ENDOGENOUS CAPACITY UTILIZATION AND THE ASYMMETRIC EFFECTS OF MONETARY POLICY

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ABSTRACT. This paper investigates the role of variable capacity utilization as a source of asymmetries in the relationship between monetary policy and economic activity within a dynamic stochastic general equilibrium framework. The source of the asymmetry is directly linked to the bottlenecks and stock-outs that emerge from the existence of capacity constraints in the real side of the economy. Money has real effects due to the presence of rigidities in households' portfolio decisions in the form of a Lucas-Fuerst 'limited participation' constraint. The model features variable capacity utilization rates across firms due to demand uncertainty. A monopolistic competitive structure provides additional effects through optimal mark-up changes. The overall message of this paper for monetary policy is that the same actions may have different effects depending on the capacity utilization rate of the economy. Given the empirically plausible link between inflation and utilization, the present analysis establishes a basis for studying the implications of asymmetric monetary policy rules based on the capacity gap.

1. INTRODUCTION

What are the effects of central bank policy? Do they depend on the state of the economy? How should monetary policy be conducted in the short run? For many years, macroeconomists have grappled with these questions, but have not yet reached a consensus. Achieving a thorough notion of the mechanics that constitute the monetary transmission mechanism requires a deep exploration of the nontrivial structure of the complete economy. This is not a straightforward task for either theorists and applied economists. From a theoretical point of view, the main difficulty has been to develop models that can generate the salient features of aggregate time series, which is the first step towards reliable policy analysis. Models of the transmission mechanism should generate a response of economic variables to a monetary policy shock consistent with those found in the data in, at least, three dimensions: sign, timing and magnitude.

The literature has provided us with models that are able to replicate reasonably well the sign and timing of the transmission mechanism. However, models that can adequately account for the magnitude of the responses to monetary policy remain

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to be developed. A relevant aspect in this regard refers to asymmetries: depending on the state of the economy, similar policy actions will generate quantitatively different effects on the economy. In this paper, I consider the hypothesis of capacity utilization constraints in the real side of the economy and portfolio rigidities in the financial sector as the basis for developing an analytical framework consistent with the aforementioned features of the monetary transmission mechanism. Such a framework consists of a dynamic stochastic general equilibrium model which displays the non-neutralities of money needed to perform policy analysis in the short run, as well as the production inflexibilities that are able to generate the asymmetric dynamics of key macroeconomic variables documented in empirical research.

1.1. **Capacity Utilization and Monetary Policy Performance.** In the literature, there are several explanations for the asymmetric response that monetary policy generates on the main macroeconomic variables. One of these arguments is known as the capacity constraint hypothesis.[1] The idea is that some firms find it difficult to increase their capacity to produce in the short run, giving rise to supply shortages and production bottlenecks. This is going to have important implications on one particular relation which is at the heart of the science of monetary policy, the Phillips curve. In this regard, when the economy experiences strong aggregate demand, the impact on inflation will be greater when more firms are restricted in their ability to raise output in the short run. Consequently, the short-run aggregate supply equation or Phillips curve will display a convex shape, which has relevant consequences for the performance of a monetary policy aimed at controlling inflation. Certainly, if the economy is initially weak, easing monetary conditions will primarily affect output, but if the economy is initially strong, a monetary expansion will mainly affect prices.

Recently, a great deal of research has been devoted to test empirically the asymmetric effects of monetary policy from the existence of a convex Phillips curve. In this vein, Cover (1992), Karras (1996) and Alvarez-Lois (2000) provide evidence of asymmetries between positive and negative monetary shocks on output and prices. Weise (1999) making use of an econometric methodology that allows to test for the different types of asymmetries finds that monetary shocks have dramatically different effects depending on the state of the economy. But prices and output are not the only macroeconomic variables studied in this context, there is also evidence of asymmetries in the behavior of nominal interest rates.[2]

Despite the empirical evidence and the strong theoretical arguments put forward, there is certainly a lack of a general equilibrium approximation to the issue of asymmetries within the monetary macroeconomic literature. This paper aims at filling this gap, developing a quantitative model of the monetary transmission mechanism and analyzing its implications for the conduct of monetary policy.

1.2. **Modeling Capacity Within a Monetary DSGE Framework.** The model developed here has two basic ingredients: (i) it incorporates a real side with production inflexibilities that result in variable rates of utilization across firms and (ii)

[1]Other arguments are based on "menu costs" and nominal wage rigidities. Dupasquier and Ricketts (1997) briefly survey some of the different sources of asymmetries in this regard. Another strand in the literature emphasizes the role credit market imperfections in the monetary transmission mechanism. See, for instance, Bernanke, Gertler and Gilchrist (1998).

[2]See, for instance, Enders and Granger (1998) for evidence in this regard.

it considers portfolio constraints that create a short run non-neutrality of monetary policy. Regarding the first component, the model presented here follows the formulation of Fagnart, Licandro and Portier (1999) in modelling the issue of capacity utilization.[3] These authors introduce idiosyncratic demand uncertainty and a rich modeling of the production sector (firms heterogeneity and absence of an aggregate production function) within a monopolistic competitive business cycle model. The bulk of their model relies on three basic aspects: first, the limited possibilities of a short run substitutability between production factors; second, the presence of uncertainty at the time of capacity choices, which explains the presence of underutilized equipments; and third, the existence of idiosyncratic uncertainty which results in a nondegenerate distribution of utilization rates across firms. In equilibrium, a proportion of firms face demand shortages and have idle capacities, while others are at full capacity and are unable to serve any extra demand. Moreover, the monopolistic competitive environment provides an additional source of dynamics through optimal mark-up changes.

Regarding the second ingredient of the model, namely the monetary side, this paper considers the existence of participation constraints in the financial market, which create non-neutralities of monetary policy. Specifically, the effects of an unexpected monetary policy action are firstly felt through the demand for money and the short term interest rate -the *liquidity effect*- which subsequently affects investment and output, known this as *output effect*. The magnitude and persistence of such effects are clearly an important issue, as they capture a key nonneutral effect of monetary policy. Explaining the strong relationship between money and real activity in a general equilibrium theory involves facing two challenges. The first is to provide a theory in which money is valued in equilibrium. This is done assuming a cash-in-advance constraint. Secondly, and more difficult, it is to show how monetary policy has real effects in a world where economic agents are behaving rationally, without simply assuming some *ad hoc* form of money illusion. The limited participation paradigm provides a rationale for this issue.[4] The basic idea is that money plays a role in the economy due to its asymmetric distribution to economic agents: money is firstly distributed to financial intermediaries an then to firms before it finally reaches consumers' hands.[5]

Two features describe the mechanism working in these models (i) changes in the money supply initially involve the monetary authority and financial sector only and (ii) the representative household's supply of funds, through bank deposits, is predetermined relative to monetary shocks. Under these circumstances, an unanticipated money injection increases the share of liquid assets held by financial intermediaries. Thus, firms are forced to absorb the excess of liquidity in the economy. The market clearing interest rate falls as a result. The liquidity effect can generate a strong real response to monetary policy by changing the financial costs of hiring factors of production. The existence of production inflexibilities that arise due to the existence of capacity utilization constraints will condition the intensity of the liquidity and

[3]Probably, the first attempt to rationalize explicitly equipment idleness in a real business cycle model is due to Cooley, Hansen and Prescott (1995).

[4]A second strand of the literature, known as the new neoclassical synthesis -see Goodfriend and King (1997)- highlights the role of nominal frictions in shaping key features of monetary economies.

[5]Basic references in the literature on limited participation models include Lucas (1990), Fuerst (1992) and Christiano (1991).

output effects.[6] Depending on the magnitude of these inflexibilities, the response of the economy to a monetary shock will differ notably.[7] These asymmetries are quantified in the model presented here.

The outline of the paper is as follows. Section 2 presents a formal description of the model's behavioral aspects. Section 3 offers a characterization of the general equilibrium of the economy and its qualitative properties. The implications for short-run dynamics are analyzed at this stage. Section 4 studies the quantitative dimension of the model, what involves the computation of impulse responses of the main variables in the model to a monetary policy shock and other numerical simulation exercises. Section 4 offers some concluding remarks and possible lines for further research.

2. The Model Economy

The basic structure of the model is taken from Christiano, Eichenbaum and Evans (1998) and Fagnart, Licandro and Portier (1999). I consider an economy consisting of households, financial intermediaries, a central bank in charge of the conduct of monetary policy and two productive sectors: a competitive sector producing a final good and a monopolistic sector providing intermediate goods. These intermediate goods are the only inputs necessary for the production of the final good. The final good can be used either for consumption or for investment purposes. Capital and labor are used in the production of intermediate goods by means of a putty-clay technology.[8] This specification of the production function allows for the introduction of a simple, but realistic, concept of capacity. Each input firm makes its investment, pricing and employment decisions under idiosyncratic demand uncertainty, that is, before knowing the exact demand for its production. This structure implies that intermediate goods firms can be either sales or capacity constrained; it also allows different firms to face different capacity constraints. Consequently, this source of uncertainty is what explains the presence of heterogeneity between firms at equilibrium regarding the degree of utilization of their productive capacities.

These production side particularities are embedded into an otherwise standard limited participation model. Before proceeding to describe in more detail the different aspects that constitute the basis of the model economy, it is convenient to define the information sets that appear in the model.

$$\Omega_{0,t} = \text{economy-wide variables dated at time } t-1 \text{ and earlier}$$
$$\Omega_{1,t} = \text{includes } \Omega_{0,t} \text{ and period } t \text{ aggregate monetary shock}$$

At this point, it is also useful to describe the elements that represent the state of the economy in the model I am developing. These are the aggregate stock of capital K, the capital-labor ratio X and the realization of the monetary policy shock, x.

[6]Christiano and Eichenbaum (1995) also analyses these margins.

[7]Finn (1996) and Cook (1999) analyze the role of capital underutilization in a monetary quantitative framework. The description of the underutilization phenomenon , which follows Burnside and Eichenbaum (1996) depreciation in use models, is highly stylized, however.

[8]Capital and labor are substitutes *ex ante*, i.e., before investing, but complement *ex post*, i.e., when equipment is installed. This implies that each firm makes a capacity choice when investing.

2.1. **Final Good Firms.** At time t, a single final good, denoted by $\mathcal{Y}$, is produced by a representative firm which sells it in a perfectly competitive market. Such commodity can either be used for consumption or for investment. There is no fixed input, which implies that the optimization program of these firms remain purely static. The production activities are carried out by combining a continuum of intermediate goods, indexed by $j \in (0,1)$. The production technology is represented by a constant return-to-scale CES function defined as follows

$$\mathcal{Y}_t = \left[\int_0^1 Y_{j,t}^{\frac{\epsilon-1}{\epsilon}} v_{j,t}^{\frac{1}{\epsilon}} \mathrm{d}j \right]^{\frac{\epsilon}{\epsilon-1}} , \tag{2.1}$$

with $\epsilon > 1$ being the elasticity of substitution of inputs and where $Y_{j,t}$ is the quantity of input j used in production at date t. Here, $v_{j,t} \geq 0$ is a productivity parameter corresponding to input j. It is assumed to be drawn from a stochastic process i.i.d. distributed across time and input firms,[9] with a log normal distribution function $\mathrm{F}(v)$ that has unit mean and is defined over the support $[\underline{\mathrm{v}},\bar{\mathrm{v}}]$ with $0 < \underline{\mathrm{v}} < 1 < \bar{\mathrm{v}}$. The representative firm purchases inputs to intermediate good firms taking into account that the supply of each input j is limited to an amount $\bar{Y}_{j,t}$. Assuming a uniform non-stochastic rationing scheme, the optimization program of the final firm can be written as follows

$$\max_{\{\mathcal{Y}_t, y_{it}\}} \mathbf{P}_t \mathcal{Y}_t - \int_0^1 P_{j,t} Y_{j,t} \mathrm{d}j \ , \tag{P1}$$

subject to

$$Y_{j,t} \leq \bar{Y}_{j,t} \ \forall j \in (0,1) \ ,$$

where $\mathbf{P}_t$ is the price of the final good which is taken as given by the firm. When maximizing profits, the final firm faces no uncertainty: it knows the input prices $\{P_{j,t}\}$, the supply constraints $\{\bar{Y}_{j,t}\}$ and the productivity parameters $\{v_{j,t}\}$. It is important to notice that the inclusion of supply constraints in the problem above is due to the particular structure of the model, where input producing firms set their prices before the idiosyncratic shock is realized.

The solution to (P.1) determines the quantity that the final good firm is going to make for the goods produced by each intermediate firm. As the production technology displays constant returns-to-scale, the competitive firm necessarily makes zero profits at the prevailing prices and is willing to produce any output level $\mathcal{Y}_t \geq 0$. Moreover, under deterministic quantity constraints and a uniform rationing scheme, effective demands are not well defined. Realized transactions can be derived, however.[10] The quantity of inputs used will be determined by the corresponding idiosyncratic productivity level of each intermediate firm as described in the next result:

Lemma 1 (Realized Transactions)**.** *The optimal allocation of inputs across intermediate good firms is given by the following system of equations*

$$Y_{j,t} = \begin{cases} \mathcal{Y}_t v_{j,t} \left(\frac{P_{j,t}}{\mathbf{P}_t} \right)^{-\epsilon} & \textit{if} \quad \underline{v}_{j,t} \leq v_{j,t} \leq \bar{v}_{j,t} \\ \bar{Y}_{j,t} & \textit{otherwise} \end{cases} \tag{2.2}$$

[9]In order to keep the model tractable, it is assumed that the idiosyncratic shock is not serially correlated. Thus, its realization influences exclusively contemporary production and employment decisions, but not investment decisions.

[10]For a detailed discussion on the theory of effective demands see Green (1980) or Svensson (1980).

with

$$\tilde{v}_{j,t} = \frac{\bar{Y}_{j,t}}{\mathcal{Y}_t \left(\frac{P_{j,t}}{\mathbf{P}_t}\right)^{-\epsilon}} . \tag{2.3}$$

The variable $\tilde{v}_{j,t}$ determines the critical value of the productivity parameter $v_{j,t}$ for which the unconstrained demand equals the supply constraint $\bar{Y}_{j,t}$. The term $(P_{j,t}/\mathbf{P}_t)^{-\epsilon}$ appearing in the demand function of a firm with excess capacities represents, at given $\mathcal{Y}_t$, the positive spillover effects a firm with idle resources benefits from. As mentioned above, for tractability purposes I shall assume that all intermediate firms are *ex-ante* equal. This symmetry means that input prices and capacities are the same across firms. Assuming that a law of large numbers applies in the present context, the final output supply can be expressed as follows

$$\mathcal{Y}_t = \left[\int_0^1 Y_{j,t}^{\frac{\epsilon-1}{\epsilon}} v_{j,t}^{\frac{1}{\epsilon}} \mathrm{d}j\right]^{\frac{\epsilon}{\epsilon-1}} \tag{2.4}$$

or taking into account equation (2.2),

$$\mathcal{Y}_t = \left\{\left[\left(\frac{P_{j,t}}{\mathbf{P}_t}\right)^{-\epsilon} \mathcal{Y}_t\right]^{\frac{\epsilon-1}{\epsilon}} \int_{\underline{\mathrm{v}}}^{\tilde{v}_t} v \mathrm{dF}\,(v) + \bar{Y}_t^{\frac{\epsilon-1}{\epsilon}} \int_{\tilde{v}_t}^{\bar{\mathrm{v}}} v^{\frac{1}{\epsilon}} \mathrm{dF}\,(v)\right\}^{\frac{\epsilon}{\epsilon-1}} . \tag{2.5}$$

Recall that $\mathrm{F}(v)$ is the distribution function of idiosyncratic shocks; thus, for a proportion $\mathrm{F}(\tilde{v})$ of intermediate firms, the realized value of the productivity parameter is below $\tilde{v}$. Some manipulation of the previous expression allows one to write relative prices as a function of $\tilde{v}_t$, the proportion of firms with excess capacities

$$\frac{P_{j,t}}{\mathbf{P}_t} = \left\{\int_{\underline{\mathrm{v}}}^{\tilde{v}_t} v \mathrm{dF}\,(v) + \tilde{v}_t^{\frac{\epsilon-1}{\epsilon}} \int_{\tilde{v}_t}^{\bar{\mathrm{v}}} v^{\frac{1}{\epsilon}} \mathrm{dF}\,(v)\right\}^{\frac{1}{\epsilon-1}} . \tag{2.6}$$

The right hand side of this expression is increasing in $\tilde{v}$ and bounded above by 1. To see this, first notice that the marginal productivity of a supply-constrained input, $\partial\mathcal{Y}_t/\partial Y_{j,t}$, remains larger that its marginal cost, $P_{j,t}$, while they are equal for unconstrained inputs. Thus, in the case that some input is supply-constrained, one obtains that

$$\mathcal{Y}_t = \int_0^1 \frac{\partial \mathcal{Y}_t}{\partial Y_{j,t}} Y_{j,t} \mathrm{d}j > \int_0^1 P_{j,t} Y_{j,t} \mathrm{d}j \tag{2.7}$$

where the first equality is achieved by applying the Euler Theorem. The price of the final good is equal to the shadow price index for intermediate inputs, which is computed by using the marginal productivities of inputs in the production of final output, that is,

$$\mathbf{P}_t = \left[\int_0^1 \left(\frac{\partial \mathcal{Y}_t}{\partial Y_{j,t}}\right)^{1-\epsilon} v_{j,t} \mathrm{d}j\right]^{\frac{\epsilon}{\epsilon-1}} \tag{2.8}$$

where the price-index expression is obtained from the maximization problem of the final-good firm. Notice that when no supply constraints are binding, $\tilde{v} \rightarrow \bar{\mathrm{v}}$, the model shrinks to the standard case and $\partial\mathcal{Y}_t/\partial Y_{j,t} = P_{j,t}$. In such a case, the symmetric equilibrium relative price of an intermediate good with respect to the final good, $P_{j,t}/\mathbf{P}_t$, is equal to one. Moreover, under these circumstances, the optimal production level of the final firm $\mathcal{Y}_t$ is indeterminate. However, when some input is supply-constrained, the final good price is larger than the input price.

$$\mathbf{P}_t = \left[\int_0^1 \left(\frac{\partial \mathcal{Y}_t}{\partial Y_{j,t}}\right)^{1-\epsilon} v_{j,t}\mathrm{d}j\right]^{\frac{\epsilon}{\epsilon-1}} > \left[\int_0^1 P_{j,t}^{1-\epsilon} v_{j,t}\mathrm{d}j\right]^{\frac{\epsilon}{\epsilon-1}} = P_t \tag{2.9}$$

As a result, the spillover term $(P_{j,t}/\mathbf{P}_t)^{-\epsilon}$is larger than one. This term is going to play a significant role in the model's behavior, as will be stressed later.

2.2. **Intermediate Good Firms.** In this sector, each intermediate good is produced by a monopolistically competitive firm making use of capital and labor, which are combined for production through a *putty-clay* technology. Intermediate firms start period t with a predetermined level of capacity. Such a production plan cannot be adapted to the needs of the firm within the period. Hence, investment achieved during period $t-1$ becomes productive at date t. Investment consists of the design of a production plan by simultaneously choosing a quantity of capital goods $K_{j,t}$ and employment capacity $N_{j,t}$ according to the following Cobb-Douglas technology:

$$\bar{Y}_{j,t} = A_t K_{j,t}^{\alpha} N_{j,t}^{1-\alpha} \tag{2.10}$$

where $0 < \alpha < 1$. The term A_t is the aggregate productivity parameter, capturing total factor productivity. The variable $N_{j,t}$ represents the maximum number of available work-stations in the firm. Hence, the firm is at full capacity when all these work-stations are operating full-time. As it is common in models featuring a *putty-clay* technology, it is convenient to express investment decision as the choice of both $K_{j,t}$ and a capital-labor ratio $X_{j,t} \equiv K_{j,t}/N_{j,t}$. Consequently, the expression in (2.10) can be rewritten as

$$\bar{Y}_{j,t} = A_t X_{j,t}^{\alpha-1} K_{j,t} \tag{2.11}$$

from where the technical productivity of the installed equipments can be deduced. For the case of capital, it is given by $A_t X_{j,t}^{\alpha-1}$, whereas $A_t X_{j,t}^{\alpha}$ represents that of labor, so that this production function displays constant returns-to-scale in the within-period labor. In particular, if the firm uses a quantity of labor $L_{j,t}^d$ smaller than $N_{j,t}$, it then produces $A_t X_{j,t}^{\alpha} L_{j,t}^d$ units of intermediate good. Once the idiosyncratic (demand) shock $v_{j,t}$ is revealed, the firm instantaneously adjusts its labor demand $L_{j,t}^d$ to cover the needs of its production plan, $Y_{j,t}$, that is,

$$L_{j,t}^d = \frac{Y_{j,t}}{A_t X_{j,t}^{\alpha}} = \frac{1}{A_t X_{j,t}^{\alpha}} \min\left\{\mathcal{Y}_t v_{j,t}\left(\frac{P_{j,t}}{\mathbf{P}_t}\right)^{-\epsilon}, \bar{Y}_{j,t}\right\} . \tag{2.12}$$

In order to finance such productive activities, intermediate good firms must borrow the necessary amount of money from a financial intermediary since cash earnings do not arrive in time to finance the period wage bill. Specifically, firms rent labor at a wage W_t which is paid with cash obtained from the financial intermediary at an interest rate $R_t^L > 0$. At the end of the period, the firm pays back the loan and the interests: $W_t L_{j,t}^d (1 + R_t^L)$.

After observing the aggregate shocks, but before knowing the idiosyncratic one, input producing firms take their price decisions. Input prices are announced on the basis of (rational) expectations, before the exact value of the demand for their production is realized. This price-setting assumption has the advantage of giving a symmetric equilibrium in prices, avoiding in this manner price aggregation difficulties. It is worthwhile to point out that this assumption on the price behavior of input firms should not have important implications on the manner in which the economy responds to aggregate shocks: since prices are announced at the time shocks are known, they are perfectly flexible in this sense.

The price decision is static and the same rule will be followed by all firms given that, *ex-ante,* all of them are identical; that is, $P_t = P_{j,t}$. Consequently, each firm chooses a price in order to maximize current period expected profits,

$$P_t \equiv \arg\max E_v \left[P_t Y_{j,t} - \left(1+R_t^L\right) W_t L_{j,t}^d\right] \tag{2.13}$$

which by (2.12) is

$$P_t \equiv \arg\max E_v \left[\left(P_t - \frac{\left(1+R_t^L\right) W_t}{A_t X_{j,t}^{\alpha}}\right) Y_{j,t}\right] \tag{2.14}$$

where $Y_{j,t}$ is the level of inputs-goods produced by firm j. The particular amount of those input-goods produced will depend on the demand shock faced by each firm. Such a demand is derived from expression (2.2) or more specifically

$$E_v\left(Y_{j,t}\right) = \left(\frac{P_t}{\mathbf{P}_t}\right)^{-\epsilon} \mathcal{Y}_t \int_{\mathrm{\underline{v}}}^{\tilde{v}_t} v \mathrm{dF}\left(v\right) + \bar{Y}_t \int_{\tilde{v}_t}^{\bar{\mathrm{v}}} \mathrm{dF}\left(v\right) \tag{2.15}$$

Taking into account these considerations, the optimal price decision can be characterized by the following result:

Lemma 2 (Intermediate-Goods Pricing)**.** *The price decision of any input firm j at date t adopts the following expression:*

$$P_t = \left(1 - \frac{1}{\epsilon\pi\left(\tilde{v}_t\right)}\right)^{-1} \frac{\left(1+R_t^L\right) W_t}{A_t X_t^{\alpha}} \tag{2.16}$$

where $\pi\left(\tilde{v}_t\right)$ represents the probability of excess capacity in the economy, that is, $\pi\left(\tilde{v}_t\right)$ is a weight measure of the proportion of firms for which demand is smaller than their productive capacity,

$$\pi\left(\tilde{v}_t\right) = \frac{\left(\frac{P_t}{\mathbf{P}_t}\right)^{-\epsilon} \mathcal{Y}_t}{E_v\left(Y_t\right)} \int_{\underline{v}}^{\tilde{v}_t} v\, dF\left(v\right) \tag{2.17}$$

Notice that $\pi\left(\tilde{v}\right)$ depends only on $\tilde{v}$, as becomes clear from the combination of equations (2.15) and (2.3) above,

$$\pi\left(\tilde{v}_t\right) = \frac{\int_{\mathrm{\underline{v}}}^{\tilde{v}_t} v\mathrm{dF}\left(v\right)}{\int_{\mathrm{\underline{v}}}^{\tilde{v}_t} v\mathrm{dF}\left(v\right) + \tilde{v}_t \int_{\tilde{v}_t}^{\bar{\mathrm{v}}} \mathrm{dF}\left(v\right)} \tag{2.18}$$

The pricing mechanism resulting from (2.16) implies that intermediate firms set their price as a mark-up over the marginal cost.[11] The mark-up rate depends negatively on the (absolute) value of the price elasticity of expected sales, which is defined as the elasticity of expected sales to expected demand, $\pi\left(\tilde{v}\right)$, times the price elasticity of expected demand, ϵ. This means that when $\pi\left(\tilde{v}\right)$, the probability of a sales constraint, is large, that is, when more input firms are likelely to produce

[11]The derivation of this condition supposes that each monopolistic firm only considers the direct effect of its price decision on demand and neglects all indirect effects (e.g. the effects through $\mathcal{Y}_t$). This approximation is reasonable in a context where there is a continuum of firms.

under their full capacity level, firm's actual market power is reduced, implying a smaller mark-up rate. Notice that when no supply constraint is binding, $\pi(\tilde{v}) = 1$, the pricing rule implies a constant mark-up over the marginal cost as in the standard case.[12] It is assumed that $\pi(\tilde{v}) > 1/\epsilon$ in order to prevent the input price being zero.

The decision concerning the installment of the productive capacity of each input firm has a dynamic nature. The objective of each firm is to maximize its dividend, $\Pi^f_{j,t}$, which is the amount of cash that remains after investment and fixed costs expenditures are made, $\mathbf{P}_t(I_t + \Psi)$, business loans (including wage payments), $W_t L^d_{j,t}(1 + R^L_t)$, are repaid to financial intermediaries and input goods, $P_t Y_{j,t}$, are delivered for cash. More compactly,

$$\Pi^f_{j,t} = P_t Y_{j,t} - W_t L^d_{j,t}(1 + R^L_t) - \mathbf{P}_t(I_t + \Psi) \tag{2.19}$$

Investment in new capital goods, I_t, is used to augment the future capital stock in the intermediate business sector, according to the following law of motion, where δ is the corresponding rate of depreciation,

$$I_{t+1} = K_{t+1} - (1 - \delta)K_t \tag{2.20}$$

Firms choose a contingency plan $\{K_{t+1}, X_{t+1}\}^{\infty}_{t=o}$ to maximize the expected discounted value of the dividend flow

$$E_{\Omega_{1,0}}\left[\sum_{t=0}^{\infty} \Delta_{t+1}\Pi^f_t\right] \tag{2.21}$$

subject to (2.12), (2.15), (2.16), given the stochastic process for $\left\{R^L_t, W_t, \Delta_t\right\}^{\infty}_{t=0}$ and given K_0 and X_0, with expectations formed rationally under the assumed information structure. For firms to act in the best interests of their shareholders, the stochastic discount factor Δ_{t+1} should correspond to the representative household's relative valuation of cash across time, which requires

$$\Delta_{t+1} = \frac{\beta^{t+1} U_c(C_{t+1}, L_{t+1})}{\mathbf{P}_{t+1}} \tag{2.22}$$

where β is the discount factor and U_c is the marginal utility for the household of consumption, as will be explained later. Thus, the value of the firm for the shareholder derives from the flow of dividends that are paid at the end of each period with cash. The reason the subscript $t+1$ appears is because the shareholder has to wait until next period to use this cash to buy consumption goods. Regarding the optimal production plan of an intermediate-good firm, the next result summarizes these decisions:

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[12] In the standard case, $\pi(\tilde{v}_t) = 1$, the pricing rule reduces to

$$P_t = \left(\frac{\epsilon - 1}{\epsilon}\right)^{-1} \frac{(1 + R_t) W_t}{A_t X^{\alpha}_t}$$

which is similar to that in the paper of Christiano et al. (1997). In the sticky-price version of their model, firms set their price equal to a constant mark-up over a weighted expectation of the marginal cost. In the present model, firms can perfectly foresee R and W so that prices are flexible in this respect. Notice that both models are not directly comparable since the production function is *Cobb-Douglas* in Christiano et al. (1997) but *Putty-Clay* here.

Lemma 3 (Capacity Choice)**.** *The optimal decision of investment in capital K_{t+1} and capital-labor ratio X_{t+1} is given, respectively, by the following Euler equations*
(2.23)
$$E_{\Omega_{1,0}}\left\{\Delta_{t+1}\mathbf{P}_t-\Delta_{t+2}\mathbf{P}_{t+1}\left(1-\delta\right)\right\}=E_{\Omega_{1,0}}\left\{\Delta_{t+2}\left(1-F\left(\tilde{v}_{t+1}\right)\right)\Phi_{t+1}\left(\frac{\bar{Y}_{t+1}}{K_{t+1}}\right)\right\}$$

and
(2.24)
$$E_{\Omega_{1,0}}\left\{\Delta_{t+2}\Phi_{t+1}\left(\frac{\bar{Y}_{t+1}}{X_{t+1}}\right)\left[\left(\frac{\alpha\left(\epsilon-1\right)}{\tilde{v}_{t+1}}\right)\int_{\underline{v}}^{\tilde{v}_{t+1}}vdF(v)-\int_{\tilde{v}_{t+1}}^{\bar{v}}dF(v)\right]\right\}=0$$

where

$$\Phi_{t+1}\equiv P_{t+1}-\frac{\left(1+R_{t+1}^{L}\right)W_{t+1}}{A_{t+1}X_{j,t+1}^{\alpha}} \tag{2.25}$$

The first equation states that the optimal capital stock is such that the expected user cost of capital is equal to its expected revenue, which is given by the discounted increase in profits generated by an additional unit of capital corrected by the probability of operating such unit. From the second equation one can observe the trade-off faced by the intermediate firm when choosing the optimal capital-labor ratio. When increasing the capital-labor ratio, the firm increases its labor productivity, which is given by $A_tX_t^{\alpha}$, something that has a favorable effect on its competitive position in case of excess capacities. However, increasing X_t means that the maximum level of employment available in period t will be lower, and likewise the maximum volume of sales of the firm. The optimal capital-labor ratio will be such that the two opposite effects on expected profits are equal in the margin.

2.3. **Money Supply and Financial Intermediation.** In this model, banks' main task is the provision of liquidity to their customers, the input producing firms. Banks begin each period with assets and liabilities that consist solely of the funds deposited with them by the households, D_t. Competition among banks for these deposits determines the market-clearing gross interest rate, $\left(1+R_t^D\right)$, which is payable at the end of the period. Banks finance their lending activities with household deposits, as well as with funds obtained from cash injections, $\mathcal{X}_t$, made by the monetary authority every period. The asset side of banks' balance sheet is composed by loans, B_t^S, that are supplied to intermediate firms. The bank charges a gross lending rate equal to $\left(1+R_t^L\right)$. Financial intermediation is assumed to be a costless activity. With no barriers to entry, competitive forces will ensure that the equilibrium interest rate on loans equals the rate paid on deposits, that is, $R_t^L=R_t^D$. Moreover, in equilibrium, the financial intermediaries will supply inelastically the total amount of loanable funds at their disposal:

$$B_t^S=D_t+\mathcal{X}_t \tag{2.26}$$

At the end of the period, banks remit $\Pi_t^b=\left(1+R_t\right)x_tM_t$ as dividends to households, where x_t is the growth rate of money,

$$x_t\equiv\frac{M_{t+1}-M_t}{M_t}=\frac{\mathcal{X}_t}{M_t} \tag{2.27}$$

which is assumed to follow an AR(1) stochastic process[13]

$$x_t = (1 - \rho_x) x + \rho_x x_{t-1} + \varepsilon_{x_t} \tag{2.28}$$

with $0 < \rho_x < 1$ and $\varepsilon_{x_t}$is an i.i.d. shock to x_t with zero mean and standard deviation σ_x. The random variable ε_{x_t} is assumed to be orthogonal to all other variables in the model.

2.4. **Households.** The economy is populated by a continuum of homogeneous households of unit measure. These agents value alternative stochastic streams of a (composite) consumption good C_t and labor L_t^s, according to the following lifetime expected utility function

$$E_0 \sum_{t=0}^{\infty} \beta^t U\left(C_t, 1 - L_t^s\right) \tag{2.29}$$

where $\beta > 0$ represents households' intertemporal discount factor. Here, E_t denotes the expectation operator conditional on the information at date t. Throughout the paper, it is assumed that the function $U(\cdot)$ is given by

$$U\left(C_t, L_t^s\right) = \begin{cases} \frac{\left[C_t^{\gamma}(1-L_t^s)^{1-\gamma}\right]^{1-\sigma}-1}{1-\sigma} & \text{for } \sigma \neq 1 \\ \gamma \log\left(C_t\right) + (1-\gamma)\log\left(1 - L_t^s\right) & \text{for } \sigma = 1 \end{cases} \tag{2.30a}$$

Here $1 - L_t$ denotes the quantity of leisure time, and the total time for work -the time endowment- is set at 1. The curvature parameter σ measures the relative risk aversion. The parameter γ is a scalar between 0 and 1 and it represents the consumption expenditure share in the utility function.

The representative household begins period t holding an amount M_t of liquid assets that represent the economy's stock of money. At this point in time, it decides how much money is going to be deposited in a saving account, D_t. The remaining currency $M_t - D_t$, together with labor income, will be used to finance purchases of a consumption good. Therefore, the household faces the following cash constraint in the final goods market:

$$\mathbf{P}_t C_t \leq M_t - D_t + W_t L_t^s \tag{2.31}$$

where L_t^s represents the fraction of time actually devoted to work and W_t is the wage paid in the competitive labor market for each unit of time supplied. Importantly, portfolio decisions take place before the realization of the monetary shock. As a result, the equilibrium rate of interest falls, and output and employment rises. Income for the household is derived from several sources: labor income, $W_t L_t^s$, which are the only source of income available to finance current period transactions; profits from financial intermediaries Π^b and from input firms Π^f, and rents from bank deposits. Thus, the stock of money, M_{t+1}, in the hands of the household at the end of period t is given by

$$M_{t+1} \leq M_t - D_t + W_t L_t^s - \mathbf{P}_t C_t + \left(1 + R_t^d\right) D_t + \Pi^f + \Pi^b \tag{2.32}$$

[13]Christiano, Eichenbaum and Evans (1998) show that this is a good approximation when money is measured by broad monetary aggregates such as M2, but when the concept of money refers to M1 or even the monetary base, the monetary policy shock is better represented by a second order MA process.

In summary, the household's problem is to maximize (2.29) subject to (2.31)-(2.32) by choice of contingency plans for $\{C_t, D_t, L_t^s\}_{t=0}^{\infty}$ given the stochastic process for

$$\left\{P_t, \mathbf{P}_t, W_t, R_t^L, R_t^d, \Pi_t^f, \Pi_t^b\right\}_{t=0}^{\infty}$$

with expectations formed rationally under the assumed information structure. Moreover, the household must respect the constraint $0 \leq M_t - D_t \leq M_{t-1}$.The first order conditions to the previous problem are represented by a set of Euler equations together with some appropriate boundary conditions. Is is assumed that the conditions for an interior solution are satisfied, and thus the cash in advance constraint (2.31) and the money stock equation (2.32) are binding. Next, I proceed to summarize these conditions.

Lemma 4. *The optimal behavior of the household is characterized as follows: the optimal consumption and labor decisions are given by*

$$-\frac{U_{L_t}}{U_{C_t}} = \frac{W_t}{\mathbf{P}_t} \tag{2.33}$$

and the optimal portfolio choice

$$E_{\Omega_{0,t}}\left\{\frac{U_{C_t}}{\mathbf{P}_t} - \frac{\beta\left(1+R_t^d\right)U_{c,t+1}}{\mathbf{P}_{t+1}}\right\} = 0, \tag{2.34}$$

where U_c and U_L denote the partial derivatives of U with respect to C and L respectively; from the Cash-in-Advance constraint, consumption is derived

$$C_t = \frac{M_t - D_t + W_t L_t^s}{\mathbf{P}_t}. \tag{2.35}$$

The formulation and results in this section are rather standard within the literature of limited participation models. Equation (2.33) governs the household's consumption and labor hour decision. Equation (2.34) is associated with the household's portfolio decision. Note that the decision on deposits is made conditional on $\Omega_{0,t}$ which excludes the time period t shocks from the time t information set. Since households cannot immediately adjust their nominal savings, a monetary shock disproportionately affects banks reserves and, hence, the supply of loanable funds. This creates the liquidity effect. Formally, we can proceed as in Fuerst (1992) and write condition (2.34) as follows

$$\Lambda_t \equiv \left(1+R_t^d\right) E_{\Omega_{1,t}}\left\{\beta\frac{U_{c,t+1}}{\mathbf{P}_{t+1}}\right\} - \frac{U_{C_t}}{\mathbf{P}_t}$$

and

$$E_{\Omega_{0,t}}\left\{\Lambda_t\right\} = 0 \tag{2.36}$$

Fuerst (1992) refers to Λ_t as the *liquidity effect.* One can think of it is as the difference, at date t, between the value of money in the goods market and its value in the loan market. When $\Lambda_t < 0$, money is more valuable in the goods market since households will be willing to borrow at a higher rate than if they had the opportunity to do so. In this case, the loan market is relatively liquid. The variable Λ_t would be zero if the households could choose the portfolios contemporaneously, as in the standard Cash-in-Advance model.[14] However, here it is zero only in

[14]This condition is $(1+R_t) = \beta E_t\left\{\frac{\mathbf{P}_{t+1}}{\mathbf{P}_t}\frac{U_{C_t}}{U_{c,t+1}}\right\}$ from where the Fisher Effect can be deduced.

expected value. Notice that it is possible to write the gross nominal interest rate as

$$(1 + R_t^d) = \frac{\frac{U_{C_t}}{\mathbf{P}_t} + \Lambda_t}{E_{\Omega_{1,t}}\left\{\beta \frac{U_{c,t+1}}{\mathbf{P}_{t+1}}\right\}} \tag{2.37}$$

so that a positive money shock (injected through the loan market) reduces the value of money in the loan market. As a result, Λ_t is negative and would reduce the nominal interest rate. This effect is compensated by the anticipated inflation effect. Fisherian fundamentals hold only on average, not period by period.

3. Qualitative Properties

In this section I explore some of the insights and qualitative implications, with the corresponding intuition, that can be derived from the model economy presented above. To that end, I first describe the equilibrium that characterizes the economy. Next, I proceed with the analysis of the long run properties of the model, which are derived from stationary equilibrium. This latter concept of equilibrium will be the basis for the dynamic analysis that will be performed in the next section. I also study the influences of the parameters on the stationary equilibrium. This section ends with the implications of capacity utilization for the shape of the short-run dynamics.

3.1. **The Competitive Equilibrium.** A competitive equilibrium for this model can be defined in the usual way. Given the initial productive equipments K_0 and X_0, the initial monetary growth rate x_0 with its corresponding stochastic process (2.28), a competitive equilibrium for the model economy described above can be stated as follows,

Definition 1 (Competitive Equilibrium)**.** *The general equilibrium of the economy during any period $t \geq 0$ is determined by a stochastic process for prices $\{\mathbf{P}_t, P_t, R_t^L, R_t^d, W_t, \Delta_t\}_{t=0}^{\infty}$ a quantity vector $\{K_t, X_t, C_t, D_t, L_t, \mathcal{Y}_t\}_{t=0}^{\infty}$ and a proportion of firms $\{F(\tilde{v}_t)\}_{t=0}^{\infty}$ that result from the optimal choices (consistent with the available information) of the central bank, the households and the firms. In a competitive equilibrium these choices are required to be made under rational expectations and consistent with the following market-clearing conditions:*

$$\mathcal{Y}_t = C_t + K_{t+1} - (1-\delta)K_t + \Phi$$
$$L_t^s = L_t^d$$
$$W_t L_t^d = D_t + \mathcal{X}_t$$
$$M_t^d = M_t^s$$

which represent the goods, labor, loans and money markets, respectively.

In the previous definition, the aggregate allocation and pricing functions depend on the relevant state. In particular, deposits, D_t, are a function of the information set $\Omega_{0,t}$ whereas all other price and allocation rules are elements of $\Omega_{1,t}$, where $\Omega_{0,t}$ and $\Omega_{1,t}$are defined as above. Recall that financial intermediation is a costless activity and, hence, $R_t^L = R_t^d$. Moreover, at equilibrium, $F(\tilde{v}_t)$ represents the proportion of firms that underuse their productive capacities (i.e., those for which $v_{j,t} \in [\underline{v}, \tilde{v}_t])$. The variable $\pi(\tilde{v}_t)$ weights this proportion of firms by the relative importance of their production in total output. An important feature of this equilibrium is its symmetry: all input firms j choose the same capacity level and take the same pricing decisions. With all prices identical, aggregate employment, denoted by L_t, is equal to individual expected employment levels (up to a scaling factor):

$$L_t = \frac{\left(\frac{P_t}{\mathbf{P}_t}\right)^{-\epsilon} \mathcal{Y}_t}{A_t X_t^{\alpha}} \int_{\underline{\mathrm{v}}}^{\tilde{v}_t} v_t dF(v_t) + \frac{K_t}{X_t} \int_{\tilde{v}_t}^{\bar{\mathrm{v}}} dF(v_t) \tag{3.1}$$

where K_t and X_t stand for aggregate capital and capital/labor respectively at time $t-1$ and available at time t, and

$$\tilde{v}_t = \frac{\bar{Y}_t}{\mathcal{Y}_t \left(\frac{P_t}{\mathbf{P}_t}\right)^{-\epsilon}} \tag{3.2}$$

represents the ratio of productive capacity to expected demand for intermediate inputs. Notice that, as $v_{j,t} > 0$, the aggregate productive capacity is underutilized at equilibrium. The individual capacity utilization rates are given by:

$$\mathcal{C}_{j,t} = \begin{cases} \left(\frac{P_t}{\mathbf{P}_t}\right)^{-\epsilon} \mathcal{Y}_t v_{j,t} / \bar{Y}_t & \text{if} \quad v_{j,t} \leq \tilde{v}_t \\ 1 & \text{if} \quad v_{j,t} > \tilde{v}_t \end{cases} \tag{3.3}$$

which introduced into (2.1) yields the aggregate capacity utilization rate,

$$\mathcal{C}_t \equiv \frac{\mathcal{Y}_t}{\bar{Y}_t} \tag{3.4}$$

For a given distribution $F(v_t)$ and thus given σ_v^2, there is a decreasing relationship between the capacity utilization rate, $\mathcal{C}_t$, and the weighted proportion of firms with idle resources, $\pi(\tilde{v}_t)$, which subsequently determines the mark-up rate. The aggregate capacity utilization rate is directly linked to the proportion of firms that produce at full capacity, $(1 - \pi(\tilde{v}_t))$. At given price elasticity of demand, ϵ, this implies a positive relationship between the capacity utilization and mark-up rates

$$\text{Mark-Up} \equiv \left(1 - \frac{1}{\epsilon \pi(\tilde{v}_t)}\right)^{-1} .$$

3.2. **Implications for Short Run Dynamics.** Next, it is presented a diagrammatic representation of the labor market equilibrium at given capacity level that will prove useful for understanding the short-run implications of the model. Specifically, the diagrammatic apparatus will provide good intuition on the interactions between capacity utilization and markup variations in the short run. As a result, it will be very useful to understand why the short run effects of a same shock are expected to depend crucially on the value of the capacity utilization rate at the time the particular shock takes place.

In Chart 1, the upward sloping curve represents the aggregate labor supply schedule, as given in equation (2.33). The other curve, concave and sloping downwards, represents the macroeconomic labor demand curve given in equation (3.1). In the very short run, at given capacity, the labor demand curve intersects both axes. The intersection with the horizontal axis is due to the fact that even at zero real wage rates, the short-run demand for labor is bounded above by the maximum number of work stations corresponding to the full employment of installed capacities.

Notice that when $\tilde{v} \rightarrow \underline{v}$, equation (3.1) reduces to the following expression:

$$L_t^d = \frac{K_t}{X_t} \tag{3.5}$$

In the opposite case, when all firms have idle resources, and thus underutilize their productive capacities, the proportion of firms $\pi(\tilde{v}_t) = 1$ and the real wage rate given in (2.16) becomes,

$$\frac{W_t}{P_t} = \left(1 - \frac{1}{\epsilon}\right) \frac{A_t X_t^{\alpha}}{\left(1 + R_t^L\right)} \tag{3.6}$$

Along the short-run labor demand curve there is a negative relationship between the demand elasticity of sales, $\pi(\tilde{v}_t)$, and employment, L_t. Also, a downwards shift along the short-run labor demand curve increases the mark-up, since the proportion of firms at full capacity is larger and so is the spill-over effect from constrained to unconstrained firms. The implications of a monetary policy shock on the response of the labor market are shown in Chart 2. An unanticipated expansionary monetary policy shock leads to a reduction in the short-term nominal interest rate through the *liquidity effect*. This implies that the maximum feasible real wage rate increases. The short-run labor demand curve intersects now the vertical axis at a higher value. As a result, the equilibrium in the labor market implies a rise in employment. The number of firms producing at full capacity also increases. This fact produces a positive spillover into the remaining firms that have idle resources. The market power of these firms naturally rises and hence does the mark-up in the economy.

The capacity utilization rate also moves in the same direction. It is important to notice that the effects of the monetary disturbance are going to depend crucially on the state of the economy at the time of the shock, with the state determined by the capacity utilization rate. Hence, further reductions in the nominal interest rate achieved through expansionary policies will have less impact on employment and, as will be shown later, a higher effect on prices.

An important shortcoming of the previous intuition about the short-run effects of a monetary shock is that it is based on an exogenous movement in the interest rate. However, the equilibrium rate of interest is determined jointly with other variables in the model such as employment and output. The results below aim at providing a general equilibrium insight into this issue.

Proposition 1. *The impact effect of an unanticipated monetary policy shock on employment is positive,*

$$L_{x,t} \equiv \frac{d \log L_t}{d \log x_t} \equiv \frac{dL_t}{dx_t} \frac{x_t}{L_t} > 0$$

as is the instantaneous correlation with output

$$\mathcal{Y}_{x,t} \equiv \frac{d \log \mathcal{Y}_t}{d \log x_t} \equiv \frac{d\mathcal{Y}_t}{dx_t} \frac{x_t}{\mathcal{Y}_t} > 0$$

Proof. Taking the ratio of the loan market-clearing condition, $W_t L_t = D_t + \mathcal{X}_t$ to the cash equation, Eq. (2.31), one obtains

$$\Gamma_t = \frac{W_t}{P_t} \frac{L_t}{C_t} = \frac{D_t + \mathcal{X}_t}{M_t + \mathcal{X}_t} \tag{3.7}$$

Notice that since $D_t < M_t$ and both variables are predetermined relative to $\mathcal{X}_t$, the response of Γ_t to an innovation in the rate of growth of money $x_t \equiv \mathcal{X}_t / M_t$ is positive, that is,

$$\Gamma_{x,t} \equiv \frac{d\Gamma_t}{dx_t} = \frac{M_t - D_t}{\left[M_t\left(1+x_t\right)\right]^2} > 0 \tag{3.8}$$

which establishes, for example, that a monetary contraction creates a relative shortage of liquidity in the financial market.

Now, introducing (2.33) into (3.7) one gets

$$\Gamma_t = -\frac{U_{L_t}}{U_{C_t}}\frac{L_t}{C_t} \tag{3.9}$$

from (2.30a)

$$-\frac{U_{L_t}}{U_{C_t}} = \left(\frac{\gamma}{1-\gamma}\right)\frac{C_t}{\left(1-L_t\right)} \tag{3.10}$$

so that

$$\Gamma_t = \left(\frac{\gamma}{1-\gamma}\right)\frac{L_t}{\left(1-L_t\right)} \tag{3.11}$$

Differentiating implicitly the previous equation yields

$$L_{x,t} \equiv \frac{d\log L_t}{d\log x_t} = \left(\frac{1-\gamma}{\gamma}\right)\frac{x_t\Gamma_{x,t}}{L_t/\left(1-L_t\right)^2} > 0 \tag{3.12}$$

From (2.4) and (2.12), final output is a function that depends positively on employment

$$\mathcal{Y}_t = \left[\int_{\underline{v}}^{\bar{v}} \left(A_t X^{\alpha} L_t\right)^{\frac{\epsilon-1}{\epsilon}} v_t^{\frac{1}{\epsilon}} \mathrm{dF}\left(v\right)\right]^{\frac{\epsilon}{\epsilon-1}} \tag{3.13}$$

Hence, a positive (negative) monetary shock increases (reduces) output in the short run, that is,

$$sign\left(\frac{d\log \mathcal{Y}_t}{d\log x_t}\right) = sign\left(\frac{d\log L_t}{d\log x_t}\right) > 0 \tag{3.14}$$

□

The previous result and the fact that, in the short-run, the level of installed equipment is fixed imply a change in the capacity utilization rate in the economy, at the same time increasing the market power of those firms with idle resources. More formally, this can be expressed as follows:

Corollary 1. *In the short-run, an increase (decrease) in the equilibrium level of employment, due to an unanticipated change in the rate of growth of the money supply, rises (reduces) the mark-up, as well as the capacity utilization rate, whereas it decreases (increases) the price relation between intermediate and final goods.*

Proof. The capacity utilization rate was defined in equation (3.4) as

$$\mathcal{C}_t \equiv \frac{\mathcal{Y}_t}{\bar{Y}_t}$$

Given that in the short-run $\bar{Y}_t$, the capacity level in the economy, is fixed and since from the previous proposition final output increases, it follows immediately that the capacity utilization rate increases.

From (2.3), the capacity utilization rate can be alternatively expressed as

$$\mathcal{C}_t = \frac{(P_t/\mathbf{P}_t)^{\epsilon}}{\tilde{v}_t} \tag{3.15}$$

Substituting the price relation for its value given in (2.6), it follows that the capacity utilization rate depends only on $\tilde{v}_t$, the cut-off value of the idiosyncratic shock

$$\mathcal{C}_t \equiv \mathcal{C}(\tilde{v}_t) = \frac{1}{\tilde{v}_t}\left\{\int_{\underline{v}}^{\tilde{v}_t} v\mathrm{dF}(v) + \tilde{v}_t^{\frac{\epsilon-1}{\epsilon}}\int_{\tilde{v}_t}^{\bar{v}} v^{\frac{1}{\epsilon}}\mathrm{dF}(v)\right\}^{\frac{\epsilon}{\epsilon-1}} \tag{3.16}$$

Since, in the short-run, the capacity utilization rate increases after a positive monetary policy shock, the cut-off value $\tilde{v}_t$ must decrease (recall that the price relation $(P_t/\mathbf{P}_t)$, is a decreasing function of $\tilde{v}_t$).

Notice that the weighted proportion of firms with idle resources, $\pi(\tilde{v}_t)$, depends positively on $\tilde{v}_t$, as becomes clear after rewriting (2.18) as

$$\pi(\tilde{v}_t) = \left[1 + \frac{\int_{\tilde{v}_t}^{\bar{v}} \mathrm{dF}(v)}{\int_{\underline{v}}^{\tilde{v}_t} v\mathrm{dF}(v)}\right]^{-1} \tag{3.17}$$

Thus, the unanticipated monetary policy shock increases the mark-up since this variable, defined as,

$$\text{Mark-Up} \equiv \left(1 - \frac{1}{\epsilon\pi(\tilde{v}_t)}\right)^{-1} \tag{3.18}$$

depends negatively on the proportion $\pi(\tilde{v}_t)$. □

It is worthwhile stressing the highly non-linear relationship that exists between the mark-up and the capacity utilization rate. This means that in a high capacity economy, the effect on the mark-up of an extra increase in the capacity utilization rate due, for instance, to a monetary policy shock will be higher than the effect of the same policy in a low capacity economy. Next, I analyze the response of the nominal interest rate and the real wage rate to an unanticipated monetary policy shock.

Proposition 2. *For a fixed level of investment and the utility function in (2.30a), the impact effect of an unanticipated monetary policy shock on the nominal interest rate is negative, while the real wage rate responds positively to the same shock. That is,*

$$R_{x,t} \equiv \frac{d\log(1+R_t)}{d\log x_t} < 0$$

and

$$(W/\mathbf{P})_{x,t} \equiv \frac{d\log(W_t/\mathbf{P}_t)}{d\log x_t} > 0$$

Proof. From (2.33) and (3.10), the equilibrium real ware rates is given by

$$\frac{W_t}{\mathbf{P}_t} = \frac{\gamma}{1-\gamma}\frac{C_t}{(1-L_t)} \tag{3.19}$$

Taking into account the final-goods market clearing condition, this can be expressed as

$$\frac{W_t}{\mathbf{P}_t} = \frac{\gamma}{1-\gamma}\frac{\mathcal{Y}_t - K_{t+1} + (1-\delta)K_t + \Phi}{(1-L_t)} \tag{3.20}$$

from where

$$\frac{d\log\left(W_t/\mathbf{P}_t\right)}{d\log x_t}=\frac{\gamma}{1-\gamma}\left(\frac{d\log\left(\mathcal{Y}_t\right)}{d\log x_t}-\frac{d\log\left(1-L_t\right)}{d\log x_t}\right)>0 \tag{3.21}$$

which is positive since in the previous proposition it was proven that employment and output are positively related to an unanticipated monetary policy shock.

Now, from (2.16) one can solve the gross nominal interest rate as a function of the mark-up, the ratio of intermediate to final-good prices and the wage rate as follows,

$$(1+R_t)=\left(1-\frac{1}{\epsilon\pi\left(\tilde{v}_t\right)}\right)\left(\frac{P_t}{\mathbf{P}_t}\right)\frac{A_tX_t^{\alpha}}{W_t/\mathbf{P}_t} \tag{3.22}$$

Consequently, the effect on the nominal interest rate due to the unanticipated monetary shock acts through three channels, namely the mark-up, the price relation and the real wage rate:

$$\frac{d\log\left(1+R_t\right)}{d\log x_t}=\frac{d\log\left(1-1/\epsilon\pi\left(\tilde{v}_t\right)\right)}{d\log x_t}+\frac{d\log\left(P_t/\mathbf{P}_t\right)}{d\log x_t}-A_tX_t^{\alpha}\frac{d\log\left(W_t/\mathbf{P}_t\right)}{d\log x_t} \tag{3.23}$$

The monetary shock rises employment and final output implying a reduction in the real wage rate. As discussed above, higher employment levels imply a higher capacity utilization rate and other related variables such as the mark-up and the proportion of firms producing at full capacity, $1-\pi\left(\tilde{v}_t\right)$, so that,

$$sign\left(\frac{d\log\left(1-1/\epsilon\pi\left(\tilde{v}_t\right)\right)}{d\log x_t}\right)<0$$

Moreover, the price ratio decreases in response to an unanticipated monetary shock. This is so because from (2.6) this ratio depends only on the cut-off value $\tilde{v}_t$, which is negatively related with the equilibrium level of employment

$$sign\left(\frac{d\log\left(P_t/\mathbf{P}_t\right)}{d\log x_t}\right)<0$$

From the discussion above, it follows that the derivative in (3.23) is negative. □

Altogether, this version of the model displays the *liquidity effect* of a money supply shock, as well as the other features that characterize monetary economies. As noted above, the presence of capacity constraints as well as the monopolistic competitive environment provide a rich source of dynamics. This point will be discussed in more detail below.

Proposition 3. *The magnitude of the response of employment (output) and the real wage rate to an unanticipated change in the growth rate of money is negatively related with the capacity utilization rate at the time of the shock, whereas the opposite is true for the nominal rate of interest.*

Proof. The strategy of the proof is the following: first it is shown that the magnitude of the response of employment to the monetary shock depends negatively on the level of employment at the time of the shock; next it is proven that in a high (low) capacity economy employment will be higher (lower).

Recall that the ratio of funds passing through the loan market to funds passing through the goods market, defined in (3.7), can be expressed as a function of the of labor to leisure ratio,

$$\Gamma_t = \left(\frac{\gamma}{1-\gamma}\right)\frac{L_t}{(1-L_t)}$$

Thus, the larger is the employment level, the larger is the corresponding ratio of funds Γ_t. This implies that for a given rate of growth of money, $x_t \equiv M_t/\mathcal{X}_t$ the ratio D_t/M_t is also high since,

$$\Gamma_t = \frac{D_t + \mathcal{X}_t}{M_t + \mathcal{X}_t} = \frac{(D_t/M_t) + x}{1+x}$$

But a high value of Γ_t implies a low value of $(M_t - D_t)$ so that the change in the pool of funds passing through the financial intermediary that are lent to firms

$$\frac{d\Gamma_t}{dx_t} = \frac{M_t - D_t}{\left[M_t\left(1+x_t\right)\right]^2} \tag{3.24}$$

will be low.

Next, it remains to be shown that in a high capacity utilization rate economy, employment is higher that in a low capacity utilization rate. To do this, notice that the capacity utilization rate, $\mathcal{C}_t$, was defined in equation (3.4) as the ratio of current output, $\mathcal{Y}_t$, to maximum output, $\bar{Y}_t$, that is,

$$\mathcal{C}_t \equiv \frac{\mathcal{Y}_t}{\bar{Y}_t}$$

Since in the short-run the maximum level of output is fixed, a high level of capacity is obtained with a more intensive use of existing resources. This implies that current output will be higher. But this can be achieved only with a higher level of employment, since current output is given by

$$\mathcal{Y}_t = \left[\int_{\underline{v}}^{\bar{v}} \left(A_t X^{\alpha} L_t\right)^{\frac{\epsilon-1}{\epsilon}} v_t^{\frac{1}{\epsilon}} \,\mathrm{dF}\left(v\right)\right]^{\frac{\epsilon}{\epsilon-1}} \tag{3.25}$$

Altogether, in the short run, a high level of capacity utilization rate implies a high level of employment, and thus the effect of the monetary shock on employment will be lower. The impact on the other macro variables follows from applying the results in the previous proposition. □

Next, it is shown how final prices and output respond asymmetrically to the unanticipated monetary policy shock. The result is illustrated in Chart 3 and the argument is as follows: assume first that the economy is in the equilibrium point (*Y,P*) and an unanticipated monetary policy shock takes place. The monetary shock shifts the short-run supply curve to the right from *SS* to *S'S'*, since it reduces production costs by driving down the equilibrium rate of interest. Notice that the supply curve is vertical at the maximum output level, Y^*. The money injection increases, at the same time, aggregate demand of the final good through the household's cash-in-advance constraint, from *DD* to *D'D'*. The new equilibrium is reached at (*Y',P'*). If a new monetary injection occurs, the supply moves to *S"S"* and demand to *D"D"*. The intersection of both curves determines the equilibrium value of output and price level at (*Y",P"*). The increase in prices will be higher than the corresponding increase in production when comparing the two equilibrium allocations and prices. This intuition is proved more formally in the following result,

Proposition 4. *The short-run response of the price level to an unanticipated monetary policy shock depends positively on the capacity utilization rate at the time of the shock.*

Proof. Combining the cash-in-advance constraint in equation (2.31), evaluated at equality, and the loan market-clearing condition, $W_t L_t = D_t + \mathcal{X}_t$, one obtains

$$P_t C_t = M_t + \mathcal{X}_t$$

Making use of the goods market-clearing condition, consumption can be substituted out, which yields

$$P_t \left(\mathcal{Y}_t - K_{t+1} + (1-\delta) K_t - \Phi \right) = M_t + \mathcal{X}_t$$

assuming that capital is kept constant, since the focus is on the intra-temporal response of the variables and noting that $x_t \equiv \mathcal{X}_t / M_t$, the previous equation becomes

$$P_t \mathcal{Y}_t = 1 + x_t \tag{3.26}$$

Taking logarithms in the previous equation and differentiating it with respect to the gross rate of monetary growth, it follows that

$$\frac{d \log \left(\mathbf{P}_t \right)}{d \log \left(1 + x_t \right)} + \frac{d \log \left(\mathcal{Y}_t \right)}{d \log \left(1 + x_t \right)} = 1 \tag{3.27}$$

Now, from the previous results the response of output was shown to be positive and negatively related to the capacity utilization rate of the economy. Hence, the response of prices is larger the smaller is the effect on output. □

Up until now, the short-run or impact effects of a monetary shock have been explored. However, in order to explore the dynamics of the model, it is necessary to determine the equilibrium laws of motion of the theoretical economy by means of a numerical approximation algorithm. This is precisely the objective of the next section, where the quantitative properties of the model are evaluated and simulation exercises are performed as well.

4. Quantitative Analysis

In this section, I describe the quantitative properties of the model economy. The objective is to illustrate the interactions between capacity utilization and mark-up rate changes by analyzing numerically the dynamic behavior of some key macroeconomic variables in response to a monetary shock. One of the results I pursue is to show how the same shock can have significantly different short run effects depending on the characteristics of the economy at the time the shock occurs. The variable of reference is the level of the capacity utilization rate. In order to compute the impulse response functions, the model has to be solved numerically. The solution method adopted is based on a linear approximation of the equilibrium policy rules about the non-stochastic steady state.

4.1. **Parameter Values.** The model is calibrated to match the long-run properties of the post-war US time-series with the non-stochastic steady state values of the model. The parameterization follows, in some extent, Christiano, Eichenbaum and Evans (1998) and Fagnart, Licandro and Portier (1999). The time period is one quarter. The parameter for preferences and technology are assigned values that are standard in the business cycle literature. Table 1 summarizes the values of the calibrated parameters which are described in the sequel. The discount factor is set at $(\beta) = (1.03)^{-.25}$; the utility parameter is chosen so that one third of the time endowment in the steady state corresponds to labor, hence, the consumption expenditure share in the utility function $(\gamma) = 0.35$; the relative risk aversion $(\sigma) = 2$. Model calibration requires that capital's share on aggregate income $(\alpha) = 0.3485$; the annual depreciation rate of 10% implying a value $(\delta) = 0.018$; the elasticity of intermediate goods is chosen to obtain a markup ratio of 1.7 and thus, $(\epsilon) = 8.7364$; the fixed cost that assures zero monopolistic profits is $\Phi = 0.1057$. I deal, in what follows, with the calibration of the aggregate uncertainty components. As stated above, I will follow the common practice in the related research by assuming an AR(1) process for the mean growth rate of money. In particular, the mean growth rate of money $(x) = 0.016$, a value that corresponds to the mean quarterly growth rate of the monetary base in the U.S. as obtained in Cook (1999) for the period 1970:1-1995:1. The persistence of the monetary shock $(\rho_x) = 0.32$ with the standard deviation of $(\sigma_x) = 0.0038$.

The structural parameters that determine the aggregate capacity utilization rate are two: the variance of the idiosyncratic shock and the degree of substitutability among intermediate goods. These parameters are chosen in order to reproduce two different situations, each featuring a different long-run capacity utilization rate. In this manner, it will be possible to study how different the dynamic properties of the model under these two different scenarios are. Specifically, the high capacity economy is characterized by a low variability of the idiosyncratic shock, $\sigma_v^2 = 0.25$, and a high value of input substitutability, $\epsilon = 15$. The opposite is true for the low capacity economy, that is $\sigma_v^2 = 1.75$ and $\epsilon = 4.85$. The steady state properties of the fully parameterized model under different scenarios are summarized in Table 2.

4.2. **Dynamic Properties.** Recall that the main objective of this paper is to provide a formal theoretical background to the recently documented asymmetric responses of key macroeconomic variables to unanticipated monetary policy shocks. In this sense, it is studied whether the level of utilization of the productive capacity of the economy alters the dynamic properties of the model. To achieve this target, the equilibrium laws of motion of prices and quantities are approximated using the undetermined coefficients method described in Christiano (1998). Specifically, the model is linearized about the non-stochastic steady state and the impulse responses computed next. The impulse response functions represent the response, over time, of the elements of the endogenous variables to a pulse in one of the elements of the vector of stochastic innovations. An important characteristic for a good model to have is its ability to reproduce real world's response to simple monetary policy experiments. This section reports the dynamic responses of selected variables in the model to a one percent increase in the gross rate of monetary growth in period 3, from the process

$$x_t = (1 - \rho_x)\, x + \rho_x x_{t-1} + \varepsilon_{x_t} \text{ with } \sigma_x = 0.0032 \tag{4.1}$$

Despite the one-time nature of the shock, the growth rate of money will stay above trend for several quarters given that the autocorrelation coefficient is $\rho_x = 0.32$. The impulse responses of the two parameterized models described in the previous section are compared. In this manner, it is possible to analyze the quantitative importance of the capacity utilization constraints as a source of asymmetry in the dynamics of the economy.

A number of results are worth noting here. First, both versions of the model are able to reproduce the stylized facts of monetary policy. According to many studies in the identified VAR literature, an expansive money supply shock leads to an increase of employment, aggregate output and real wages and to a decrease of nominal interest rates. A liquidity effect is found in the model in that the monetary shock leads to a decrease in nominal interest rates and an increase in capital and labor. The capital/labor ratio also increases after the shock, thus, the maximum level of employment available in the period after the shock decreases, and likewise the maximum volume of sales of input firms. This negative effect is compensated by an increase in firms' labor productivity, something that has a favorable effect on their competitive position in case of excess capacities. The liquidity effect also causes output to rise immediately. Employment and investment respond to the policy shock much like output. Another important feature of the result is that real wages rise after a positive money shock. The real wage rate exerts upward pressure on the marginal cost of hiring labor, which had declined in the impact period because of the lower interest rates. Lower production costs push input prices downwards leading to an increase in input demands and inducing to a more extensive use of productive capacities in all the firms with idle productive resources. Reflecting the dynamics of output, prices initially rise and later decrease to slowly return to its non-stochastic steady state value.[15] The mark-up and the capacity utilization rates increase, whereas the weighted proportion of firms underusing their resources falls. The dynamics of these variables, in particular the increase in mark-ups induced by the higher capacity utilization, will partially offset the reduction in input prices. Consequently, the magnitude of the response of variables such as prices, output an employment, will depend crucially on the magnitude of the response of the mark-up. Recall that the response of this variable is closely related to the proportion of firms producing at full capacity. When capacity is high, the spill-over effect described above is high and thus is the market power and mark-up. Consequently, in situations of high capacity, and implied high mark-up's, the *liquidity effect* is to some extent compensated by a *capacity effect*. This is the source of asymmetry that is found in the responses of the main macroeconomic variables of this model.

The important result of this exercise is that the responses of the endogenous variables to the monetary shock depend crucially on the extent to which real resources are used. Panel (a) of Figures 1 to 10 show the impulse responses to an unanticipated shock happening in the third quarter, whereas Panel (b) shows the impact effect of the same shock for a level of capacity utilization rate ranging, at the

[15]In this version of the model, the dynamic response functions of the endogenous variables lack persistence. For instance, output and employment do not display the delayed hump shape response that the estimated response functions exhibit as reported in Chirstiano et al. (1998).

time of the monetary policy action, from 65% to 95%.[16] Notice that the response of output, labor, real wages and investment is stronger when the capacity utilization rate is low. Intuitively, when the economy experiences a low level of capacity utilization, an expansive monetary policy shock will lead to a strong increase in output since less firms are producing at full capacity. Thus, in the low capacity case, the constraints that are associated to the predetermined level of equipment are less restrictive for a large set of input producing firms. The resulting expansion in output is achieved with the subsequent increase in employment. Under this same environment, the response of the nominal interest rate is higher due to a strong liquidity effect. The equilibrium interest rate at which firms will accept the new currency is much lower when more firms cannot increase their production due to the existence of capacity utilization constraints. Notice also the highly non-linear path that the impact response of this variable traces when the capacity utilization rate, at the time of the shock, increases. This result is, somehow, related to that of Cook (1999) who develops a model in which firms cannot transfer capital across sectors.

As expected, output prices are more sensible in a high capacity economy provided that investment is either a cash good or there are adjustment costs in capital. The monetary shock also produces an impact change on some other important endogenous variables. The response of the capital-labor ratio is significantly different depending on the capacity utilization rate of the economy. The capacity utilization rate increases more and the price relation decreases more, the lower is the capacity at the time of the shock. The mark-up increases more in a high capacity economy, and the weighted proportion of firms producing while having idle resources also decreases more in a high capacity economy. The dynamics of these variables also display a remarkably non-linear shape. It must be pointed out that the monetary shock does not produce a dynamic response in these capacity-related variables. This reflects the intraperiod nature of the real frictions embedded in the model. As a result, the qualitative characteristics of the contemporaneous impact do not extend beyond the period of the monetary policy shock. The asymmetric dynamics are not kept along time. Hence, a rather interesting extension of the model presented here is to achieve more persistency in the response of the endogenous variables to the monetary shock, for instance, by extending the intratemporal nature of the idiosyncratic shock towards an intertemporal dimension.

Finally, Figure 11 represents a Pseudo Phillips curve. Each point in this figure corresponds to a cumulated increase in the capacity and inflation gap due to a series of 1% unanticipated monetary policy shocks. It is relevant to see the non-linearity in such a relationship. For low levels of capacity utilization rate, the monetary policy shock exerts more pressure on real economic activity than on prices. As the economy moves toward a situation with a higher rates of aggregate capacity utilization, the effects of subsequent monetary policy shocks are comparatively more intense on prices. This result illustrates the direct link between the empirical findings described, for instance, in Alvarez-Lois (2000) with those coming from the theoretical model of this paper.

[16]The simulations are obtained by varying the parameters ϵ and σ_v in order to achieve a given capacity utilization rate. It must be pointed out that the results are independent of the specific combination chosen of those parameters.

5. Concluding Remarks and Extensions

Despite the empirical evidence and the strong theoretical arguments, there is a lack of a general equilibrium approximation to the issue of asymmetries in the monetary macroeconomic literature. This paper aims at filling this gap, developing a quantitative model of the monetary transmission mechanism in this regard and analyzing its implications for the conduct of monetary policy. The overall message of this article for monetary policy is that the same central bank actions may have quantitatively different macroeconomic effects depending on the extent to which productive resources are being used, that is, depending on the capacity utilization rate in the economy. A dynamic stochastic general equilibrium model consistent with these facts is developed. Specifically, it has been considered the interaction of endogenous capacity utilization (derived from productive constraints and firm heterogeneity) and market power within a quantitative macroeconomic model of the monetary transmission mechanism. The monetary structure of the model assumes a Lucas-Fuerst 'limited participation' constraint. In the real side, the fact that firms face a positive probability of being producing at variable capacity provides credible microfoundations to the idea of *ex post* inflexibilities in production sector that have recently been the object of study in the related literature.

The source of the asymmetry is directly linked to the bottlenecks and stock-outs that emerge from the existence of capacity constraints in the real side of the economy. Hence, these constraints act as a source of amplification of monetary shocks and generates asymmetries in the response of key macroeconomic variables. These effects interact additionally with those emerging from the imperfectly-competitive environment that characterizes the intermediate-good sector. Such effects work through optimal mark-up changes. Within the structure of the model, a non-walrasian pricing behavior in line with 'sticky' price models could easily be incorporated and thus, follow the results of recent empirical evaluation exercises of DGSE models, such as those of Christiano, et al. (1997), where it is claimed that a combination of limited participation with sticky-price behavior could successfully account for the basic stylized facts observed in the data. Hence, developing a model equipped with both types of frictions will be of notably interest.

The quantitative analysis presented here focuses on the asymmetric effects of monetary policy, but there is an important issue that has to be considered: the timing of the response of the macroeconomic variables to the shock. In the model above, such response is immediate and there is a lack of propagation. Andolfatto et al. (2000) generate persistent liquidity effects assuming that individuals are not able to perfectly observe the current monetary policy shock. It will be interesting to incorporate this latter feature into the model presented here and see how the resulting outcome is.

The empirically plausible asymmetry of the Phillips curve, due to the fact that some firms find it difficult to increase their capacity to produce in the short run, is going to have important implications for the conduct of monetary policy. In this sense, Nobay and Peel (2000) have shown that the analysis of optimal discretionary monetary policy under a non-linear Phillips Curve yields results that are in marked contrast with those obtained under the conventional linear paradigm. All these particularities, that are likely to offer interesting insights into the monetary transmission mechanism, are worthwhile exploring using the analytical framework developed here.

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TABLE 1: CALIBRATION

Consumption/leisure share	γ	0.35
Risk Aversion	σ	2
Intertemporal discount rate	β	$(1.03)^{-.25}$
Capital share	α	0.3485
Depreciation rate	δ	0.018
Fixed costs	Φ	0.1057
Autocorrelation monetary shock	ρ_x	0.32
Standard deviation monetary shock	σ_x	0.0038
Mean monetary shock	x	0.016

TABLE 2: STEADY STATE PROPERTIES

		Low Capacity: $\sigma_v^2 = 1.75$, $\epsilon = 4.85$	High Capacity: $\sigma_v^2 = 0.25$, $\epsilon = 15$
Output	$\mathcal{Y}$	0.87	1.23
Investment	$\delta K/\mathcal{Y}$	0.17	0.30
Consumption	C	0.59	0.83
Capital	K	9.48	16.70
Capital-Labor	X	20.24	50.49
Labor	L	0.32	0.32
Capital/output	$K/\mathcal{Y}$	10.88	13.49
Consumption/Output	$C/\mathcal{Y}$	0.69	0.67
Leisure-Labor Ratio	$(1-L)/L$	2.11	2.16
Mark-up	$Mk-up$	1.93	1.65
Monopolistic profits	$MP/\mathcal{Y}$	0.48	0.13
Deposits	D/M	0.67	0.85
Price Relation	$\mathbf{P}/P$	0.87	0.96
Firms Full Capacity	$\mathrm{F}(v)$	0.39	0.60
Capacity utilization	$\mathcal{C}$	0.65	0.95

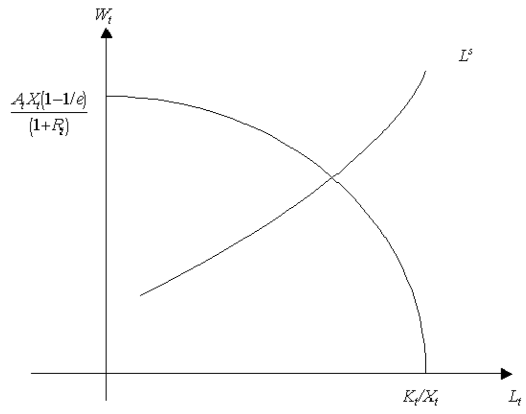


Chart 1: Short-Run Labor Market Equilibrium

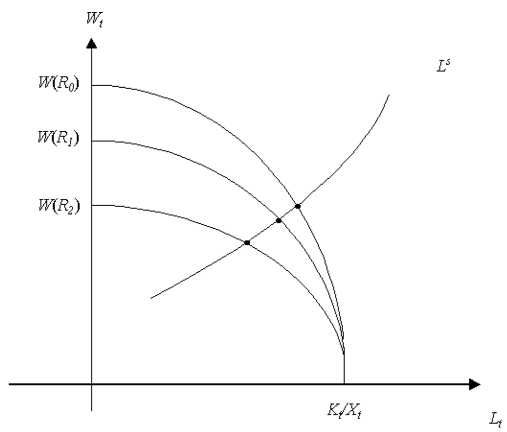


Chart 2: Short-Run Effect of Monetary Policy Shock

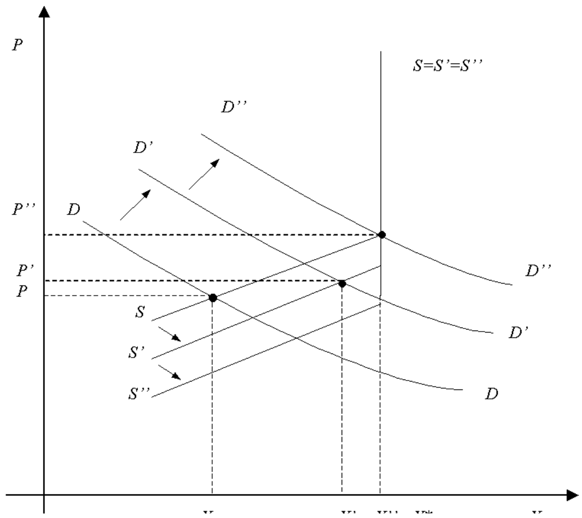


Chart 3: Price and Output Response to Money Shock

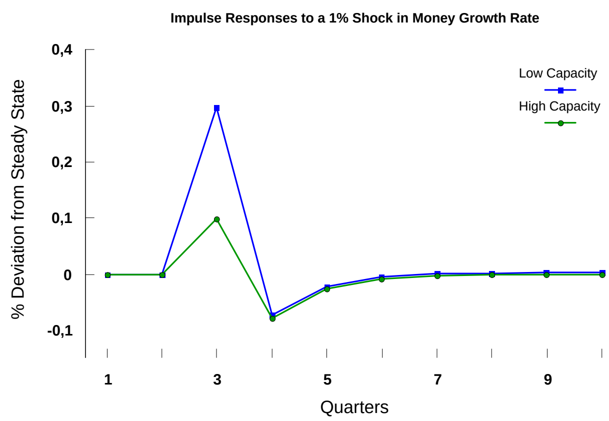


Figure 1a: Final Output

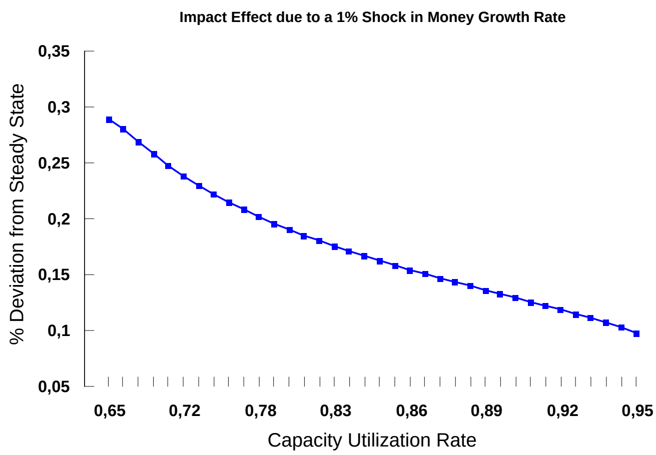


Figure 1b: Final Output

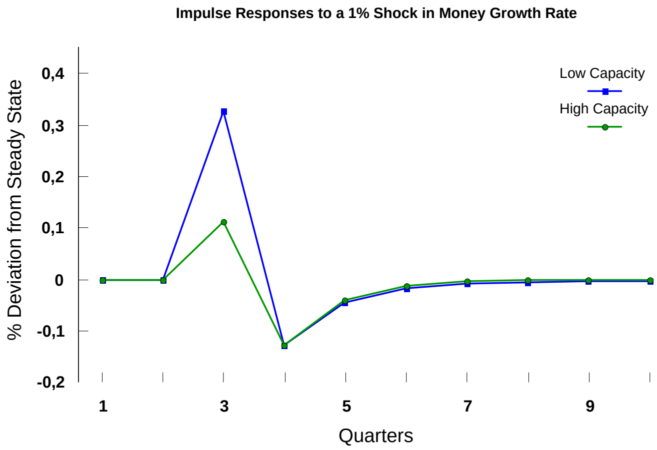


Figure 2a: Employment

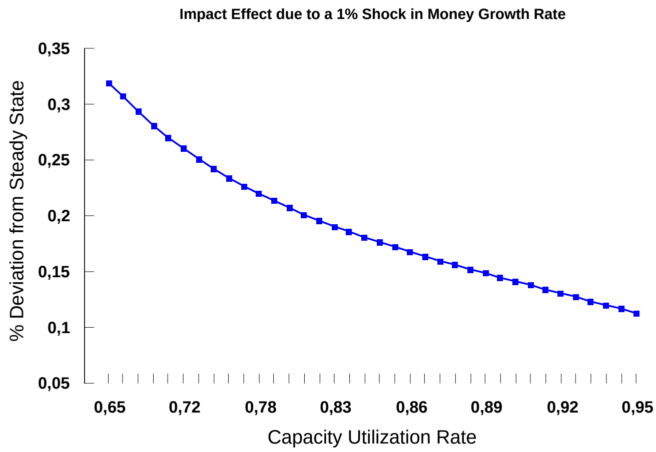


Figure 2b: Employment

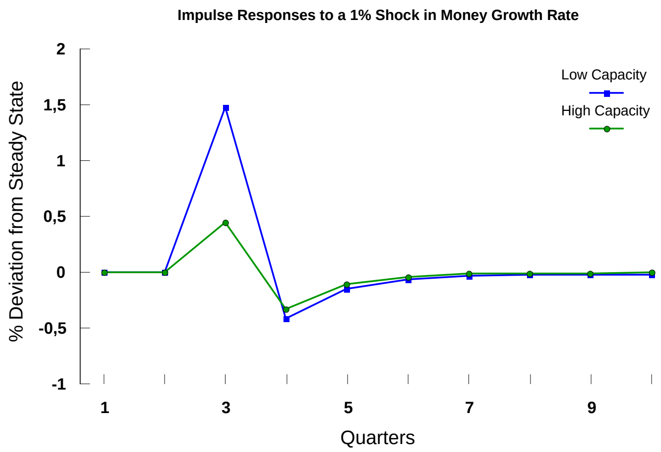


Figure 3a: Investment

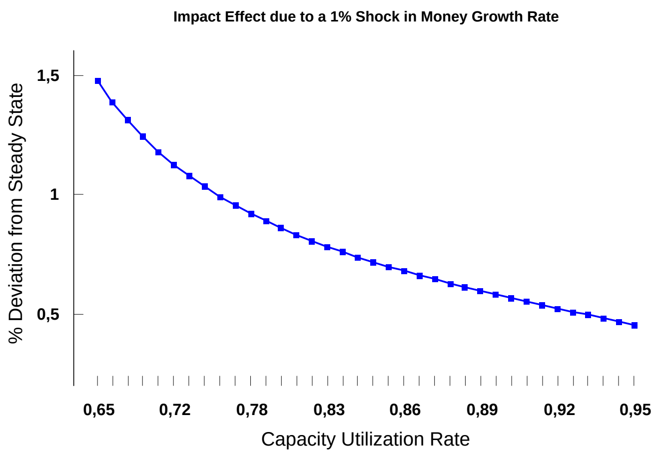


Figure 3b: Investment

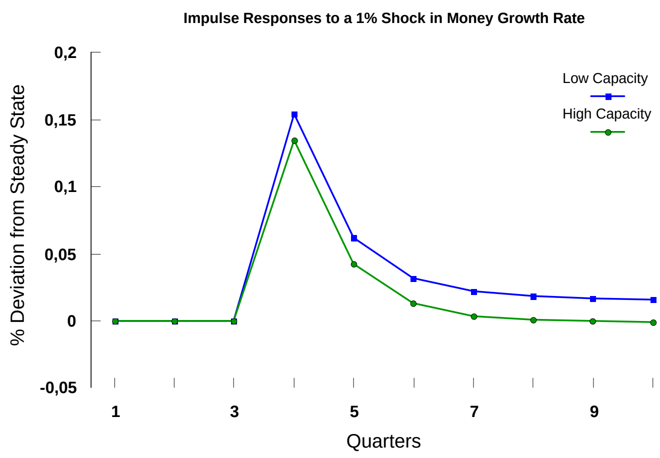


Figure 4a: Capital-Labor Ratio

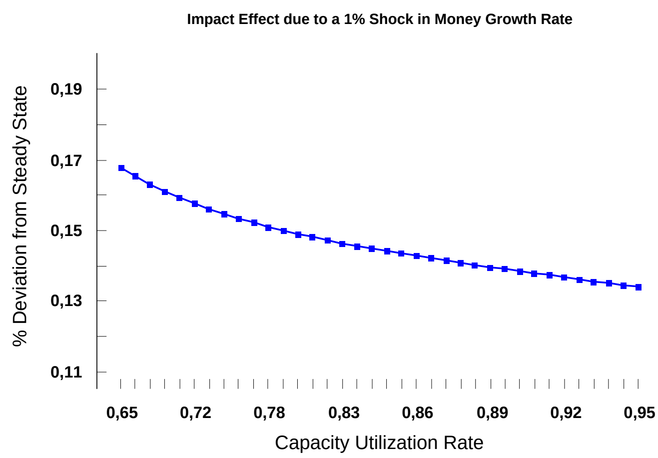


Figure 4b: Capital-Labor Ratio

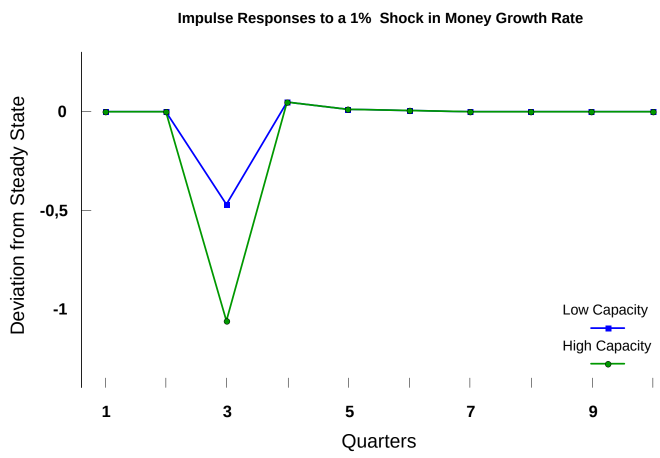


Figure 5a: Nominal Interest Rate

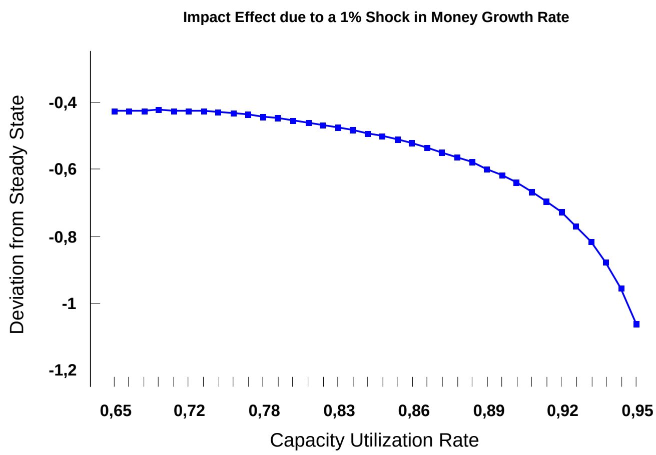


Figure 5b: Nominal Interest Rate

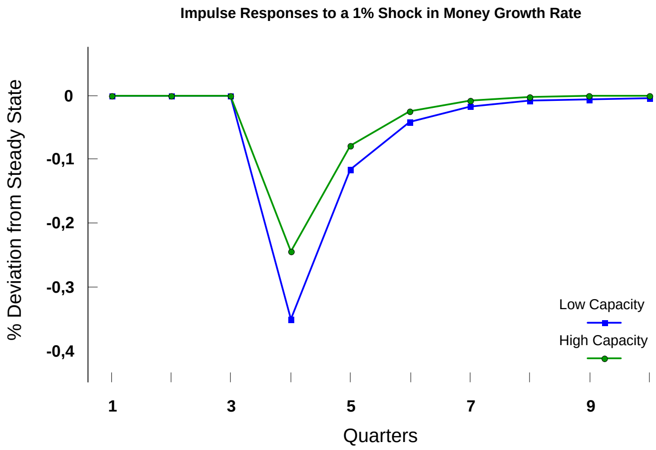


Figure 6a: Deposits

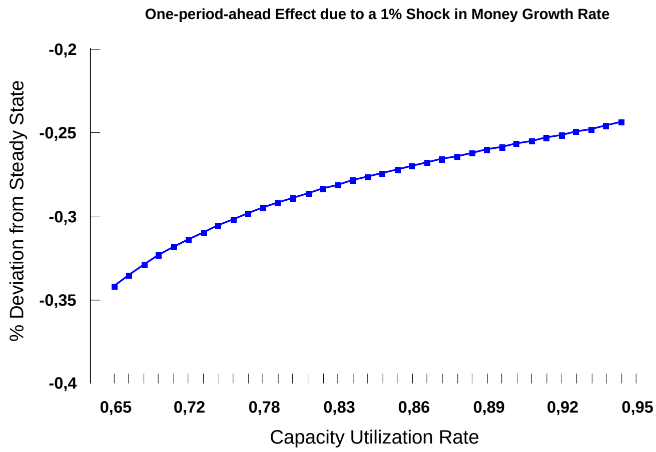


Figure 6b: Deposits

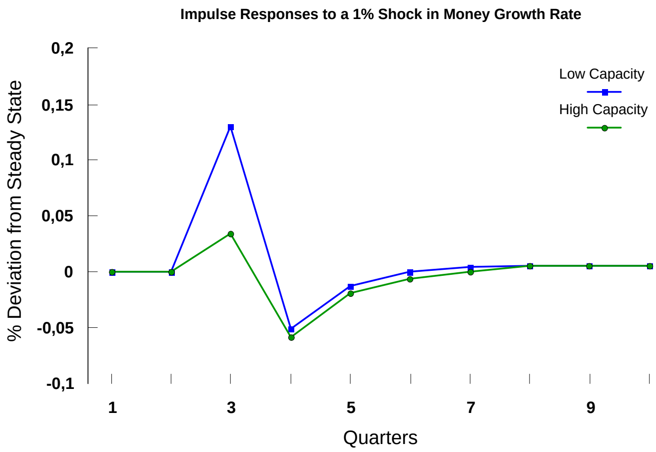


Figure 7a: Real Wage Rate

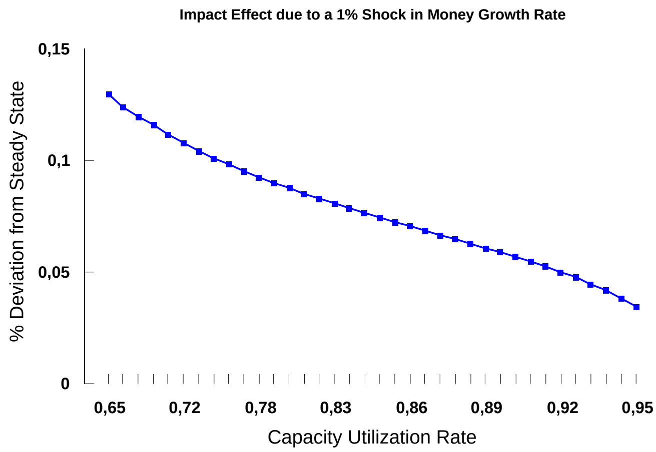


Figure 7b: Real Wage Rate

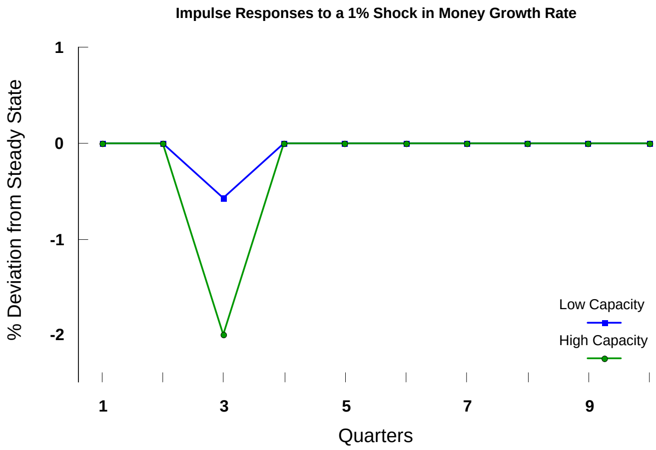


Figure 8a: Underused Resources

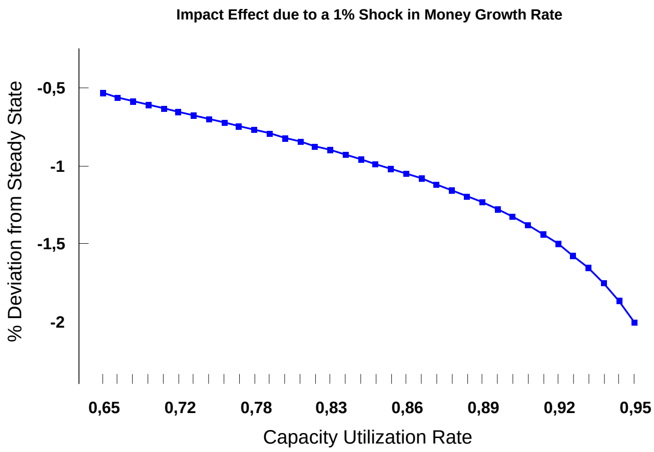


Figure 8b: Underused Resources

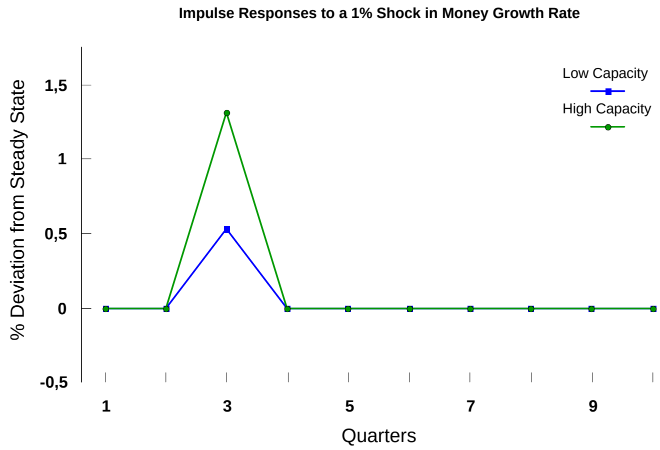


Figure 9a: Mark Up

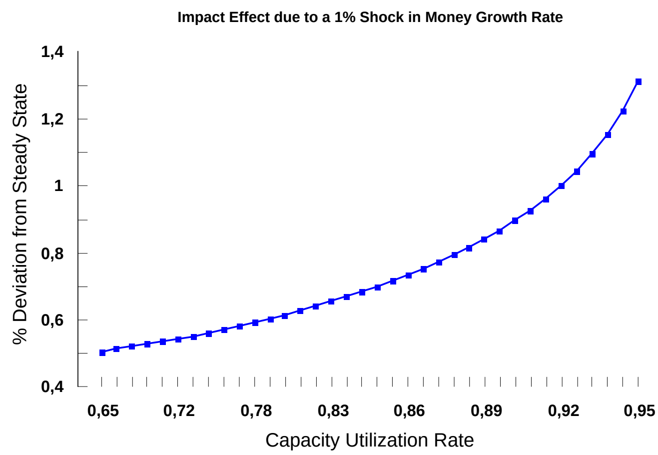


Figure 9b: Mark Up

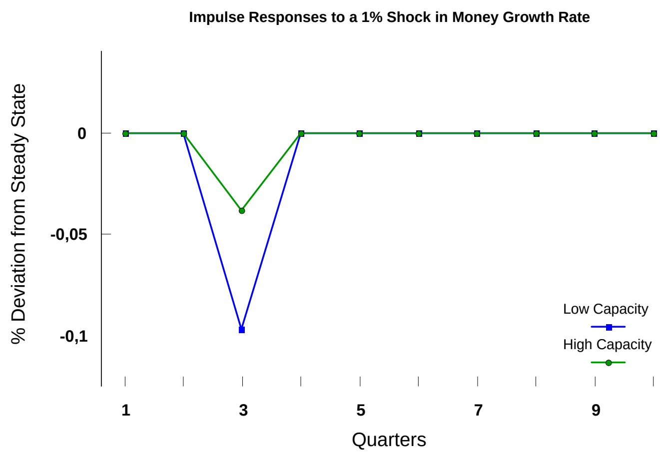


Figure 10a: Price Relation

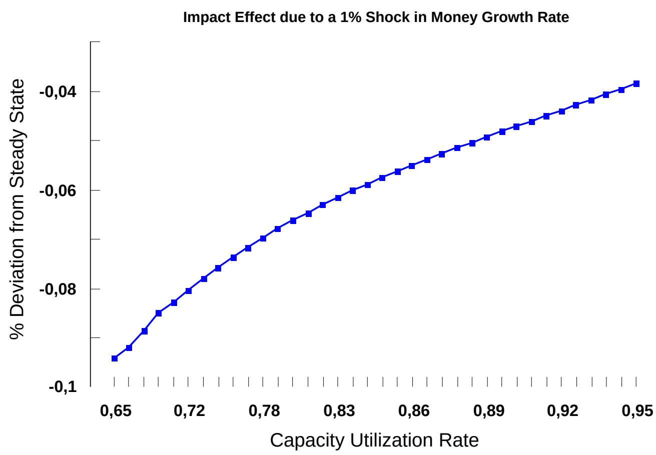
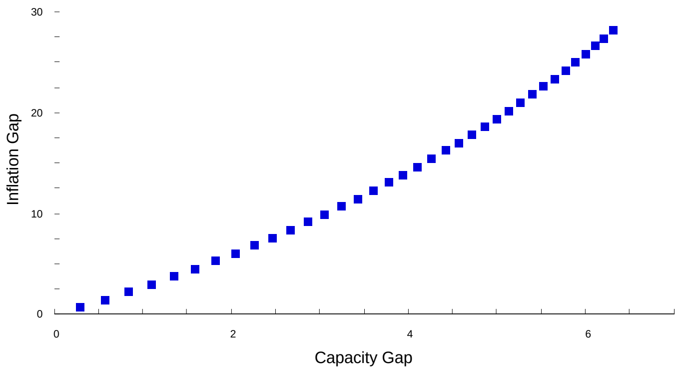


Figure 10b: Price Relation



Note: Each point in the figure represent the cumulated increase in equilibriu values of the capacity and inflation gap that results from a series of 1% monetary policy shocks.

Figure 11: Pseudo Phillips Curve

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