditionally to the information available at period $t = 0$:

$$E_0\left[V_{j,0}\right] = E_0\left[\sum_{t=0}^{\infty} \rho_t P_t \Pi_{j,t}\right] \tag{17}$$

with

$$P_t\Pi_{j,t} = P_{j,t}Y_{j,t} - P_t w_t H_{j,t} - P_t z_t K_{j,t} - P_t\mathcal{CA}_{j,t} \tag{18}$$

Following Rotemberg and Woodford [1989], the firm discount factor is given by the stochastic process $\{\rho_t\}$, which represents a pricing kernel for contingent claims[9].

Let $\nu_{j,t}$ be the Lagrange multiplier of the constraint

$$Y_{j,t} \leq Y_{j,t}^d \tag{19}$$

[7] The separation of the household program in a static and a dynamic one allows us to adopt a very general utility function. As far as we know, only Cho [1990b] introduces an imperfectly competitive assumption in a *RBC* model, but his solution method imposes a very particular utility function (linear in the consumption), which narrows the scope of his results.

[8] If these costs have a lump sum component, the optimal price rule may be very complicated. In some special cases, it can take a (S, s) recursive form but rises tedious aggregation problems (see Bertola and Caballero [1990] for a survey and Portier [1991] for an example.)

[9] We thank the referee for his comment on that point.

where $Y^d_{j,t}$ is the total demand addressed to firm j. From (10),(11) and (16), the demand is given by:

$$Y^d_{j,t} = P_{j,t}^{-\frac{1+\gamma}{\gamma}} P_t^{\frac{1+\gamma}{\gamma}} \frac{Y^d_t}{n} \tag{20}$$

where

$$Y^d_t = \sum_{i=1}^{h} (C_{i,t} + I_{i,t}) + \sum_{j=1}^{n} \mathcal{CA}_{j,t}$$

is the total demand index.

Knowing its demand function, firm j chooses at period t its price and its labour and capital demands, subject to the constraints (1) and (19). The firm behaviour is then derived from the Bellman equation:

$$V_j\left(P_{j,t-1}, \mathcal{I}_{j,t}\right) = \max_{P_{j,t},H_{j,t},K_{j,t}} \left\{ P_t \Pi_{j,t} + E_t \left[\frac{\rho_{t+1}}{\rho_t} V_j\left(P_{j,t}, \mathcal{I}_{j,t+1}\right) \right] \right\}$$

with respect to the constraints (1) and (19), and where $\mathcal{I}_{j,t}$ is the informational set of firm j at period t: $\mathcal{I}_{j,t} = \{g_t, A_t, P_t, z_t, w_t\}$. We also impose the transversality condition:

$$\lim_{\tau \to +\infty} E_t \left[\frac{\rho_{t+\tau+1}}{\rho_{t+\tau}} \frac{\partial V_{j,t+\tau+1}}{\partial P_{j,t+\tau}} P_{j,t+\tau} \right] = 0 \tag{21}$$

1.1.6 Intertemporal Substitution Elasticity of Leisure and Labour Indivisibility

We first assume that $v(L_{i,t})$ is concave and that the elasticity of its derivative with respect to L is constant:

$$\frac{L_{i,t} v"(L_{i,t})}{v'(L_{i,t})} = \zeta \quad \forall L_{i,t} \tag{22}$$

This elasticity ζ is inversely related to the intertemporal substitution elasticity of leisure, and will be particularly important when we will calibrate the model.

Following Hansen [1985] and Rogerson [1988], we will assume that jobs are indivisible in our economy: each household works H_0 hours or does not work. This is linked to the fact that a large part of worked hours fluctuations are in the extensive margin (jobs fluctuations) and not in the intensive one (fluctuations in the average hour length of a job). Under this assumption, the household problem is convexified using Rogerson [1988] lotteries. We assume that each household sells at each period a contract, specifying that he will work H_0 with probability $\pi_{i,t}$ and 0 with probability 1-$\pi_{i,t}$. Its wage is given by the price of this contract; whether it works or not, it will get that wage. As households are identical, they all choose the same $\pi_{i,t} = \pi_t$ and only π_t% of them will work; 1-π_t is then the unemployment rate of the economy.

One can easily show that, at the symetrical equilibrium, the representative agent utility function is linear in labour, and that the elasticity of the marginal disutility of labour ζ is null, which means that the intertemporal elasticity of substitution of leisure is infinite.

1.2 Definition and Resolution of the Equilibrium

We first define a symetrical monopolistic competition equilibrium of the economy, and then briefly describe the resolution method. As we cannot solve analytically for the equilibrium, we linearize the system defining the equilibrium around its steady state. We obtain a linear dynamic system which gives the path of the engogeneous variables relative deviations from their steady state level, in presence of exogeneous shocks.

1.2.1 Symetrical Monopolistic Competition Equilibrium of the Economy

A *symetrical monopolistic competition equilibrium of the economy* is given by a set of decision rules of household i $C_{i,t}(s_{i,t})$, $K_{i,t+1}(s_{i,t})$, $M_{i,t+1}(s_{i,t})$ and $H_{i,t}(s_{i,t})$ (where $s_{i,t} = (K_{i,t}, M_{i,t}, \mathcal{I}_{i,t})$ is the state variables vector of household i), a capital demand rule $K_{j,t}(s_{j,t})$, a labour demand rule $H_{j,t}(s_{j,t})$ and a price rule $P_{j,t}(s_{j,t})$ of firm j (where $s_{j,t}$=($P_{j,t-1}$,$\mathcal{I}_{j,t}$) is the state variables vector of firm j), a price vector ($\{P_{j,t}(s_t)\}_{j=1}^n, w(s_t)$,$z(s_t)$) (where $s_t = \left(\{s_{i,t}\}_{i=1}^h, \{s_{j,t}\}_{j=1}^n\right)$ is the aggregate state of the economy) such that:

- $C_{i,t}(s_{i,t})$, $H_{i,t}(s_{i,t})$ $M_{i,t+1}(s_{i,t})$ and $K_{i,t+1}(s_{i,t})$ maximise $V_{i,t}\left(K_{i,t}, M_{i,t}, \mathcal{I}_{i,t}\right)$ subject to the constraints (12), (13) and (14),
- $K_{j,t}(s_{j,t})$, $H_{j,t}(s_{j,t})$ and $P_{j,t}(s_{j,t})$ maximise $V_{j,t}\left(P_{j,t-1}, \mathcal{I}_{j,t}\right)$ subject to the constraints (1), (19) and (21),
- $(\{P_{j,t}(s_t)\}_{j=1}^n, w_t(s_t), z_t(s_t))$ clear the goods markets, the capital market, the labour market and the money market (the numeraire of the economy); that is respectively $Y_{j,t}^d(s_t) = Y_{j,t}(s_t)$ $\forall j \in \{1, n\}$, $\sum_{i=1}^h K_{i,t}(s_{i,t-1}) = \sum_{j=1}^n K_{j,t}(s_{j,t})$, $\sum_{i=1}^h H_{i,t}(s_{i,t}) = \sum_{j=1}^n H_{j,t}(s_{j,t})$ and $\sum_{i=1}^h M_{i,t+1}(s_t) = g_t M_t$
- $s_{i,t} = s_t^h$ $\forall i \in \{1, h\}$ $\forall t$ and $s_{j,t} = s_t^f$ $\forall j \in \{1, n\}$ $\forall t$ (Symetry of the equilibrium[10]).

1.2.2 Extensive Definition of the Equilibrium

The set of equations defining the equilibrium is given by equations (23) to (40) (where $u_{x,i,t}$ is the first derivative of the utility function with respect to $x_{i,t}$ (successsively $C_{i,t}$, $M_{i,t}/P$ and $H_{i,t}$), and where $\lambda_{i,t} = \Lambda_{i,t} P_t = \beta E_t \left[\frac{\partial V_{i,t+1}}{\partial K_{i,t+1}}\right] = \beta P_t E_t \left[\frac{\partial V_{i,t+1}}{\partial M_{i,t+1}}\right]$ is the marginal utility of real wealth):

$$u_{C,i,t} = \lambda_{i,t} \tag{23}$$

$$u_{H,i,t} = -\lambda_{i,t} w_t \tag{24}$$

$$0 = E_t \left[\frac{P_t}{P_{t+1}} \left(\lambda_{i,t+1} \left(\frac{P_{t+1}}{P_t}(1 + z_{t+1} - \delta) - 1\right) - u_{M/P,i,t+1}\right)\right] \tag{25}$$

$$1 = \beta E_t \left[(1 + z_{t+1} - \delta)\frac{\lambda_{i,t+1}}{\lambda_{i,t}}\right] \tag{26}$$

$$P_t K_{i,t+1} + M_{i,t+1} - P_t(1-\delta)K_{i,t} - M_{i,t} - N_{i,t} - P_t z_t K_{i,t}$$
$$-P_t w_t H_{i,t} - P_t \sum_{j=1}^n (v_{i,j} \Pi_{j,t}) + P_t C_{i,t} = 0 \tag{27}$$

$$\lim_{\tau \to +\infty} E_t \left[\beta^{t+\tau} \lambda_{i,t+\tau} K_{i,t+\tau+1}\right] = 0 \tag{28}$$

$$\lim_{\tau \to +\infty} E_t \left[\beta^{t+\tau} \lambda_{i,t+\tau} \frac{M_{i,t+\tau+1}}{P_{t+\tau}}\right] = 0 \tag{29}$$

[10] In the following, we will use the normalization $n = h = 1$.

Equation (23) equalizes marginal utility and price of current consumption, equation (24) marginal disutility and revenue of current labour, equation (25) anticipated marginal utility and anticipated price of money balances, where the price of money is the nominal interest rate $\left(\frac{P_{t+1}}{P_t}(1-\delta+z_{t+1})-1\right)$, and illustrates the presence of an inflationary tax. Equation (26) corresponds to the optimal intertemporal wealth allocation.

$$
\begin{aligned}
P_t w_t &= (1-\alpha)\frac{Y_{j,t}}{H_{j,t}}(P_{j,t}-\nu_{j,t}) && (30)\\
P_t z_t &= \alpha\frac{Y_{j,t}}{K_{j,t}}(P_{j,t}-\nu_{j,t}) && (31)\\
Y_{j,t} &= \frac{1+\gamma}{\gamma}\nu_{j,t}P_{j,t}^{-\frac{1+\gamma}{\gamma}-1}P_t^{\frac{1+\gamma}{\gamma}}\frac{Y_t^d}{n}+\phi\left(\frac{P_t}{P_{j,t-1}}\right)\left(\frac{P_{j,t}}{P_{j,t-1}}-\overline{g}\right)\\
&- E_t\left[\phi\frac{\rho_{t+1}}{\rho_t}\left(\frac{P_{j,t+1}}{P_{j,t}}\right)^2\left(\frac{P_{t+1}}{P_{j,t+1}}\right)\left(\frac{P_{j,t+1}}{P_{j,t}}-\overline{g}\right)\right] && (32)\\
Y_{j,t} &= Y_{j,t}^d && (33)\\
Y_{j,t} &= A_t(K_{j,t})^\alpha(H_{j,t})^{1-\alpha} && (34)\\
P_t\Pi_{j,t} &= P_{j,t}Y_{j,t}-P_t w_t H_{j,t}-P_t z_t K_{j,t}\\
&- P_t\frac{\phi}{2}\left(\frac{P_{j,t}}{P_{j,t-1}}-\overline{g}\right)^2 && (35)
\end{aligned}
$$

$$
\lim_{\tau\to+\infty} E_t\left[\frac{\rho_{t+\tau+1}}{\rho_{t+\tau}}\frac{\partial V_{j,t+\tau+1}}{\partial P_{j,t+\tau}}P_{t+\tau}\right]=0 \quad (36)
$$

Equations (30) and (31) equalize marginal revenue and marginal cost of capital and labor inputs, and equation (32) marginal cost and marginal revenue of production.

$$
\begin{aligned}
\sum_{i=1}^{h}K_{i,t} &= \sum_{j=1}^{n}K_{j,t} && (37)\\
\sum_{i=1}^{h}H_{i,t} &= \sum_{j=1}^{n}H_{j,t} && (38)\\
M_t+\sum_{i=1}^{h}N_{i,t} &= \sum_{i=1}^{h}M_{i,t+1} && (39)\\
M_{t+1} &= g_t M_t && (40)\\
\lambda_{i,t} &= \beta^{-t}\alpha_i\rho_t && (41)
\end{aligned}
$$

Equations (37) to (40) ensure that capital, labour and money markets clear. Finally, we assume that households and firms have access to a complete set of frictioneless securities market, so that (41) is verified at all times for some constant α_i.

By symetry, we have $X_{i,t}=X_t\ \forall i$ and $Z_{j,t}=Z_t\ \forall j$, for all variables (X,Z) of the model.

One can compute the mark-up of the economy from multiplier ν. Equations (30) and (31) give the condition:

$$C_{m,j,t}(Y_{j,t})=P_{j,t}-\nu_{j,t}$$

where $C_{m,j,t}(Y_{j,t})$ is the marginal cost of firm i. The mark-up $\mu_{j,t}$ is then given by:

$$P_{j,t} = (1 + \mu_{j,t})C_{m,j,t} \Longleftrightarrow \mu_{j,t} = \frac{\nu_{j,t}}{P_t - \nu_{j,t}} \tag{42}$$

and at the equilibrium steady state:

$$\mu = \gamma$$

With infinite elasticity of substitution between the different consumption goods ($\gamma = 0$), the mark-up μ is null. If this elasticity is finite, μ will measure the market power of the firms. With flexible prices, this value is constant. When a positive technological shock occurs, the marginal cost curve shifts downward, and firms supply more for a lower price[11], according to equation (42). When a positive demand shock occurs, prices increase to equalize marginal cost and marginal revenue. If a positive technological shock occurs, the firm will less decrease its price (relatively to the fully flexible case) and the mark-up will increase as the marginal cost curve shifts downward. If a positive demand (monetary) shock occurs, demand shifts along the demand curve, prices increase less than the fully flexible case and output increases, which leads to a cut in the mark-up. Thus, mark-ups are countercyclical when a demand shock occurs and procyclical when a supply shock occurs.

1.2.3 The Equilibrium Steady State

With $m_t = \frac{M_t}{P_{t-1}}$ and $f_t = \frac{P_t}{P_{t-1}}$, one can write equation (40) as:

$$\frac{m_t}{m_{t+1}} = \frac{f_t}{g_t} \tag{43}$$

Stationarity of m_t means that prices grow at rate $(\overline{g} - 1)$. Then, all the nominal variables (M, P, ν) will grow at rate $(\overline{g} - 1)$.

With arbitrary values for $\overline{A}$ and P, and for given (calibrated) values of H and $\frac{M}{PY}$ [12], we can calculate the equilibrium steady state, which is given by the following set of equation:

$$\begin{aligned}
z &= \left(\frac{1}{\beta}\right) - 1 + \delta \\
\frac{\nu}{P} &= \frac{\gamma}{1+\gamma} \\
\frac{K}{Y} &= \left(\frac{\alpha}{1+\gamma}\right)\frac{1}{z} \\
\frac{C}{Y} &= 1 - \delta\left(\frac{K}{Y}\right) \\
Y &= A^{1/(1-\alpha)}\left(\frac{K}{Y}\right)^{\alpha/(1-\alpha)} H \\
w &= \left(\frac{1-\alpha}{1+\gamma}\right)\left(\frac{Y}{H}\right) \\
\gamma_2 &= -\left(1 - \overline{g}(1+z-\delta)\right)\left(\frac{M}{P}\right)^{1/\sigma} C^{-1/\sigma}
\end{aligned}$$

[11] These effects are less important than in the competitive case, as the firm profit increases in the monopolistic case.

[12] Imposing specific steady-state values of H and $\frac{M}{PY}$ is equivalent to calibrating the utility function parameters γ_1 and γ_2.

1.2.4 Linearization and Resolution

We log-linearized the system defining the equilibrium to obtain the following system (where $\widehat{x}_t$ is the percentage of deviation of X_t from its stationary value X):

$$
\begin{aligned}
M_1\widehat{\Omega}_t &= M_2\widehat{\Theta}_t + M_3\widehat{e}_t & (44)\\
M_4(L)E_t\left[\widehat{\Theta}_{t+1}\right] &= M_5(L)E_t\left[\widehat{\Omega}_{t+1}\right] + M_6(L)E_t\left[\widehat{e}_{t+1}\right] & (45)
\end{aligned}
$$

where the M_j are real matrix and the $M_j(L)$ are polynomial matrix of order less or equal to one. L is the lag operator and

$$
\widehat{\Theta}_t = \begin{pmatrix} \widehat{k}_t \\ \widehat{m}_t \\ \widehat{m}_{t+1} \\ \widehat{\mu}_t \\ \widehat{\lambda}_t \end{pmatrix}, \ \widehat{\Omega}_t = \begin{pmatrix} \widehat{c}_t \\ \widehat{h}_t \\ \widehat{w}_t \\ \widehat{z}_t \\ \widehat{y}_t \\ \widehat{\pi}_t \\ \widehat{f}_t \end{pmatrix}, \ \widehat{e}_t = \begin{pmatrix} \widehat{A}_t \\ \widehat{g}_t \end{pmatrix}
$$

This system is solved following Blanchard and Kahn [1980] and King, Plosser, and Rebelo [1987] and the solution is given by the set of equations:

$$
\begin{aligned}
\widehat{s}_{t+1} &= M\widehat{s}_t + \varepsilon_{t+1} & (46)\\
\widehat{d}_t &= \Pi\widehat{s}_t & (47)
\end{aligned}
$$

where $\widehat{s}_t$ is the vector of state variables (predeterminated or exogeneous) and $\widehat{d}_t$ is the vector of controls:

$$
\widehat{s}_t = \begin{pmatrix} \widehat{k}_t \\ \widehat{m}_t \\ \widehat{A}_t \\ \widehat{g}_t \end{pmatrix}, \ \widehat{d}_t = \begin{pmatrix} \widehat{c}_t \\ \widehat{h}_t \\ \widehat{w}_t \\ \widehat{r}_t \\ \widehat{y}_t \\ \widehat{\pi}_t \\ \widehat{\mu}_t \\ \widehat{\lambda}_t \\ \widehat{f}_t \end{pmatrix}, \ \varepsilon_t = \begin{pmatrix} 0 \\ 0 \\ \varepsilon_{A,t} \\ \varepsilon_{g,t} \end{pmatrix}
$$

and

$$
M = \begin{pmatrix} \pi_{kk} & \pi_{km} & \pi_{kA} & \pi_{kg} \\ \pi_{mk} & \pi_{mm} & \pi_{mA} & \pi_{mg} \\ 0 & 0 & \rho_A & 0 \\ 0 & 0 & 0 & \rho_g \end{pmatrix}, \ \Pi = \begin{pmatrix} \pi_{ck} & \pi_{cm} & \pi_{cA} & \pi_{cg} \\ \pi_{Hk} & \pi_{Hm} & \pi_{HA} & \pi_{Hg} \\ \pi_{wk} & \pi_{wm} & \pi_{wA} & \pi_{wg} \\ \pi_{zk} & \pi_{zm} & \pi_{zA} & \pi_{zg} \\ \pi_{Yk} & \pi_{Ym} & \pi_{YA} & \pi_{Yg} \\ \pi_{\Pi k} & \pi_{\Pi m} & \pi_{\Pi A} & \pi_{\Pi g} \\ \pi_{\mu k} & \pi_{\mu m} & \pi_{\mu A} & \pi_{\mu g} \\ \pi_{fk} & \pi_{fm} & \pi_{fA} & \pi_{fg} \end{pmatrix}
$$

The Π matrix is the optimal policy rule matrix. Its π_{jl} coefficients are instantaneous elasticities whose values will be crucial in the dynamics. Equations (46) and (47) allow us to simulate the model and to compute population moments and impulse responses functions.

2 Monetary Disturbances and Business Cycle in France and the United States

The *RBC* literature assesses that technological shocks are sufficient to reproduce the most important stylised facts of the business cycle. This result extends in a more theoretical framework the empirical proposition of Nelson and Plosser [1982]: monetary shocks are not necessary to explain output fluctuations. As it is shown in Hairault and Portier [1991b], the cyclical properties of a flex-price competitive model with money in the utility function are very similar to those of a purely real model, and the nominal features of the business cycle are not well reproduced.

Are these results robust to a deviation from such a purely neoclassical framework? As the New-Keynesian literature stressed the importance of non-competitive behaviour and price adjustment costs, we ask the question of the necessity of introducing monetary shock in such a theoretical framework.

Using the US case for parameter calibration, we first simulate six different models, each one relative to a particular specification of our model, to evaluate the importance of monopolistic competition, price adjustment costs and monetary shocks. Following the *RBC* literature, we describe the cyclical properties of these models by computing order two moments (standard deviations, correlations, autocorrelations) of the Hodrick-Prescott cyclical components of the macroeconomic series generated by stochastic simulations of the model decision rules. The six models are:

- a model without monopoly power, without adjustment costs, without monetary shocks and with Solow residual as a measure of technological shock (Model $M1$)
- a model with monopoly power, without adjustment costs, without monetary shocks and with Solow residual as a measure of technological shock (Model $M2$)
- a model with monopoly power, without adjustment costs, with monetary shocks and with Solow residual as a measure of technological shock (Model $M3$)
- a model with monopoly power, with adjustment costs, without monetary shocks and with Solow residual as a measure of technological shock (Model $M4$)
- a model with monopoly power, with adjustment costs, with monetary shocks and with Solow residual as a measure of technological shock (Model $M5$)
- a model with monopoly power, with adjustment costs, with monetary shocks and without technological shocks (Model $M6$)

We then simulate, for French and US parameter calibration, our benchmark model with monopolistic competition, price adjustment costs, monetary shocks, and with a Solow residual *purged* of the monetary shock as a measure of technological shock. The moments of the Hodrick-Prescott cyclical components of the series generated by these models are compared to the sample ones to evaluate the model ability to reproduce the main stylized facts. We also propose a qualitative validation by computing impulse responses to monetary shocks.

2.1 Parameter Calibration

The parameter of the model are calibrated partly according to previous studies on US and French data and partly according to our own computations.

In the US case, we follow King, Plosser, and Rebelo [1988] for a first group of parameters (H, δ and β). α is set to get a share of labour income in total income of .58, and the measure of money supply is $M1$.

Table 1

α	H	δ	β	$\frac{M}{PY}$
.3	.2	.025	.988	.1

We assume indivisibility of labour supply, which is equivalent to $\zeta = 0$. Elasticities σ, $\frac{1}{1-a}$ and γ are set according to previous panel data estimations. The elasticity of substitution between consumption index and real balances σ is small but significatively different from zero on US data (Koenig [1990]); we set it at 1/9. This value can also be interpreted as the interest elasticity of real money balances (which is given by $-\sigma$ in the model). Eichenbaum, Hansen, and Singleton [1988] showed that the intertemporal elasticity of substitution is between 1/3 and 2; we choose a value of 3/4 ($a = -1/3$). This value is smaller than the one chosen in most *RBC* models with log utility function ($a = 1$). The value of the parameter γ (which is equal to the mark-up μ at the steady state) relies on Morrison [1990]. This author estimated $\mu = .197$ for the american manufacturing sector (1960-1986). This estimation is based uppon a more general model (including increasing returns, imperfect competition and quasi-fixed factors) than Domowitz, Hubbard, and Petersen [1987] who obtained .36 for the all US industry 1958-1981 and Hall [1989] who estimated $\mu > 1$. As there are no materials in our model, this mark-up value is very conservative, and if one assumes that material inputs are about half of the total costs (as shown by Domowitz, Hubbard, and Petersen [1987]), then Morrisson's estimate suggest a value around $\mu = .5$. Nevertheless, we did not choose such a large mark-up because the pure profit share in total income is already 17% in our artificial economy (with $\mu = .197$), which seems to be higher than any empirical studies for the US economy[13].

We do not dispose of any estimations of the price adjustment costs parameter ϕ and we set it arbitrarily. A small value will be enough to get significative effects, according to the menu cost literature. To measure this cost, we compute the real adjustment cost of an increase of 1 point (.01) of the price growth rate, as a percentage of the steady state output. This ratio is denoted $\frac{\mathcal{CA}(.01)}{Y}$. A study of the model sensibility to the parameter ϕ is presented in appendix D.

Table 2

a	σ	ζ	γ	ϕ	$\frac{\mathcal{CA}(.01)}{Y}$
-1/3	1/9	0	.197	1	.01%

We estimated on quarterly US data (1959-1990) an $AR(1)$ process for the technological and monetary shocks. This $AR(1)$ is estimated on the relative deviations of the total factor productivity (Solow residual) from its average level on the period and on the relative deviations of the growth rate of $M1$ from its average level on the period. As the Solow residual is contaminated by demand shocks with imperfect competition (Hall [1989]), it is not a good proxy for the technological shock, and we need to purged it from the demand shocks (monetary shocks in our model). We then estimated a two dimension VAR composed of the relative deviations from their average of the Solow residual and the money growth rate. We identify the technological shock as the share of the Solow residual innovation not explained by the monetary innovation. The *purged* Solow residual

[13] We thank the referee for pointing out this weakness of our model. The only possible way of increasing μ and decreasing the share of pure profit is to include increasing returns (through a fixed cost of installation), as it is done in Rotemberg and Woodford [1989]. Nevertheless, one will need an irrealistic level of fixed costs (42% of net output) to get a 5% share of pure profit when mark-up is set to .5. Furthermore, this specification will need an increase of α (from .3 to .38). The economy will then be less volatile as the weight of the less volatile production factor (capital) is higher in the production function (simulations results are available upon request).

$\widehat{A}$ will be the variable generated only by the technological innovation, by oppostion to the *naive* (unpurged) Solow residual[14]. The estimated $AR(1)$ coefficients are given in table 3:

Table 3

$\overline{g}$	ρ_g	ε_g	ρ_A naive	ε_A naive	ρ_A purged	ε_A purged
1.014	.377	.009	.95	.009	.95	.008

We follow the same method to calibrate French parameters. Labour income share in total income is 54%, as it is computed on Quarterly National Accounts. Laffargue, Malgrange, and Pujol [1990] set a mark-up of .41 in their model. For the same reasons than in the US case, and as we do not dispose of any empirical studies on French data, we arbitrarily set it at .225, higher than the US rate, as the French economy is considered less competitive than the US one. We choose the same value of a and σ than in the US, following Charpin [1989]. Price adjustment cost parameter ϕ is also set equal to the US one. We choose the money supply $M2$, because it better explains output on the period.

The correction of the Solow residual is more important on French data, which supports the greater monopoly power we retained.

Table 4

α	H	δ	β	$\frac{M}{PY}$
.335	.2	.0125	.988	.25%

Table 5

a	σ	ζ	γ	ϕ	$\frac{\mathcal{CA}(.01)}{Y}$
-1/3	1/9	0	.225	1	.007%

Table 6

$\overline{g}$	ρ_g	ε_g	ρ_A naive	ε_A naive	ρ_A purged	ε_A purged
1.028	.50	.0098	.98	.009	.99	.0058

We simulate the model using equations (46) and (47) and generate series of shocks according to their estimated process. Each simulated series is 124 points long (which is the size of the data sample), and simulations are repeated 100 times. The resulting moments are the average of these 100 simulations, and we also computed the standard deviation of each moments on these 100 simulations.

[14]The estimation method and the econometric results are presented in appendix C.

2.2 The Effect of Monetary Shocks, Monopolistic Competition and Price Stickiness

Models $M1$ and $M2$ are models with money, and real money balances in the utility function, but a constant growth rate of the money supply is assumed.

Model $M1$ is closely related to the canonical *RBC* model of King, Plosser, and Rebelo [1988], with a more realistic intertemporal elasticity of substitution of consumption (King, Plosser, and Rebelo [1988] used a *log* utility function with unit elasticity). As there is no pure profit in that economy, α is set to 42, to keep a 58% share of labour income in national income. We obtained the following results[15]:

Table 7. Model $M1$
(US calibration)

Variable	$\widehat{y}$	$\widehat{c}$	$\widehat{i}$	$\widehat{h}$	$\widehat{x}$	$\widehat{f}$
S.D.	1.86	.50	5.56	1.29	.67	.36
S.D./S.D.($\widehat{y}$)	1	.27	2.98	.69	.35	.19
Autocor. order 1	.67	.75	.66	.66	.75	-.02
Cor. with $\widehat{y}$	1	.89	.99	.97	.89	-.57
Cor. with $\widehat{h}$	-	-	-	-	.77	-

The model exhibits the traditional *RBC* relative variability of consumption, output and investment and a worked hours standard deviation higher than the labor productivity ($\widehat{x}$) one, due to the indivisibility assumption. Autocorrelations are relatively high (.67 for output) and correlations of real variables with output are all positive. The labor productivity-worked hours correlation is large and positive (.77), as the labour market clears by shifts of the labour demand curve along the labor supply curve with technological shocks. The output-inflation correlation is negative, as the cycle is driven by technological shocks.

Model $M2$ includes monopoly power:

Table 8.Model $M2$
(US calibration)

Variable	$\widehat{y}$	$\widehat{c}$	$\widehat{i}$	$\widehat{h}$	$\widehat{x}$	$\widehat{f}$
S.D.	2.06	.71	9.36	1.25	.94	.51
S.D./S.D.($\widehat{y}$)	1	.34	4.52	.60	.45	.25
Autocor. order 1	.70	.77	.68	.68	.77	.02
Cor. with $\widehat{y}$	1	.92	.98	.95	.92	-.54
Cor. with $\widehat{h}$	-	-	-	-	.76	-

As prices are fully flexible, mark-up are constants in model $M2$. Absolute levels of standard-errors are slightly higher than in the perfect competitive case. Despite the indivisibility hypothesis,

[15] As the standard deviation are very similar from a model to another, we only present them for the benchmark model.

labour productivity standard deviation is close to hours one. Output-inflation correlation is still negative. Globally, monopolistic competition by itself does not provide significant differences, except for the hight investment variability (9.36 *vs* 5.56 in model $M1$).

Model $M3$ introduces money as in Hairault and Portier [1991b], but in a monopolistic competition framework. As prices are still fully flexible, mark-up are constant. $\widehat{M}$ represents the Hodrick-Prescott cyclical component of the money supply level.

Table 9. Model $M3$
(US calibration)

Variable	$\widehat{y}$	$\widehat{c}$	$\widehat{i}$	$\widehat{h}$	$\widehat{x}$	$\widehat{M}$	$\widehat{f}$
S.D.	2.05	.71	9.31	1.24	.94	1.65	1.31
S.D./S.D.($\widehat{y}$)	1	.34	4.54	.60	.45	.81	.64
Autocor. order 1	.69	.77	.67	.68	.77	.83	.01
Cor. with $\widehat{y}$	1	.92	.98	.95	.92	.00	-.22
Cor. with $\widehat{h}$	-	-	-	-	.76	-	-

We obtain the same results than in the competitive case studied by Hairault and Portier [1991b]: money has little effect upon the real features of the model; money-output correlation is null and inflation-output correlation is negative in the short run. Inflation variability is nevertheless higher than in model $M2$, because of the growth monetary shocks. We must notice that the effects of money growth shocks are smaller than in Cooley and Hansen [1989] model, as we do not impose a strict cash-in-advance constraint (which will correspond to the case $\sigma = 0$).

There are no monetary shocks in model $M4$, but prices adjustment costs are introduced.

Table 10. Model $M4$
(US calibration)

Variable	$\widehat{y}$	$\widehat{c}$	$\widehat{i}$	$\widehat{h}$	$\widehat{x}$	$\widehat{\mu}$	$\widehat{f}$
S.D.	1.78	.65	7.86	.99	.93	.98	.47
S.D./S.D.($\widehat{y}$)	1	.36	4.40	.55	.52	.55	.26
Autocor. order 1	.77	.75	.78	.80	.60	-.11	-.06
Cor. with $\widehat{y}$	1	.92	.98	.92	.91	.30	-.39
Cor. with $\widehat{h}$	-	-	-	-	.70	-	-

Mark-up $\widehat{\mu}$ are procyclical, as technological shocks drive the cycle. Standard deviations of real variables are smaller than in the fully flexible case, but the moments are globally close to the fully flexible model ones, except than hours and labour productivity standard deviations are now almost equal.

Model $M5$ is the theoretical model of the first section: monopolistic competition with sticky prices and monetary shocks. In that model, monetary shocks do modify the simulated business cycle (compared to model $M4$), by opposition to previous studies.

Table 11. Model $M5$
(US calibration)

Variable	$\widehat{y}$	$\widehat{c}$	$\widehat{i}$	$\widehat{h}$	$\widehat{x}$	$\widehat{\mu}$	$\widehat{M}$	$\widehat{f}$
S.D.	2.05	.65	9.93	1.71	1.05	2.62	1.67	1.27
S.D./S.D.($\widehat{y}$)	1	.32	4.85	.84	.51	1.29	.82	.62
Autocor. order 1	.61	.75	.51	.27	.49	-.01	.83	.01
Cor. with $\widehat{y}$	1	.82	.97	.85	.53	-.32	.09	.29
Cor. with $\widehat{h}$	-	-	-	-	.03	-	-	-

The standard deviation of output and the wedge between consumption and investment standard deviations are higher. Worked hours are now more volatile than labour productivity and real variables autocorrelation are smaller, in particular for worked hours. Mark-up are countercyclical. As output responses to technological and monetary shocks are always positive and mark-up response is positive for a monetary shock and negative for a technological one, this indicates that the cycle is not only driven by technological shocks.

The worked hours-labour productivity is now negative and close to zero, which is the opposite result than the *RBC* literature. This correlation stresses again the dominance of demand (monetary) shocks in the cycle.

The nominal features of the simulated cycle are now sharply different: money-output and inflation-output correlation are positive. The model clearly exhibits an output-inflation trade-off in the short run.

Model $M6$ allows us to get some insight on the specific effect of monetary growth shocks, as they are the only impulsion source in that model.

Table 12. Model $M6$
(US calibration)

Variable	$\widehat{y}$	$\widehat{c}$	$\widehat{i}$	$\widehat{h}$	$\widehat{x}$	$\widehat{\mu}$	$\widehat{M}$	$\widehat{f}$
S.D.	.94	.06	5.51	1.36	.43	2.38	1.58	1.15
S.D./S.D.($\widehat{y}$)	1	.06	5.86	1.45	.46	2.54	1.68	1.23
Autocor. order 1	-.03	.83	-.04	-.04	-.03	-.03	.83	-.00
Cor. with $\widehat{y}$	1	.20	.99	.99	-.98	-.99	.14	.99
Cor. with $\widehat{h}$	-	-	-	-	-.99	-	-	-

These results emphasize the difference between models $M4$ and $M5$. The labor productivity becomes sharply countercyclical and its correlation with labor highly negative.

The simulated moments of our model are then dependent on the presence of monetary shocks. In this theoretical framework, we now discuss the RBC proposition and ask whether monetary shocks improve or not the ability of the model to mimic the French and US business cycle?

2.3 The Model and the Business Cycle on US and French Data

We computed the business cycle caracteristics on the cyclical component of each macroeconomic series, by applying Holdrick-Prescott filter to US and French data[16].

Table 13. Cyclical properties of US business cycle
Quarterly data (CitiBase) 1959-1990

Variable	$\widehat{y}$	$\widehat{c}$	$\widehat{i}$	$\widehat{h}$	$\widehat{x}$	$\widehat{M}$	$\widehat{f}$
S.D.	1.76	1.28	8.47	1.42	.89	1.27	.39
S.D./S.D.($\widehat{y}$)	1	.72	4.81	.80	.50	.72	.22
Autocor. order 1	.85	.86	.81	.84	.52	.72	.24
Cor. with $\widehat{y}$	1	.81	.90	.86	.59	.36	.18
Cor. with $\widehat{h}$	-	-	-	-	.06	-	-

In the United States, the consumption standard deviation is less than the output one, which is less than the investment one. The worked hours standard deviation is close to the output one, and higher than the labor productivity one. All these variables are strongly procyclical, and worked hours-labour productivity correlation is close to zero. Persistence, measured by first order autocorrelation, is quite important, except for labour productivity and inflation[17].

Table 14. Cyclical properties of French business cycle
Quarterly data (INSEE Base) 1970-1990

Variable	$\widehat{y}$	$\widehat{c}$	$\widehat{i}$	$\widehat{h}$	$\widehat{x}$	$\widehat{M}$	$\widehat{f}$
S.D.	.91	.81	3.64	.83	.65	1.35	.52
S.D./S.D.($\widehat{y}$)	1	.9	4.01	.92	.72	6	.57
Autocor. order 1	.76	.67	.82	.89	.63	.63	.20
Cor. with $\widehat{y}$	1	.63	.80	.71	.45	.18	.15
Cor. with $\widehat{h}$	-	-	-	-	-.35	-	-

We observe on French data the same relative variance of consumption, output and investment, as this feature is common to all OECD countries. Nevertheless, output standard deviation is one half less important than in the US (which means that shocks are less important or that the French economy accomodates them more) and consumption relative standard deviation is higher. All the variables cyclical components are less autocorrelated than in the US, and all correlations with output are weaker.

Worked hours have a standard deviation close to the output one and higher than the labor productivity one, which is similar to the US case. Nevertheless, worked hours-labour productivity

[16] As usual for quarterly data, we choose $\lambda = 1600$. French data are taken from INSEE quarterly data bank and US data from the Citibase. See appendix A for a description of the data.

[17] Some *RBC* studies use *Current Population Survey* data for worked hours and labour productivity, which leads to different standard deviations. The worked hours standard deviation is around 1.7 and the labor productivity one is equal to 1.1. Nevertheless, our computations are in the same range.

correlation is negative (-.35). In both countries, money-output and inflation-output correlation are positive.

We simulate the theoretical model for each country calibration and with purged Solow residual.

Table 15. Simulation of the benchmark model with US calibration

Variable	$\widehat{y}$	$\widehat{c}$	$\widehat{i}$	$\widehat{h}$	$\widehat{x}$	$\widehat{\mu}$	$\widehat{M}$	$\widehat{f}$
S.D.	1.86 (.17)	.58 (.08)	9.06 (.88)	1.63 (.12)	.94 (.11)	2.53 (.19)	1.60 (.24)	1.22 (.1)
S.D./S.D.($\widehat{y}$)	1 (0)	.31 (.0200)	4.88 (.15)	.88 (.0666)	.50 (.034)	1.37 (.169)	.85 (.159)	.66 (.082)
Autocor. order 1	.56 (.0758)	.76 (.065)	.46 (.0812)	.21 (.09)	.48 (.11)	-.03 (.0870)	.82 (.030)	-.00 (.0872)
Cor. with $\widehat{y}$	1 (0)	.80 (.031)	.97 (.0045)	.86 (.019)	.46 (.0948)	-.38 (.08)	.1 (.17)	.36 (.09)
Cor. with $\widehat{h}$	-	-	-	-	-.03 (.12)	-	-	-

Table 16. Simulation of the benchmark model with French calibration

Variable	$\widehat{y}$	$\widehat{c}$	$\widehat{i}$	$\widehat{h}$	$\widehat{x}$	$\widehat{\mu}$	$\widehat{M}$	$\widehat{f}$
S.D.	1.16 (.1)	.47 (.06)	6.70 (.7)	1.09 (.06)	.76 (.07)	1.75 (.1)	1.86 (.27)	1.31 (.1)
S.D./S.D.($\widehat{y}$)	1 (0)	.40 (.026)	5.80 (.36)	.94 (.087)	.65 (.046)	1.52 (.163)	1.62 (.285)	1.14 (.12)
Autocor. order 1	.54 (.09)	.70 (.069)	.34 (.10)	.1 (.09)	.44 (.10)	.00 (.08)	.85 (.04)	.06 (.088)
Cor. with $\widehat{y}$	1 (0)	.70 (.066)	.95 (.008)	.77 (.03)	.40 (.11)	-.47 (.07)	.08 (.15)	.48 (.070)
Cor. with $\widehat{h}$	-	-	-	-	-.25 (.11)	-	-	-

Does the model provide significant improvements in describing US and French stylised facts when *both* monetary shocks and technology shocks are taken into account?

- First of all, the model reproduces the standard deviation of output in both countries with *estimated* shocks[18]. This point is remarquable, as these levels are very different from one country to another. The complete model with a *naive* Solow residual produces too high levels of output standard errror; the gain with *purged* Solow residual is particularly important on French calibration.

[18] The results of the french simulation with *naive* Solow residual are given in the following table:

- Only the benchmark model provides a correct description of the nominal features of the business cycle. Money-output and inflation-output correlations are positive. Unlike others monetarized *RBC* models (for instance Cooley and Hansen [1989]), we reproduce the empirical inflation-output trade-off in the short run.

- The worked hours-labour productivity correlation is well reproduced in both countries, close to zero for the US and negative for France. This result is strongly related to the presence of monetary (demand) shocks and improves greatly the cyclical properties of traditionnal RBC models.

- Worked hours standard deviation is higher than labour productivity one, which is not the case in a monopolistic model without monetary shocks. We reproduce the variance of these two variables both in United States and in France.

- Mark-up are countercyclical in the model. This stylised fact has been widely studied in the empirical literature and many authors concluded explicitely (Bils [1987] and Morrison [1990] on US data, Morrison [1989] on Canadian data) or implicitely (Hall [1988] on US data) that mark-up are countercyclical[19]. In a model with quasi-fixed factors, Morrison [1990] estimated a value of -.419 for the correlation between mark-up and a measure of capacity utilization. As we do not allow for excess capacity, the equivalent correlation is between mark-up and output. We found a value of -.36, which is in the same range than Morrison [1990].

So, monetary shocks in a monopolistic competition framework with price adjustment costs improve the understanding of some real and nominal aspects of the business cycle without damaging the main results of standard *RBC* models.

2.4 Impulse Responses to Technological and Monetary Shocks

Impulse responses to a technological shock are similar to the traditionnal *RBC* model ones. A positive shock increases temporarily consumption, real wage, capital, real balances, investment, output, profits and mark-up. The first four variables exhibit an hump-shape response, and the last four are always above their steady state level.

Impulse responses to a monetary shock (Figures 1 to 7[20]) are coherent with previous econometric studies (see Blanchard [1989] and Bec and Hairault [1991] for instance). A 1% shock on the money rate of growth increases instantaneously output by 1% in the US and .8% in France. Investment, worked hours and inflation also react positively. The negative (or slighlty positive at the first

Table 17. Modèle $M5'$

Simulation of the benchmark model with French calibration and *naive* Solow residual

Variable	$\widehat{y}$	$\widehat{c}$	$\widehat{i}$	$\widehat{h}$	$\widehat{x}$	$\widehat{\mu}$	$\widehat{M}$	$\widehat{f}$
S.D.	2.06	.53	13.1	1.63	.82	1.75	1.86	1.32
S.D./S.D.($\widehat{y}$)	1	.25	6.35	.79	.39	.85	.9	.64
Autocor. order 1	.65	.72	.60	.47	.49	-.01	.85	.04
Cor. with $\widehat{y}$	1	.83	.97	.92	.65	-.18	.04	.18
Cor. with $\widehat{h}$	-	-	-	-	.32	-	-	-

[19] We must notice however that Domowitz, Hubbard, and Petersen [1987] founded a positive correlation between mark-up and output.

[20] All these impulse responses are presented in appendix B.

period in France) response of the interest rate to a monetary growth shock differs from the results of King [1990] (positive response), as money is explicitely in the utility function. At the opposite, profits and mark-up stay under their steady state level during all the adjustment. The low serial correlation of all variables after a mmonetary shock is a consequence of the low autocorrelation coefficient of the $AR(1)$ process of the monetary growth shock.

Conclusion

Our ambition was not to asses that monetary shocks are the main impulse of the business cycle, but to show that they allow for a better understanding of it in a model which departs from the perfectly competitive and flex-price framework. Our results showed that the New Keynesian perspective (imperfect competition and nominal rigidities) proposes an answer to some empirical puzzles within a *RBC* methodology. As the model is able to mimic two sets of cyclical stylized facts in two different countries (France and the United States), with a suitably redefined measure of the technological impulse in the spirit of Hall [1989], we consider it as a usefull step towards a better understanding of the role of demand factors, and particularly monetary shocks, in the business cycle.

Beyond the shortcomings of the *RBC* models, due to a too narrow view of cyclical impulses and a too idealized view of the way the markets work, modern macroeconomics may well benefit from the methodological message of this approach: fully worked out intertemporal computable equilibrium models are worth to be considered seriously[21].

[21] See Danthine and Donaldson [1991] and Hénin [1991] for a similar view.

Appendix

A The data

Table A.1. presents the data code of the series for French and US data.

table A.1.

	databank		Code	
	France	USA	France	USA
Y	Insee	Citibase	PIBT8	GNP82
C	Ocde	Citibase	FRACSMRX	GC82
I	Insee	Citibase	P41TUIP8	GPI82
H	Insee	Citibase	(EFMOA1 × DUMOA1)	(LHEM × LHCH)
X	Insee	Citibase	Y/H	Y/H
P	Ocde	Citibase	Fradefl	GD
M	Ocde	Citibase	FraM1QS	FM1

B Impulse reponses to a monetary growth shock

Figure 1: Monetary shock (1% shock on g)

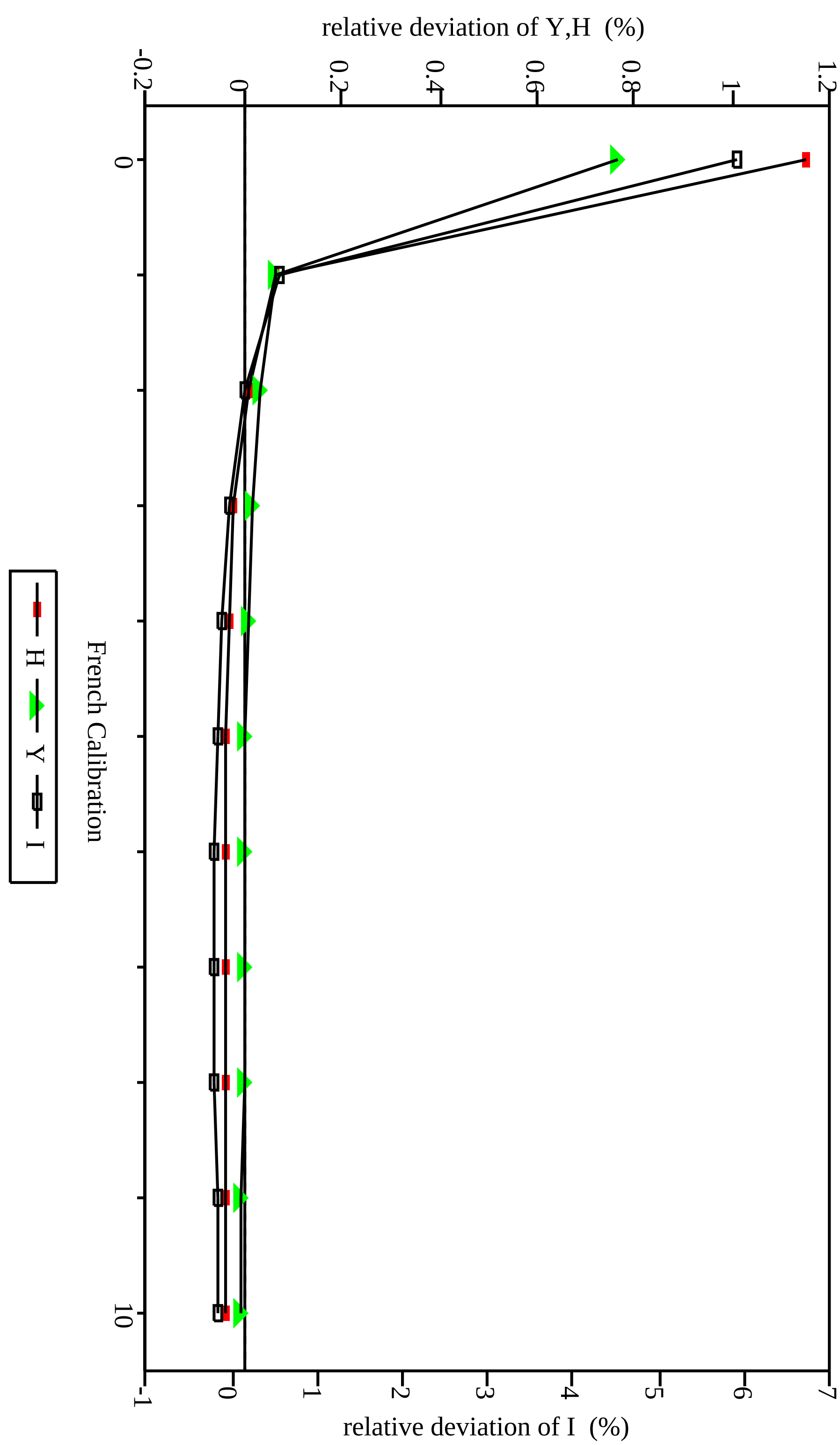


Figure 2: Monetary shock (1% shock on g)

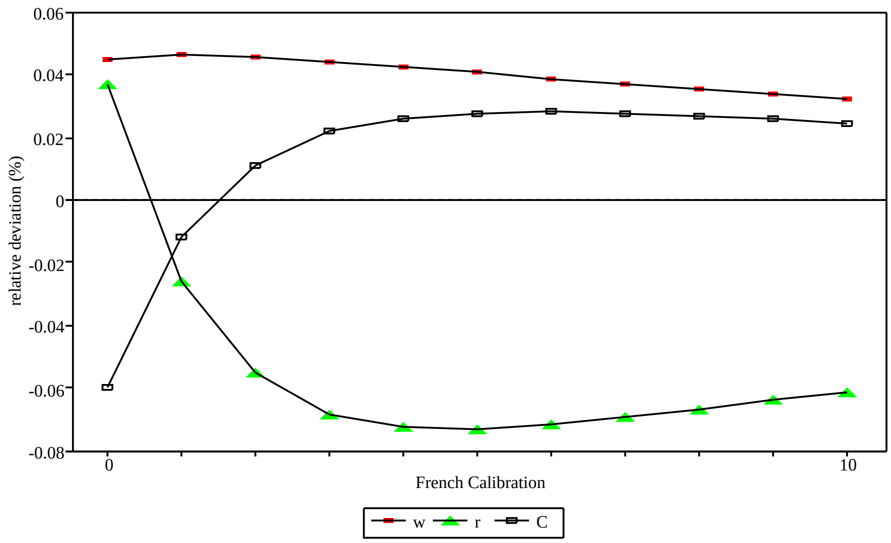


Figure 3: Monetary shock (1% shock on g)

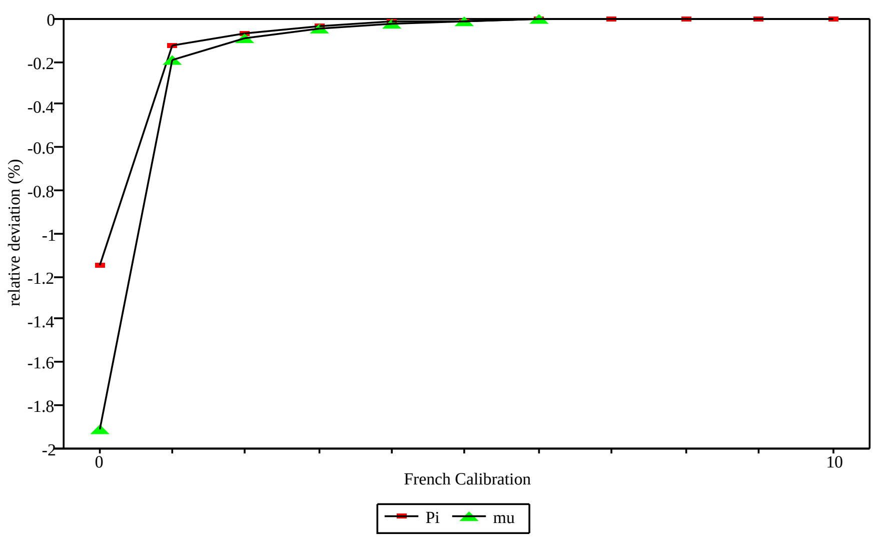


Figure 4: Monetary shock (1% shock on g)

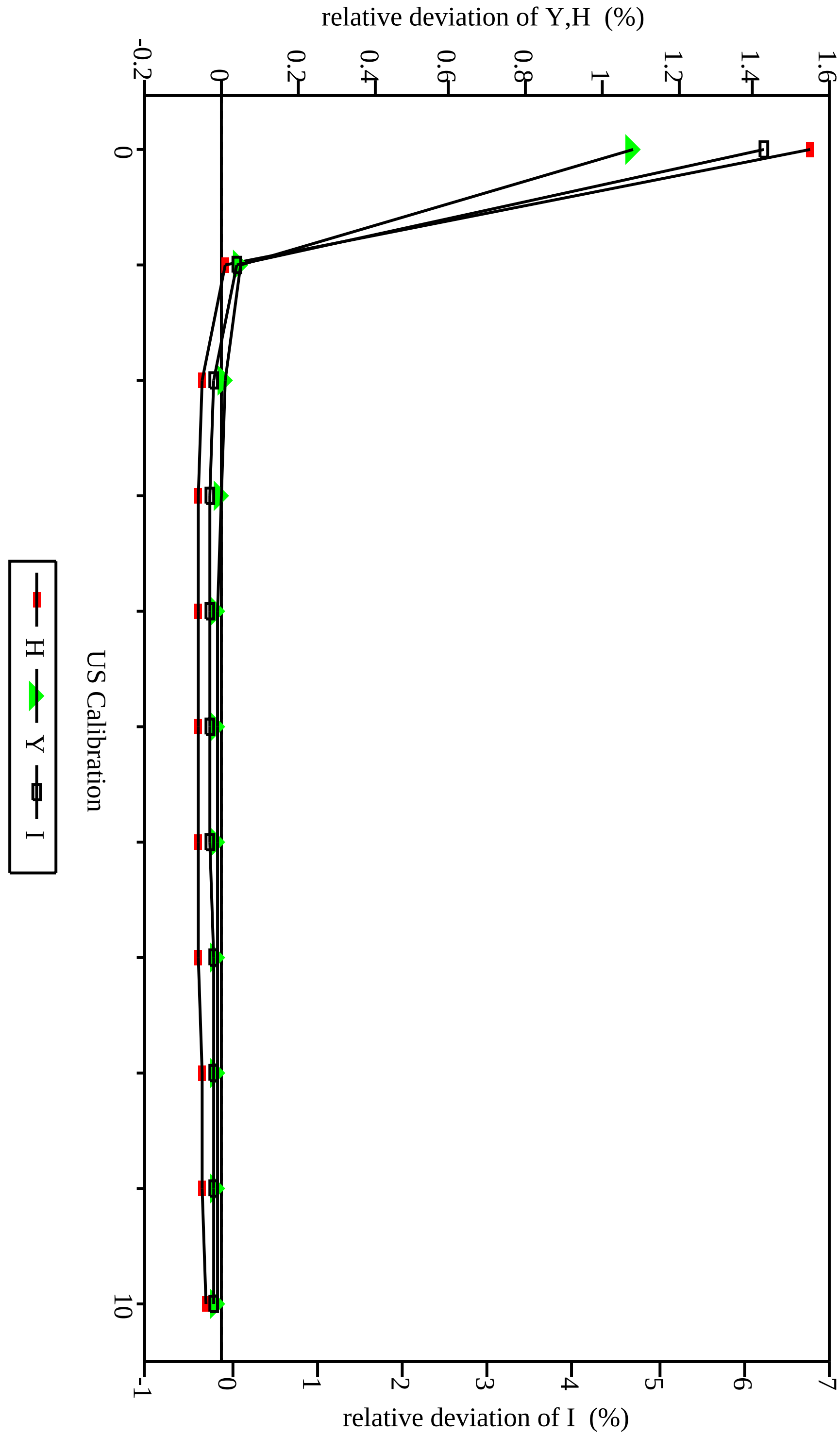


Figure 5: Monetary shock (1% shock on g)

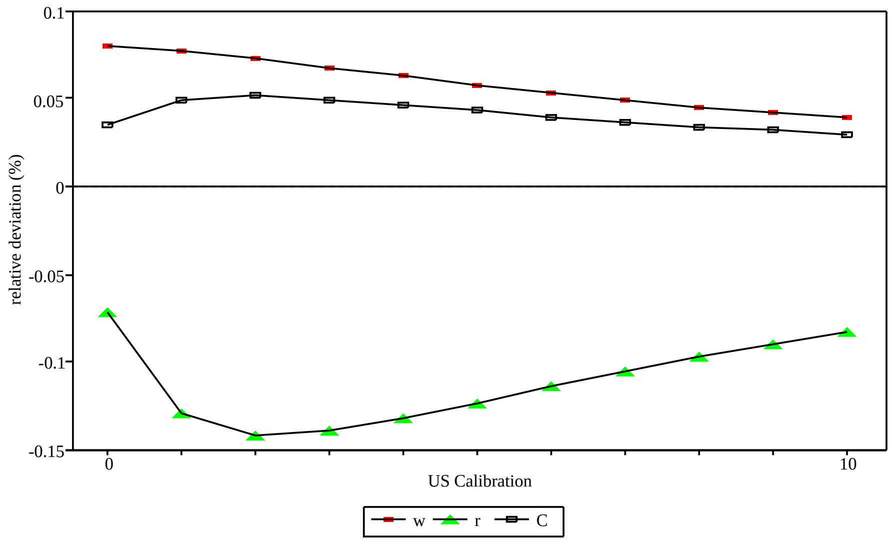


Figure 6: Monetary shock (1% shock on g)

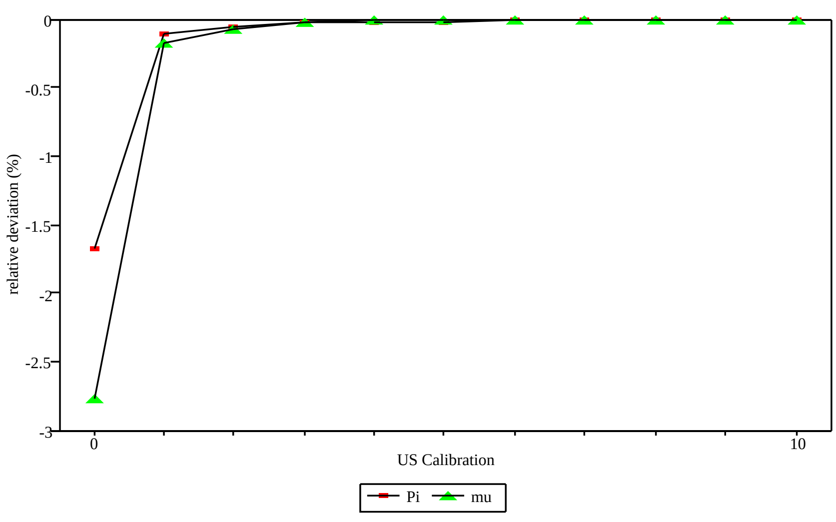
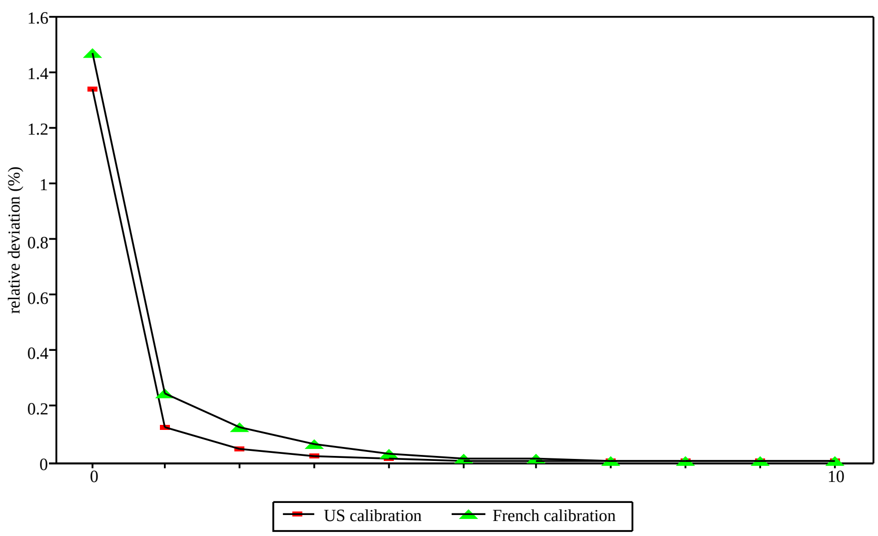


Figure 7: Inflation after a monetary shock (1% shock on g)



C Construction of a purged Solow residual

As there is imperfect competition in our model, the Solow residual is contaminated by demand shocks (monetary shocks in the model). Our aim is then to purge the Solow residual from the influence of these money growth shocks. The process of $\widehat{A}$ has to be generated only by the *true* technological shocks ϵ_A.

Let be ϵ the vector of structural shocks, ϵ_A and ϵ_g. The joint process of the money growth (g) and the *naive* Solow residual (SR), both as relative deviation from their average level, is given by the following Vectorial Moving Average representation:

$$\begin{pmatrix} \widehat{g}_t \\ \widehat{SR}_t \end{pmatrix} = A(L) \begin{pmatrix} \epsilon_{g,t} \\ \epsilon_{A,t} \end{pmatrix} = \begin{pmatrix} A_{(1,1)}(L) A_{(1,2)}(L) \\ A_{(2,1)}(L) A_{(2,2)}(L) \end{pmatrix} \begin{pmatrix} \epsilon_{g,t} \\ \epsilon_{A,t} \end{pmatrix} \tag{48}$$

We define the *purged* Solow residual[22] $\widehat{A}$ as the component of the Solow residual generated only by ϵ_A.

$$\widehat{A} = A_{(2,2)}(L)\epsilon_{A,t} \tag{49}$$

To recover $A_{22}(L)$ and ϵ_A, we estimate a two dimension VAR with $\widehat{SR}$ and $\widehat{g}$, including four lags. The estimation on US and French data are given in tables C.1 and C.2, where the Student statistics are given under each coeffícent, and the significance level of the Fisher statistics (global exclusion of the variable in the equation) is given under its value:

Table C.1. Estimations of the VAR model (U.S. data)

Dep var	$\widehat{g}_{t-1}$	$\widehat{g}_{t-2}$	$\widehat{g}_{t-3}$	$\widehat{g}_{t-4}$	F-stat	$\widehat{SR}_{t-1}$	$\widehat{SR}_{t-2}$	$\widehat{SRg}_{t-3}$	$\widehat{SR}_{t-4}$	F-stat
$\widehat{g}_t$	.27	.04	-.06	.13	2.6	-.04	.14	-.14	.83	.94
	(2.76)	(.43)	(.59)	(1.26)	(.04%)	(.40)	(.91)	(.95)	(.82)	(.44%)
$\widehat{SR}_t$	.09	.22	-.09	-.008	2.24	1.0	.12	-.24	.03	342
	(1.07)	(2.4)	(1.02)	(.087)	(.07%)	(9.82)	(.90)	(1.79)	(.35)	(.00%)

Table C.2. Estimations of the VAR model (French data)

Dep Var	$\widehat{g}_{t-1}$	$\widehat{g}_{t-2}$	$\widehat{g}_{t-3}$	$\widehat{g}_{t-4}$	F-stat	$\widehat{SR}_{t-1}$	$\widehat{SR}_{t-2}$	$\widehat{SRg}_{t-3}$	$\widehat{SR}_{t-4}$	F-stat
$\widehat{g}_t$	.006	-.04	-.14	-.01	.34	-.07	-.03	-.05	.05	3.69
	(.05)	(.35)	(1.1)	(.08)	(.84%)	(.51)	(.13)	(.23)	(.42)	(.01%)
$\widehat{SR}_t$	.01	-.01	.25	-.20	2.84	1.22	.01	-.001	-.22	624
	(1.02)	(.18)	(2.49)	(2.01)	(.03%)	(10.3)	(.07)	(.01)	(2.05)	(.00%)

We invert that VAR representation to get the Wold representation of the bivariate process:

[22] Another strategy to recover the *pure* technological innovation is to built a *purged* Solow residual from data on output and factors, as it is developped in Hall [1989] and illustrated in Rotemberg and Woodford [1991].

$$\left(\begin{array}{c} \widehat{g}_t \\ \widehat{SR}_t \end{array} \right) = C(L) \left(\begin{array}{c} u_{g,t} \\ u_{A,t} \end{array} \right) \tag{50}$$

where $u = (u_g, u_{SR})'$ is the vector of VAR residuals.

From equation (48), there is a rectangular matrix (2,2) A_0 such that $u_t = A_0\epsilon_t$ and $A(L) = C(L)A_0$. As long as A_0 is identified, $A(L)$ is known and one can recovers thethe ϵ's from the u's. We assume that the two true exogeneous shocks of the model ϵ_g and ϵ_A are uncorrelated. Then one must have:

$$A_0A_0' = V$$

where V is the variance-covariance matrix of the estimated shocks ε. This equation implies three restrictions on the coefficients of A_0, as V is symmetric. Then, an additionnal restriction is needed to identify A_0. We assume that $A_{0(1,2)} = 0$, the technological shock has no immediate effect on money growth. With that restriction, we recover the VMA representation (48) and compute the *purged* Solow residual $\widehat{A}$ according to (49).

D Sensibility to the price adjustment cost parameter ϕ

The existence of nominal rigidities is crucial determinant of the model response to a demand shock, as table D.1. shows how instantaneous responses (the Π matrix) evolve when adjustment costs increase[23]:

Table D.1.

ϕ	0	1/100	1/10	1	5
$\frac{\mathcal{CA}(.01)}{Y}$	0%	.0001%	.001%	.01%	.05%
Π_{cg}	-.024	-.023	-.017	.035	.218
Π_{Hg}	-.006	.010	.157	1.545	6.33
Π_{wg}	.002	.003	.010	.080	.323
Π_{rg}	-.004	-.004	-.012	-.072	-.24
Π_{yg}	.005	.007	.110	1.08	4.43
$\Pi_{\Pi g}$	-.005	-.022	-.181	-1.68	-6.85
$\Pi_{\mu g}$	0	.029	-.297	-2.76	-11.2
Π_{ig}	. .090	.155	.737	6.23	25.2
Π_{xg}	.001	-.003	-.047	-.463	-1.90
Π_{fg}	1.410	1.410	1.402	1.340	1.12

The reduction of the mark-up becomes larger with the magnitude of the adjustment costs. The increase in good demand leads to high level of output and low price level when adjustment costs are high. Besides, hours and investment positive response increase with adjustment costs.

Table D.2. shows how variables simulated standard deviations evolve with ϕ (100 simulations).

[23]These results are obtained for the US calibration

Table D.2. Simulated standard deviations for different values of ϕ
(US calibration)

ϕ	0	1/100	1/10	1	5
$\frac{\mathcal{CA}(.01)}{Y}$	0%	.0001%	.001%	.01%	.05%
$\widehat{c}$	.61 (.08)	.59 (.08)	.59 (.08)	.58 (.08)	.59 (.09)
$\widehat{h}$	1.07 (.12)	1.03 (.12)	1.01 (.11)	1.63 (.12)	5.83 (.4)
$\widehat{x}$	.81 (.1)	.78 (.1)	.79 (.11)	.94 (.11)	2.07 (.1)
$\widehat{y}$	1.77 (.2)	1.71 (.2)	1.70 (.2)	1.86 (.17)	4.17 (.28)
$\widehat{i}$	7.97 (.96)	7.7 (.92)	7.66 (.97)	9.06 (.88)	26.98 (4.36)
$\widehat{f}$	1.29 (.08)	1.29 (.08)	1.29 (.08)	1.22 (.1)	1.01 (.07)
$\widehat{\pi}$	1.77 (.2)	1.72 (.2)	1.74 (.2)	2.52 (.2)	6.8 (.5)

Consumption standard deviation is not sensible to ϕ[24], hours, investment, output and labour productivity standard deviations increase with ϕ. Inflation standard deviation is a decreasing function of ϕ.

One must notice that inflation standard deviation is always higher than in the data (1.22 for the US benchmark model and .52 on US data), even with high price adjustment costs (1.2 for $\phi = 5$). This failure of the model is linked to the existence of a substitution effect between money and consumption. In a model with adjustment cost on a real variable (*e.g.* capital), one can arbitrarily reduce the standard deviation of the variable by increasing the adjustment cost. In that model, households arbitrate between money and consumption. Therefore, the elasticity of substitution between money and consumption (σ) is a key parameter in the variance of inflation. For a given σ, the instantaneous response of inflation (and its standard deviation if we simulate the model) is of course a decreasing function of the price adjustment cost parameter ϕ. For a given ϕ, this response is an increasing function of the elasticity of substitution σ (figure 8).

Figure 8: Instantaneous response of inflation to a 1% monetary shock as a function of the elasticity of substitution between money and consumption σ and of the size of the price adjustment cost ϕ

See the published version for this figure

The more money can be substituted to consumption (high values of σ) and the more inflation will be important after a monetary growth shock. As a monetary shock increases the inflationary

[24]These standard deviation are not exact values but simulated ones. Therefore, one must not interpret small variations of them for different values of ϕ.

tax, households substitute consumption to real balances. The higher σ is, the higher is the demand for good and the higher is inflation. This effect dominates the effect of the adjusment cost in the model. If we increase the price adjustment costs, inflation will not be much lower after a monetary shock, but profits will be, as firms incurred higher adjustment costs (see table D.1.).

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