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The “Credit-Cost Channel” of Monetary Policy. A Theoretical Assessment

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Abstract

Drawing on the modern literature on the monetary transmission mechanisms with capital market imperfections, this paper presents a model of the “credit-cost channel” of monetary policy. The thrust of the model is that firms' reliance on bank loans (“credit channel”) may make *aggregate supply* sensitive to bank interest rates (“cost channel”), which are in turn driven by the official rate controlled by the central bank. The model is assessed theoretically by examining whether, and under what conditions, changes in the policy interest rate produce the *whole* pattern of the observed stylized effects of monetary policy, with no recourse to non-competitive hypotheses and frictions in the goods and labour markets. This result is obtained for parameter values in the range of available consensus estimates, with a caveat concerning labour-supply elasticity to the real wage rate.

JEL: E51, C 32

Keywords: Macroeconomics and monetary economics; monetary transmission mechanisms; credit channel; cost channel

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1 Introduction

It is now widely held that "monetary policy matters", in the sense that policy interventions (mainly activated by changes in administered rates and money-market rates) are typically followed by

- quick and large responses in short-term interest rates, monetary aggregates, total credit
- sizeable and persistent effects on different measures of real economic activity: real wages and profits, employment and output
- damped adjustments of price indexes.

Still controversial is the explanation of the impact of monetary policy on economic activity, in particular an explanation which encompasses the *whole* set of stylized facts stated above. Even if discussion is restricted to the post Keynesian-Monetarist-Debate period, today's macro-modellers face a rather extended menu, which can be organized into a 2x2 table with the types of transmission markets on one side, and the types of macroeconomic effects on the other.

Table 1: A Taxonomy of Transmission Channels and Macroeconomic Effects of Monetary Policy

•	• Demand side effects	• Supply side effects
• Money market	<ul style="list-style-type: none"> • <u>+ nominal rigidities</u> • Standard NNS: Woodford (2003) 	<ul style="list-style-type: none"> • – nominal rigidities • <u>+ financial frictions</u> • cost channel: Christiano et al. (1997) • • <u>+ nominal rigidities</u> • NNS- cost channel: Ravenna-Walsh (2006), Chowdhury et al. (2006)
• Credit market	<ul style="list-style-type: none"> • + nominal rigidities • <u>+ financial frictions</u> • Early NK- credit channel: Blinder-Stiglitz (1983), Bernanke-Blinder (1992) 	<ul style="list-style-type: none"> • – nominal rigidities • <u>+ financial frictions</u> • Early NK -business cycles: Greenwald-Stiglitz (1988, 1993a), Bernanke-Gertler (1989) Kiyotaki-Moore (1997) Bernanke et al. (1999) • • + nominal rigidities • <u>+ financial frictions</u> • NNS- financial frictions: Goodfriend and McCallum (2007), Christiano et al. (2007a, b)
• NNS = New Neoclassical Synthesis; NK = New Keynesian		

The rows indicate whether the key market for the transmission mechanism of monetary policy is only the money market or also (instead) the credit market. The columns indicate whether the key effects of monetary policy concern only aggregate demand or (also) aggregate supply. Each column also indicates the presence (+) or absence (–) of two other important ingredients. "Nominal rigidities" stand for sticky goods prices and/or wages and/or other non-indexed nominal contracts. "Financial frictions" is a recent jargon that covers various forms of capital market imperfections. Each entry in the table is accompanied by a few representative references.

Overall, the combination of credit, cost and supply-side effects of monetary policy seems to furnish a richer and comprehensive account of how monetary policy works, as well as shedding new light on some long-standing theoretical issues.

First of all, under certain conditions the cost-driven supply-side effects of monetary policy may improve explanation of the entire set of stylized empirical regularities mentioned above: in particular showing that real wages and profits are *negatively* correlated with policy interest rates in a way that standard demand-side effects with sticky prices cannot (Christiano et al. (1997)). If, say, a monetary restriction raises firms' variable costs and/or forces them to cut production, then, for a given monetary wage, prices may well increase and real wages fall. Alternatively, firms may respond by cutting back labour demand, thus forcing real wages to fall directly.

Second, these effects call into question the general presumption that monetary policy can only affect real economic activity as a consequence of sticky prices. As stressed by Greenwald and Stiglitz (1993b), and also by Christiano et al. (1997), co-movements of demand and supply after a monetary shock can provide a straightforward explanation for the observed pattern of large adjustments in quantities and small ones in prices even in competitive markets with flexible prices.

Third, Ravenna and Walsh (2006) have explored the optimal policy implications of the presence of the cost channel with or without sticky prices. Their main point is that this channel revives the key output-inflation trade-offs that are notably absent from the Standard NNS framework, and that may modify the policy problem in important ways. An example is that feedback rules which concentrate on inflation and ignore the supply-side effects of the rule itself may be misleading in that the actual expansion (contraction) of economic activity is barely translated into inflation signals to the central bank (Borio and Lowe (2002), Leijonhufvud (2008)). On the other hand, co-movements of demand and supply in a general-equilibrium framework offer the appropriate key to establish whether the so-called "price puzzle" (Sims (1992)) – the inflationary effect of a monetary restriction – occurs or not.

Finally, it is typical of some of the models cited above that, in one way or another, the *equilibrium* level of output (employment) comes to depend on the policy interest rate as an element of firms' real unit cost along with the wage rate (and possibly other input prices). Hence, it can no longer be taken for granted that monetary policy interventions (transmitted through the interest rate) are bound to generate mere transitory effects around, with no permanent impact on, potential output, the natural rate of unemployment, etc. (Greenwald and Stiglitz (1993a)).

Therefore, this paper's contribution lies in the lower-right cell of *Table 1*, more specifically in the subset where nominal rigidities are absent, and it consists of a "theoretical assessment" (in the sense explained below) of the hypothesis that the credit and cost effects activated by interest-rate based monetary policy are indeed consistent

with, and can account for, the above-mentioned issues. To this end, the paper presents a general-equilibrium model of a competitive, flex-price economy that blends the credit and cost channels of monetary policy into a single, integrated "credit-cost channel" (CCC). The model has been devised in the most parsimonious and general form possible. Parsimonious means that actors, markets, "frictions", and hence parameters are reduced to the minimum necessary. General means that the least possible restrictions or specific functional forms are imposed.

The treatment is divided into three parts. To begin with, Section 2 provides a more detailed discussion of the relationship of the CCC hypothesis and the model presented here with the relevant literature.

Section 3 presents the model, which draws and elaborates on Greenwald and Stiglitz (1988, 1993a: GS henceforth). The model includes three agents (firms, households and banks) and a central bank. Labour, credit and goods markets are competitive and all relevant nominal contracts and prices are flexible. Firms operate under revenue uncertainty, and need to borrow to pay for working capital. Asymmetric information about the actual revenue of firms, resolved by standard debt contracts with banks, with a parallel deposit-in-advance constraint for households, are the sole "frictions" in the economy. The thrust of the model is that firms' reliance on bank loans (credit channel) may make aggregate supply sensitive to bank interest rates (cost channel), which are in turn driven by the official rate controlled by the central bank plus a credit risk premium charged by banks on firms. Hence, in equilibrium, the economy displays a risk-based interest-rate spread between the policy rate and the bank lending rate. A first key feature of the model is that both aggregate demand and supply are affected by monetary policy. At the same time, the model allows to examine the independent effect of shifts in credit risk.

Section 4 presents a "theoretical assessment" of the CCC hypothesis: that is, a quantitative "test" of whether, and under what conditions, the CCC model is able to reproduce (explain) the entire set of phenomena of interest. The same approach has been followed by Christiano et al. (1997; CEE henceforth) and consists of two steps. First, the focus is on comparing the rational-equilibrium states of the economy (that is, when all the transitory adjustments have taken place) after exogenous changes in the policy interest rate, with a discussion of the parametric conditions that govern the equilibrium outcomes. Second, considering the consensus estimates of the relevant (six) parameters, it is possible to establish whether the model is consistent with the set of outcomes of interest.

The result, summarized in Section 5, is that the CCC hypothesis passes the test of the stylized effects of monetary policy, with one caveat. As in CEE, an important condition is the extent of labour-supply elasticity, which should not be so small as in some empirical findings. However the set of parameters and their interactions highlighted by the CCC model qualifies this requirement, in that the magnitude of the labour-supply elasticity should be gauged (and may be reduced) in relation to the parameters regulating the forward-looking behaviour of households, which are not present in the CEE model.

2 The CCC Hypothesis and the Related Literature

Starting from the upper-left cell of *Table 1*, Standard NNS indicates macro-models of the demand-side effects of interest-rate based monetary policy with sticky prices as epitomized by Woodford (2003). This class of models makes no explicit consideration of the credit market, and the money market simply works behind the central bank's operations on "the" interest rate (see e.g. Bernanke and Mihov (1995) for details). These models have proved able to account for the observed correlations among policy interest rates, output and inflation, but they fail to explain the other empirical regularities, in particular, the *negative* effects of policy shocks on real wages and profits (a balanced assessment is provided by Tovar (2008)). Indeed, sticky goods prices combined with the traditional demand-side effects of monetary policy typically entail the well-known counterfactual effect that competitive real wages are positively correlated with the policy interest rate (e.g. CEE). Moreover, the absence of the credit market and the related variables is now (as a consequence of the unforeseen 2007 financial crisis) regarded as a major limitation of this framework for monetary policy (e.g. Crockett (2003), Christiano et al. (2007c), Goodfriend and McCallum (2007), Tovar (2008)).

The credit market indeed played the key role in the transmission mechanism in the immediate NK antecedents of the Standard NNS: the models with the so-called "credit channel" of monetary policy. These revived the long-standing view that monetary policy first and foremost affects the supply of credit and bank lending rates upon framing monetary policy in the context of imperfect capital markets. The latter help explain the large impact that monetary interventions are observed to exert on private expenditure, notably asymmetric information generating agency problems between the firm and its external financial suppliers. Bank credit has no perfect substitutes at the market interest rate. According to a large body of evidence, bank credit is the first, or exclusive, choice among external sources, most likely for small firms with poor internal accumulation and with limited access to open markets (e.g. Bernanke and Gertler (1995), Gertler and Gilchrist (1993)). At that time, however, the credit channel was confined within the traditional demand-side effects of monetary policy: it still required sticky prices as a *sine qua non* condition for monetary policy to have real effects, and furnished incomplete coverage of all relevant phenomena (see e.g. Eichenbaum (1994)).

Another research path has followed the theoretical argument that limiting the link between monetary policy and economic activity to aggregate-demand effects is an oversimplification of microeconomic relationships. There are, in fact, several possible links with aggregate supply as well. In the first place, besides fixed capital, also working capital may need financial resources, as current inputs should be paid before output can be sold, and these resources (liquidity, inventories, etc.) carry a financial cost. Consequently, the interest rate paid on working capital affects production costs – a view widely shared by businessmen (e.g. Goodhart (1986)). Monetary policy, by altering interest rates, can influence aggregate supply through this "cost channel". All entries in this column include, in one way or another, this transmission channel.

CEE address the question of whether the cost channel alone can provide better coverage of the stylized effects of monetary policy than can sticky prices, using a quantity monetary model with a financial friction given by the so-called "limited

participation" hypothesis¹ (their answer is affirmative). Chowdhury et al. (2006), Ravenna and Walsh (2006) instead exemplify the straightforward insertion of the cost channel in an otherwise Standard NNS model with sticky-price-making firms, where the interest rate also appears in the Phillips curve as a production cost. Ravenna and Walsh also show the case with no nominal rigidities. The absence of an explicit bank credit channel in these models, however, seems to be a major limitation, since credit is by far the largest source of working capital, as shown by the credit-channel literature². Specifically, these NNS models with the cost channel capture only one side of the mechanism: the fact that raising (reducing) the policy interest rate feeds higher (lower) inflation through the Phillips curve (it operates as a supply-side shock). The concomitant fact that aggregate demand may also be affected is not contemplated: hence their theoretical analysis of the effects of monetary policy is incomplete, and entirely dependent on the assumptions on the degree of monopoly power and price stickiness.

Analyses including the credit market in the generation of the cost-channel, supply-side effects of monetary policy were first offered by a subset of early NK models with imperfect capital markets that may be dubbed "NK business cycles". In some of these models credit is mostly relevant as a production input (Greenwald and Stiglitz (1988, 1993a)), in others it acts as a quantity or signalling constraint on firms' ability to raise funds, the so-called "net worth (or balance-sheet) channel" (Bernanke and Gertler (1989), Kiyotaki and Moore (1997), Bernanke et al. (1999)). The link with monetary policy is treated in greater or lesser detail. Overall, credit market terms and conditions play a key role in the generation and/or propagation of real as well as monetary business cycles.

This so-to-speak unfinished work prior to the advent of the Standard NNS model is now being revived in an attempt to extend the latter to include these transmission mechanisms and channels of monetary policy left by the wayside. The Bernanke and co-authors' models are the reference point as regards financial frictions, and dynamic stochastic general equilibrium (DSGE) is the standard method (see e.g. Blanchard (2008) for this research programme, and Tovar (2008) for related empirical aspects)³. Unlike earlier NK models, however, now financial frictions are grafted onto sticky prices or, as in Christiano et al. (2007a, b), appear in another form of nominal rigidity due to non-indexed financial contracts.

As regards this new strand of NNS-DSGE models with financial frictions, from the point of view of interest in this paper their shortcoming is that they are neither parsimonious nor general. The point is that the DSGE methodology typically aims at producing models to be taken to the data for applied policy making. Since the real world is full of imperfections, and fitting the real world data is an important task for applied policy purposes, as seen in *Table 1* these models tend to pick up and combine various frictions and channels whose relative importance is difficult to disentangle. In addition,

¹ That is to say, money supply flows directly to households, but these cannot immediately adjust their money holdings after a monetary shock, so that the latter has a high impact on the interest rate on advances to firms.

² Note that all the models cited have financially unconstrained firms borrowing from unspecified intermediaries. The reason why firms resort to these intermediaries, instead to direct funding from households that own them, is not explained.

³ It is worth mentioning that a line of defence of the Standard model has been put forward by Woodford (2008) and Canzoneri et al. (2008).

modellers are forced to posit specific functional forms for preferences and technology, which raise the well-known issue of joint hypotheses that may impair the scope of validity of results.

On analytical grounds, models more closely derived from the Standard NNS ignore the labour market, and they consequently beg the question of how monetary policy affects real wages. Exceptions are Goodfriend and McCallum (2007), and a recent string of models by Christiano and co-authors where, however, the labour market brings in its own frictions whether real (2007d) or nominal (2007a, b, c).

Moreover, one of the key facts that the inclusion of the banking sector is supposed to capture, namely interest-rate spreads above the policy rate, is eventually obtained in a rather uneasy way. Remarkably, in this class of models interest-rate spreads are *not* the result of their most obvious cause: credit risk (they are the result of some sort of "loan technology" (Goodfriend and McCallum (2007), Curdia and Woodford (2008)) or of monopolistic competition in the banking sector (e.g. Gerali et al. (2008), Aslam and Santoro (2008)). The main reason why risk disappears is that the typical financial friction takes the form of collateralized bank loans whereby banks fully cover their loans⁴. In this respect, the GS type of models includes credit risk premium in a consistent and simple way.

Finally, DSGE methodology *per se* is best suited to focusing on transitory dynamics towards a predetermined steady-state. By contrast, some important issues in the theory of monetary policy traditionally concern comparison between equilibria after transient adjustments have petered out. This sort of short-termism that has come to dominate research in this field may be due to the unquestioned principle of long-run neutrality of money supply. But, as explained in Section 1, the credit, cost and supply-side effects of monetary policy are such that this principle can no longer be taken for granted even when labour and goods markets are frictionless. Hence the return to frictionless comparative-static analysis (such as in GE, CEE) may be opportune.

Therefore, among the relevant subset of reference works in the lower-right cell, I have drawn and elaborated on GS as the most suitable general-equilibrium framework in which to accommodate the CCC according to the previous criteria. As far as the choice of no nominal rigidities is concerned, CEE is also a reference (and comparable) point, with respect to which the question becomes the value added of a proper introduction of the credit channel. This paper can thus be related to the NNS-DSGE literature as a preliminary theoretical investigation and clarification of the explanatory potential of the CCC hypothesis.

3 A Model of the “Credit-Cost Channel” of Monetary Policy

3.1 The Economy

- The economy consists of three competitive markets, for labour (the single input of production), for credit, and for final consumption (the single output of production);

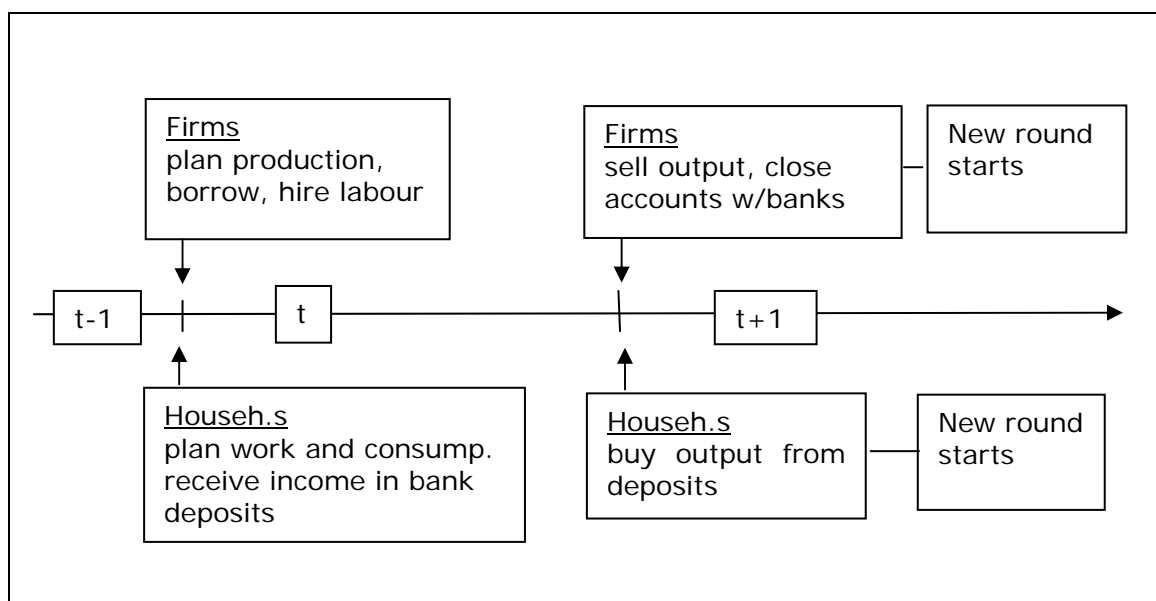
⁴ These papers also generally fail to provide proof that collateralized loans are the optimal solutions of the bank-borrower relationships in their specific context.

there are three representative classes of agents, households, firms and banks, and a central bank as the single policy authority.

- The economy operates sequentially along discrete time periods indexed by $t, t+1, \dots$, where production takes 1 period of time regardless of the scale of production. Firms can start a new production round only after "closing accounts" (i.e. the entire output has been sold and all various claimants paid)⁵.
- At the beginning of period t firms plan production for sale at $t+1$. They face uncertainty about revenue from output sales, and the true realization of revenue is private information of each firm. Firms hire workers in the labour market; in order to pay for the planned labour input, they should borrow the wage bill in the credit market. Households are paid their wage bills in the form of bank deposits, and production takes place.
- Banks grant standard debt contracts to firms *vis-à-vis* zero interest deposits from households. They can also insure against credit risk by borrowing reserves from the central bank at a given official rate.
- At the beginning of period $t+1$ output is sold for consumption and firms should pay back their loans. Afterwards, a new production round starts.

The sequence of events is depicted in Figure 1.

Figure 1: Timing of Transactions



3.2 Firms

The core of the model is firms' bank dependence *à la* GS. First, firms produce under revenue uncertainty. The simple and convenient treatment of revenue uncertainty proposed by GS is that a firm j starts production at time t for sale at $t+1$, $Q(t)_{t+1}$. Yet the unit revenue at time $t+1$ is a random draw from a probability distribution with density

⁵ This assumption is not essential, but it avoids undue complications arising from overlapping firms' cash flows and expenditures, and it allows for more clear-cut firm-bank relationships. GS relax this condition.

$f(\tilde{P}_{jt+1})$, cumulative function F , and expected value $E_t(\tilde{P}_{jt+1}) = P_{t+1}$ for all j , where P_{t+1} will be the actual market-clearing price. Hence, note, all firms operate under rational expectations. Then it is convenient to think of \tilde{P}_{jt+1} as the take-home unit revenue of the firm, and consider that it may differ from P_{t+1} for a variety of reasons embedded in the internal organization of the firm, such as unexpected events or costs in the retail branches, etc.

Second, the above description of the economy entails an ex-post verification problem for firms' lenders about the true state of firms. The true realization of revenue \tilde{P}_{jt+1} can only be observed at a cost. This information asymmetry is sufficient to preclude efficient direct lending by households, and it makes it efficient to delegate lending and monitoring to specialized intermediaries, i.e. banks⁶. In this context, banks offer standard debt contracts to firms at the following terms⁷. Against a loan L_t , the firm is committed to paying in $t+1$

- $L_t R_t$ if the solvency state $\tilde{P}_{jt+1} Q(t)_{t+1} \geq L_t R_t$ is declared
- $\tilde{P}_{jt+1} Q(t)_{t+1}$ if the default state $\tilde{P}_{jt+1} Q(t)_{t+1} < L_t R_t$ is declared, with deterministic monitoring

In this setup, let each firm j produce a homogeneous output by means of a common labour technology with decreasing marginal returns and one-period production time,

$$(1) \quad Q(t)_{jt+1} = Q(N_{jt}), \quad Q'(N_{jt}) > 0, Q''(N_{jt}) < 0$$

For any level of labour input N_{jt} , and nominal wage rate W_t , the corresponding wage bill determines the amount of working capital that the firm should finance, $L_t^d = W_t N_{jt}$. Since the debt contract has no bankruptcy costs⁸, the stream of future expected profits for any firm j in any period t is the sequence:

$$E_t\{Z_{jt+1}, \dots, Z_{jt+s}, \dots\}$$

with

$$(2) \quad E_t Z_{jt+s} = E_t(\tilde{P}_{jt+s}) Q(t)_{jt+s} - W_{t+s-1} N_{jt+s-1} R_{t+s-1}, \quad s = 1, \dots$$

and where, $R_t \equiv (1 + r_t)$ is the gross nominal interest rate charged by banks. Now let us denote the current real wage rate with $\underline{W}_t \equiv W_t/P_t$, the one-period expected price growth factor (expected inflation for short) with $E_t \Pi_{t+1} \equiv E_t(\tilde{P}_{jt+1})/P_t = P_{t+1}/P_t \equiv (1 + \pi_{t+1})$, and the gross (expected) real interest rate with $\underline{R}_t \equiv E_t(R_t/\Pi_{t+1})$. Given that the firm can start a new production round only after "closing accounts", the intertemporal profit maximization problem can be split into independent one-period problems. Along the optimal production path the following first order condition for maximum real profit should hold in each period t

$$Q'(N_{jt}) = \Gamma_t \equiv \underline{W}_t \underline{R}_t$$

⁶ As shown by Townsend (1979) and Diamond (1984) among others.

⁷ Fiorentini and Tamborini (2002) show that in a firm-lender problem like the present one the standard debt contract is the optimal one.

⁸ These costs play an important role in the GS models because they bring default risk into the picture; here they are not necessary because default risk is introduced through bank's credit supply.

This condition states that the firm in each period t employs labour up to the point where its marginal product equals its *expected real unit cost* Γ_t , which is the compound real cost of labour and credit. Under standard assumptions concerning the production function, the labour demand function can be written as

$$(3) \quad N_{jt}^d = N^d(\Gamma_t) \quad N^d(\Gamma_t) < 0$$

Output supply is derived from labour demand by means of the production function, i.e.:

$$(4) \quad Q(t)_{jt+1} = Q(N^d(\Gamma_t)) \quad Q'(N^d) > 0$$

3.3 Households

As a consequence of the missing market for direct firms' financing, we can also assume that firms are self-owned by individual entrepreneurs, who do not distribute profits which they retain for self-consumption. Consequently, households consist solely of workers who only earn wages, while market demand for output only comes from workers' consumption.

Households perform three activities: they work, consume and save. At any point in time t , the plan of household h consists of labour supply to be realized in each production period (N_{ht}, N_{ht+1}, \dots) and of consumption demand to be realized *at the end* of each same production period ($C_{ht+1}, C_{ht+2}, \dots$) before the new production starts (then consumption activity takes place during the production period).

In addition to the total resources available, each household's plan should fulfill two specific constraints imposed by banks: no borrowing and deposit in advance. The former is not strictly necessary (possible effects of relaxation of this constraint will be discussed in the empirical part) but it is introduced for analytical convenience⁹. The latter is by now a standard tool to introduce deposits into the economy (e.g. Goodfriend and McCallum (2007))¹⁰. Hence note that C_{ht+1} will be constrained by available deposits from period t and cannot exceed D_{ht}/P_{t+1} , while nominal deposits evolve according to $D_{ht} = D_{ht-1} - P_t C_{ht} + W_t N_{ht}$.

The general representation of the household's problem at the beginning of any production period t is a sequence of choices

$$\{N_h: N_{ht}, N_{ht+1}, \dots\}, \{C_h: C_{ht+1}, C_{ht+2}, \dots\},$$

such that

⁹ Yet it may also be justified on the grounds that, in the aggregate economy, households are typically a net lending sector. This clear-cut specialization, in connection with information problems, is typical of New Keynesian models (e.g. Bernanke et al. (1999)) because it offers an obvious advantage when it comes to determining the spillover effects of changes in borrowing and lending.

¹⁰ In fact, cash is traditionally unimportant in the New-Keynesian, credit-channel world. Note also that the households' deposit-in-advance constraint is less dramatic than it seems in the case with pure cash. Deposits (not cash) are generally the means to access payment facilities granted by banks.

$$(5) \quad \max_{C,N} U_{ht} = U(C_h, N_h), \quad U'(C_{ht}) > 0, U''(C_{ht}) < 0, \\ U'(N_{ht}) < 0, U''(N_{ht}) < 0, \text{ all } t^{11}$$

$$\text{s.t.} \quad P_{t+1}C_{ht+1} \leq D_{ht} \\ D_{ht} = D_{ht-1} - P_t C_{ht} + W_t N_{ht}$$

This timing has two consequences. First, the household operates under the first deposit constraint. The possibility that the constraint is not binding arises because at the end of each period the household cannot spend more than available deposits, but may choose to spend less and carry more resources over to the next period, depending on intertemporal preferences (see below). Second, the vector of allocations C_h, N_h is realized conditionally upon all available information in t , which at that point in time includes possible credit and labour market innovations (notably interest rates), i.e. E_t should be read as the expectation conditional upon $\Omega_t \equiv \{k_t, r_t, \dots\}$. Since we are considering permanent changes in the monetary policy stance, it is consistent for households to hold that $E_t[\Pi_{t+1+s}|\Omega_t] = \dots = E_t[\Pi_{t+1}|\Omega_t]$. For notational simplicity Ω_t will be dropped.

Using P_t as numeraire, the generic form of the solution to the foregoing problem at any t along the optimal path includes the following first-order conditions:

$$-U'(N_t) = \underline{W}_t E_t[\Pi_{t+1}]^{-1} U'(C_{t+1}) \\ U'(C_{t+1}) = E_t[\Pi_{t+1}]^{-1} U'(C_{t+2})$$

The first condition yields the optimal work-consumption choice, which, owing to the transaction timing, is such that the *current* working time N_{ht} during t is the means to buy consumption C_{ht+1} at the *end* of the production period. It indicates that labour supply is therefore regulated by the current real wage rate discounted by $E_t[\Pi_{t+1}]$ *vis-à-vis* C_{ht+1} . Since $U'(N_{ht}) < 0$, \underline{W}_t has a positive, while $E_t[\Pi_{t+1}]$ has a negative, effect on N_{ht} (incentive effect). On the other hand, the second condition yields the value of C_{ht+1} along the optimal consumption path as of time t . For regular utility functions, a higher $E_t[\Pi_{t+1}]$ (the inflation rate expected to prevail from $t+1$ onwards) redistributes consumption towards C_{ht+1} , which, in turn, reduces N_{ht} (substitution effect)¹². We can thus write a labour supply function taking the form:

$$(6) \quad N_{ht}^s = N^s(\underline{W}_t, E_t \pi_{t+1}) \quad N^{s'}(\underline{W}_t) > 0, N^{s'}(E_t \pi_{t+1}) < 0$$

¹¹ The sole restriction that we impose on (5) is that $U'(C_{ht})$ is independent of N_{ht-1} and $U'(N_{ht})$ is independent of C_{ht+1} . The standard additive separable intertemporal utility function satisfies this restriction.

¹² Note that forward iteration of the first condition implies that $U'(C_{t+2}) = -U'(N_{t+1}) E_t[\Pi_{t+1}] \underline{W}_t^{-1}$. Substituting this expression into the second condition, and then $U'(C_{t+1})$ back into the first, yields

$$U'(N_t) = (\underline{W}_t / \underline{W}_{t+1}) E_t[\Pi_{t+1}]^{-1} U'(N_{t+1})$$

This expression measures the intertemporal substitution of labour supply and has been widely employed in the real business cycle literature. Again, it implies that, *cet. par.*, an increase in expected inflation redistributes work effort from the the present to the future (in standard models where households receive a positive interest rate on wealth, this corresponds to the well-known principle that labour supply is increasing in the real interest rate)

Looking at the constraints of the household's problem we can also deduce a generic function for consumption, which at the end of each period t cannot exceed the real value of deposits. This function should respond positively to the expected real value of deposits at time $t+1$, $E_t(D_t/P_{t+1}) = E_t(\underline{D}_t/\Pi_{t+1})$, with $\underline{D}_t \equiv D_t/P_t$, (income effect), as well as to $E_t[\Pi_{t+1}]$ (intertemporal substitution effect). Thus we can also write

$$(A1) \quad C_{ht+1} = C(\underline{D}_t, E_t\pi_{t+1}) \quad C'(\underline{D}_t) > 0, C'(E_t\pi_{t+1}) ?$$

The partial derivative $C'(E_t\pi_{t+1})$ has ambiguous sign because it is the result of two opposite effects of expected inflation: the real income effect (with negative sign) and the intertemporal substitution effect (with positive sign).

3.4 Banks and Central Bank

In order to obtain bank's credit supply, let us first compute the probability of default on loans.

Since firms are ex-ante homogenous, banks have no screening problems. However, they incur monitoring costs whenever a firm defaults on payments. Since the incentive to monitor firms exists up to equality between credit recovery and monitoring cost, without loss of generality we can set the net revenue from defaulting firms to zero¹³.

Default occurs in all states such that

$$(7) \quad \tilde{P}_{jt+1} < V_t$$

where $V_t \equiv L^d R_t / Q(t)_{t+1}$ is the firm's debt-output ratio at time t . Since, from the assumption of rational expectations, the probability distribution of \tilde{P}_{jt+1} is unique and common knowledge, and from the assumption of firms' ex ante homogeneity V_t is the same for all firms, the default probability is also the same for all firms and can be computed as

$$(8) \quad \phi_t = \text{Prob}(\tilde{P}_{jt+1} < V_t) = F(V_t)$$

From these premises, we can now obtain the competitive interest rate on loans charged by banks. Because of the time structure of the economy, banks' balance sheets evolve intertemporally over production periods. At the beginning of each t , a bank b can grant loans L^s_{bt} . Loans finance the wage bill for period t which is redeposited on behalf of households. Hence the resulting balance sheet is

$$(9) \quad L^s_{bt} = D_{bt}$$

In view of the fact that households will claim on D_{bt} one period later, the bank should secure itself a sufficient amount of liquid resources. This requirement acts as a

¹³ If this value were positive, the credit risk premium would be lower. This, however, has no significant impact on the core results (qualitative and quantitative) of the model. The reason is that the bank lending rate would remain approximated by a log-linear relationship with the central bank rate and the risk premium (see eqs. 10 and 11). Of course, the spread would be smaller, and changes in credit risk would have smaller effect, but nothing would change as far as shifts in the central bank rate are concerned.

liquidity constraint on the bank's decision problem¹⁴. The bank expects a gross return from loans $E_t Z_{bt+1}$. As is clear from (9), if all firms repaid capital, the bank would be certain that its liquidity constraint would be satisfied. Yet each loan at time t embodies (the same) default risk ϕ_t . Therefore, recalling that the bank expects zero net revenue at time $t+1$ from each defaulting firm, it anticipates a liquidity risk (the probability of capital repayments falling short of deposits) equal to $L^s_{bt}\phi_t$ associated with its loans portfolio. The bank can insure itself against this risk by borrowing reserves BR_t from the central bank at the gross official interest rate $K_t \equiv (1 + k_t)$, i.e. it can cover all illiquidity states $L^s_{bt}\phi_t$ under the obligation to repay $L^s_{bt}\phi_t K_t$ in $t+1$.

Hence the bank's expected gross return on the loan portfolio at the market gross rate R_t is $E_t Z_{bt+1} = L^s_{bt} R_t (1 - \phi_t)$, while its expected net profit is

$$(10) \quad L^s_{bt} R_t (1 - \phi_t) - L^s_{bt} K_t \phi_t - L^s_{bt} \geq 0$$

Competitive pressure will drive this expression to equality, with the bank gross interest rate equal to¹⁵

$$(11) \quad R_t = \frac{1 + \phi_t K_t}{1 - \phi_t}$$

A simple algebraic manipulation allows a more transparent interpretation of this result. The actual interest rates can be approximated by $r_t \approx \log R_t$ and $k_t \approx \log K_t$. In addition, if k_t is a small fractional number, i.e. around $K_t = 1$, the logarithm of expression (11) is closely approximated by

$$(12) \quad r_t \approx \rho_t + k_t$$

where $\rho_t = \log \frac{1 + \phi_t}{1 - \phi_t}$ is a proxy for credit risk increasing in ϕ_t . Hence, r_t can be

interpreted as the sum of the official rate plus a credit risk premium providing the link between the policy rate and aggregate supply.

4 Macroeconomic Equilibrium and the Effects of Monetary Policy

The relationships obtained in the previous section can be summarized as follows

Labour market

$$(13) \quad N^d(\Gamma_t) = N^s(\underline{W}_t, E_t \pi_{t+1}),$$

¹⁴ The amount of liquid resources is generally given by the statistical expectation of withdrawals, i.e. the aggregation of the individual withdrawals $C(D_{ht}) \leq D_{ht}$ from our households' model. Having assumed $C(D_{ht}) = D_{ht}$ for all h , the bank's liquidity constraint should strictly hold as equality.

¹⁵ Note that the following result is independent of expected inflation. In fact, if we take the bank's expected real net profit and deflate (10) by expected inflation, we still obtain (11).

Credit market

$$(14) \quad L_t = W_t N_t$$

$$(15) \quad D_t = L_t$$

$$(16) \quad r_t \approx \rho_t + k_t$$

Output market

$$(17) \quad Q(N^d(\Gamma_t)) = C(\underline{D}_t, E_t \pi_{t+1})$$

$$(18) \quad E_t \pi_{t+1} = E_t(\tilde{P}_{t+1}/P_t) - 1 = P_{t+1}/P_t - 1$$

This model indicates that, for any given change in the policy interest rate k_t or in credit risk ρ_t , macroeconomic general equilibrium implies a corresponding set of values for output, inflation, real wage rate, and nominal and real interest rates. The aim of the following analysis is to detect whether, with no ancillary hypotheses like monopolistic competition or wage-price stickiness, variations of k_t can, under certain conditions to be discussed below, modify macroeconomic equilibrium in a way that is consistent with the set of stylized facts regarded as the *explanandum* of monetary macro-models¹⁶. Namely,

- negative correlation between the policy rate and the real wage, $d\underline{W}_t/dk_t < 0$ ¹⁷, (future) output $dQ(t)_{t+1}/dk_t < 0$ ¹⁸, and inflation, $d\pi_{t+1}/dk_t < 0$
- output reacting more than prices, $|dQ(t)_{t+1}/dk_t| > |d\pi_{t+1}/dk_t|$

To begin with, Appendix A1 shows that the model can be expressed in terms of total "rates of change" of the endogenous variables $\delta\underline{W}_t$, $\delta Q(t)_{t+1}$ and $\delta\pi_{t+1}$, with respect to a (permanent) change in the policy rate δk_t at time t (where for any variable X , $\delta X \equiv dX/X$). The system's behaviour is regulated by six parameters corresponding to the elasticities of the relevant functions, that is (defining $Y_x \equiv \partial Y/\partial X \div Y/X$): $-N^d_\Gamma$ (labour demand w.r.t. real unit cost), Q_N (output w.r.t. labour input), N^s_w (labour supply w.r.t.

¹⁶ A critical issue is whether ρ_t can be regarded as independent of k_t . This may not be the case if credit risk (see eq. (7)) is sensitive either to the bank lending rate and/or to the loan/output ratio of firms. This is basically an empirical matter depending on the production function and the ensuing demand for labour. From equation (7), it can easily be checked that a Cobb-Douglas function, as will be assumed in the empirical assessment, implies that credit risk is constant.

¹⁷ The set of variables to explain also include profits. I do not treat them explicitly in the model. The reason is that profits' behaviour depends on technology. If a Cobb-Douglas technology is assumed as in the quantitative assessment of the model, it is easy to see that total profits (on average) are a constant share of output, and hence fall with output and total wages after a monetary contraction.

¹⁸ Since output is a positive function of employment, this condition includes the observed effects of the policy rate on employment. In the absence of sticky prices, the present model suggests that the other well-known fact of the time lag between the monetary intervention and the change in output and inflation can be traced back to the production gestation time. This is of course a matter of empirical analysis, as is the sticky price assumption, that will not be addressed here. Moreover, the analysis will be run by comparing rational-expectations equilibrium states of the economy, that is to say, when all transitory adjustments due to frictions and imperfections have petered out.

real wage), $-N^s_\pi$ (labour supply w.r.t. expected inflation), C_D (consumption w.r.t. real deposits), C_π (consumption w.r.t. expected inflation). Other available models of the credit or cost channel usually include subsets of these parameters (see the literature in Section 2), depending on the structure of the model economy and on the specific utility and production functions assumed. The first result provided in the Appendix (see (A2)) is that the model presented here encompasses the desired adjustment pattern of the endogenous variable as a possible result of *particular combinations* of values of *all* these parameters. To gain further insight, we may resort to the consensus estimates of some critical elasticities to be found in the literature.

4.1 A Quantitative Assessment

First of all, it is generally the case in industrialized countries that $Q_N < 1$, and that Q_N is consistent with the labour coefficient of a Cobb-Douglas production function, say α . If we accept this restriction, then it follows that $-N^d_\Gamma = -1/(1 - \alpha)$. A consensus value of Q_N may be around 0.6 (e.g. CEE, p.1232), which implies $-N^d_\Gamma = -2.5$.

Given these two parameters, the signs of the total variations of the endogenous variables eventually depend on the relative size of the parameters governing household behaviour, namely N^s_w , N^s_π , C_D , C_π . These represent a much more controversial issue, especially on empirical grounds.

To begin with, let us see the conditions that are required to obtain the desired adjustment pattern set out above (with elasticities appearing in absolute values)

- $\alpha < C_D < 1$
- $C_\pi < \frac{\alpha(1 - C_D)}{1 - \alpha}$
- $N^s_w > \frac{C_D(1 + \alpha N^s_\pi)}{\alpha(1 - C_\pi) - C_D(1 - \alpha)}$

(note that the third condition is necessary only for $|dQ(t)_{t+1}/dk_t| > |d\pi_{t+1}/dk_t|$).

As to C_D it should first be noted that in our model (with zero nominal interest rate and non-human wealth, and no borrowing against future incomes) the $t+1$ real value of deposits as of time t ($E_t(\underline{D}_t/\Pi_{t+1})$) is equivalent to the present value of total wealth in the standard, permanent income consumption model. Hence, $0.6 < C_D < 1$ is consistent with a large body of empirical evidence, a major example being the " λ model" of Mankiw and Campbell (1991). " λ " is meant to capture various imperfections in households' consumption planning relative to the standard model (where $\lambda = 0$), and $1 - \lambda$ is the corrected elasticity of consumption w.r.t. permanent income. Mankiw and Campbell's estimates of λ for various countries, broadly confirmed by subsequent independent works, imply that $C_D = 0.7$ may be regarded as a representative size of this parameter. Note that, with reference to our model of household behaviour in 3.3, $\lambda > 0$ is consistent with the assumed no-borrowing constraint. If this constraint is relaxed, consumption becomes less sensitive to available real deposits and C_D is reduced. As will be seen below, low values of C_D play in favour of the required parametric conditions.

Inserting the foregoing values of $\alpha = 0.6$, $C_D = 0.7$, into the first two inequality conditions we obtain $C_\pi < 0.45$, where C_π represents the elasticity of intertemporal substitution in consumption¹⁹. Early investigations at the macro-level converged on the conclusion that this elasticity is unlikely to exceed 0.1-0.2 and may well be zero (e.g. Hall (1988), and Hahm (1998) for a survey). Mankiw and Campbell's joint estimates of this elasticity with λ confirmed this finding. Recent calibrations of this parameter fall in the same range of values (see e.g. Woodford (2003, ch. 5)). Hahm (1998), however, obtained significant values of about 0.3 for both durables and non-durables. Higher significant values were instead found in the micro-data (e.g. Attanasio and Weber (1995)). We may therefore conclude that the first two inequalities, which grant the desired negative correlations between k_t and $Q(t)_{t+1}$, π_{t+1} and \underline{W}_{t+1} , can be satisfied by parameter values in the range of empirical findings.

Let us now turn to the third inequality and the parameters in the labour supply function. The wage elasticity N_w^s is discussed at length in the CEE paper. They warn that the size of this parameter is yet another contentious issue. In this case, microeconomic studies tend to yield negligible values whereas macroeconomic ones point to sizeable estimates, generally well above 1. CEE choose 1 as the benchmark value for their comparative exercises. Closely related to this issue is the one concerning the labour-supply intertemporal counterpart of consumption, that is, N_π^s . This parameter is absent from the CEE model, but it has drawn a substantial amount of attention spurred by the early real business cycle literature. Overall, the general opinion seems that N_π^s is probably close to zero (e.g. Mankiw (1989)), so that we may take 0.1 as a tentative value.

Inserting $\alpha = 0.6$, $C_D = 0.7$, $-N_\pi^s = -0.1$ into the third inequality condition we obtain $N_w^s > 18.5(8-15C_\pi)^{-1}$, given $C_\pi < 0.45$. In the first place, this range for C_π is consistent with N_w^s being positive. If we consider the relatively high value $C_\pi = 0.3$ proposed by Hahm, it follows that $N_w^s > 5.3$. This latter result seems to confirm CEE's conclusion that quite a large wage elasticity of labour supply is necessary for the cost channel to generate larger adjustments in quantities than in prices. However, the CCC model shows that this conclusion should be qualified, in that N_w^s interacts with the other parameters, in particular those governing households' forward-looking behaviour, which are absent in the CEE model. This same point has been made by Pfajfar and Santoro (2007), who find that the ratio between N_w^s and C_π should be greater than one. In this regard, it should be noted that the threshold value of N_w^s falls as C_π and N_π^s fall. For instance if C_π and N_π^s were actually close to zero, the threshold value for N_w^s would fall to 2.1. This is a figure in the range of estimates at the macro-level, and it is a comforting result with respect to the real business cycle approach, where it is generally required that N_π^s and N_w^s be both large. Other factors reducing the value of N_w^s that yields the desired outcome are a larger labour elasticity of output α and/or a smaller propensity to consume C_D .

Overall, we may conclude that our general representation of the CCC is likely to generate the pattern of adjustments typically observed after a monetary shock under plausible empirical conditions, in particular small intertemporal elasticities of

¹⁹ As recalled above, given $E_t(D_t/\Pi_{t+1})$, standard consumption theory indicates that C_{t+1} may also respond to intertemporal substitution incentives, which, with zero interest rate, arise from the expected *subsequent* path of inflation. After a permanent monetary shock at the beginning of t , households (rationally) figure out a new expected inflation path with $E_t\pi_{t+1}$ remaining constant from $t+1$ onwards.

substitution for consumption and labour supply. Moreover, the choice of not considering goods and labour market imperfections has only been dictated by reasons of a theoretical nature, namely to show that these are not necessary to obtain results that match the observed facts. Nonetheless, these imperfections are pervasive in real economies, and adding them to the basic model may enhance its likelihood. As regards equilibrium states of the economy, rather than transitory dynamics, so-called "real rigidities" are more relevant than nominal ones. For instance, as also suggested by CEE, the presence of a real rigidity in the labour market may yield the desired pattern of outcomes even with a very low labour-supply elasticity to the wage rate. Subsequent works by Christiano and co-authors (e.g. 2007b) have moved in this direction.

4.2 The CCC at Work

It was pointed out in Section 1 that the supply-side effects of the CCC of monetary policy may not only provide a consistent account of the stylized facts discussed in the previous paragraph, but they may also shed light on other broader issues concerning the macroeconomic effects of monetary policy, such as the co-movements of aggregate demand and supply or the long-run effects of monetary policy.

In this regard, it may be useful to examine the entire adjustment process of the economy under the conditions established in 4.1²⁰. Assume that the economy is in equilibrium and consider the case that, as the labour and credit markets are opened at the beginning of period t , the central bank raises the policy rate k_t . First of all, the nominal bank rate r_t increases. The key point is how firms react, and this depends on the real interest rate *vis-à-vis* the real wage rate (see Figure 2).

Suppose firms expect that a higher r_t will lower inflation; then they anticipate a higher *real* interest rate which leads them to cut labour demand. As the current wage rate falls, households are induced to supply less labour (according to N^s_w), while the expected lower inflation induces them to supply more (according to N^s_π), imposing further competitive pressure on \underline{W}_t . If the overall fall of the real wage rate does not offset the rise in the real interest rate (N^s_π is relatively small, N^s_w is relatively large), firms are left with higher real unit costs. The consequence is a net cut in employment and production.

Moving to the output market (see Figure 3), in the (π, Q) space, aggregate supply is vertical because the quantity produced can no longer be changed. Aggregate demand is downward sloping owing to the real balance effect on deposits (regulated by the parameter C_D). As a consequence of what was described in Figure 2, the output market opens with less supply than in the previous period. In parallel, less employment at a lower wage rate has generated fewer bank loans and deposits: this shifts aggregate demand as well. Demand may also be displaced further by the fact that anticipated deflation from $t+1$ onwards shifts consumption from $t+1$ to the future (according to C_π). The rational expectations hypothesis implies that the component of supply and demand changes due to anticipated deflation should be consistent with the actual fall in the inflation rate.

The co-movement of demand and supply is the key factor in the CCC transmission mechanism that impinges upon the response of the price index. Since aggregate demand

²⁰ Compare with the graphical analysis in CEE, sec. 4.

and supply are both negatively affected by the policy rate (and supply is non-decreasing in the inflation rate), then 1) inflation falls with output (no "price puzzle") as the shift of aggregate demand is larger than that of aggregate supply; 2) the flatter is the aggregate demand curve, the less inflation falls with respect to output, the more a *seemingly sticky-price effect* occurs²¹.

Figure 2: The Labour-Market Response to an Increase in the Bank Interest Rate

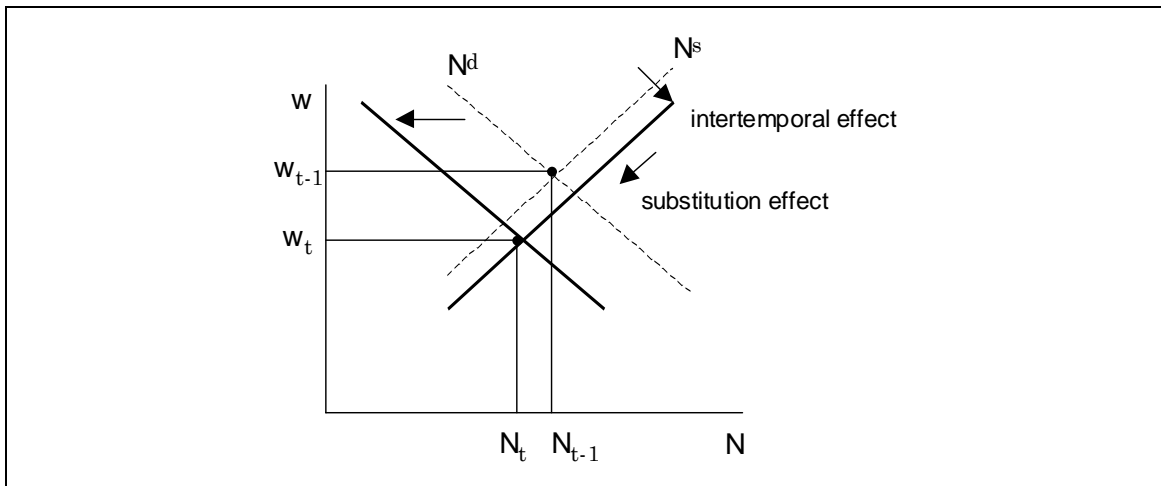
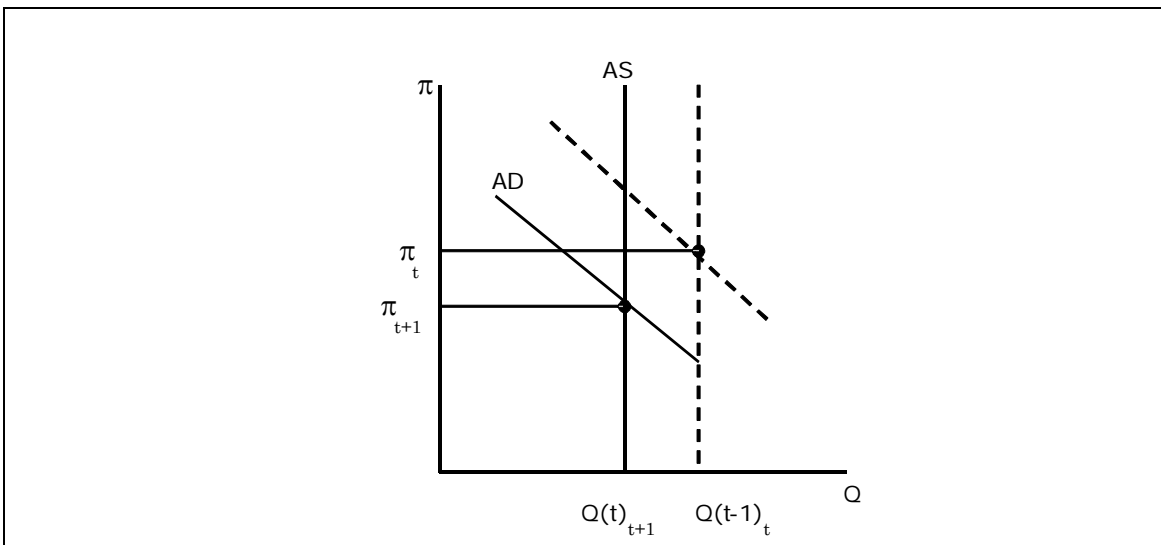


Figure 3: The Output-Market Response to an Increase in the Bank Interest Rate



²¹ Note the difference from models with sticky-price-making firms such as those of the type developed by Chowdhury et al. (2006) and Ravenna and Walsh (2006). In this type of models aggregate demand movements play no role. The relationship among the policy rate, the inflation rate and output is only intermediated by the relative movement of marginal costs and optimal markup in the face of policy shocks. The price effect of policy interventions may be reversed (e.g. raising the interest rate also raises inflation) only if the pass-through of firms is sufficiently strong (Chowdhury et al. do not find evidence of this for the G7 countries). For instance, in the case of flexible prices examined by Ravenna and Walsh, the final effect of the interest rate of output is, in our terms, simply given by $(N_w + C_\pi)^{-1}$ (compare with Appendix here), but with no (or constant) markup, the inflation rate is undetermined.

If the conditions indicated by the theoretical model hold, the basic policy message is that managing the interest rate is an effective means to curb inflation to the extent that the agents *anticipate* that the *real* interest rate will be raised sufficiently (relative to the real wage rate). This is in line with the majority view as expressed for instance by Woodford (2003, ch. 4)²². On the other hand, as argued by Ravenna and Walsh (2006), the cost channel of monetary policy, *even with flexible prices*, generates the typical output-inflation trade-off which makes disinflation a non-trivial policy problem, contrary to the "divine coincidence" that makes it disappear in the Standard NNS framework with the sole demand-side effects. In other words, there is no reason to rule out the case that monetary policy has permanent real effects.

Note, also, that it may therefore not be sufficient for the central bank to monitor only inflation, since it may react too little to large adjustments in economic activity due to the co-movement of aggregate demand and supply. As argued by an increasing number of scholars, it seems necessary for central banks to include credit-market indicators in their information apparatus, and make it clear to the public that they may react to these indicators as well (e.g. Crockett (2003), Christiano et al. (2007c), Leijonhufvud (2008)).

Though not developed here (see e.g. Passamani and Tamborini (2007)), also worth considering is the interplay between the policy interest rate and credit risk – another hot issue at present. As can easily be seen, in the CCC model the latter has essentially the same macroeconomic effects as the former. Consequently, there is clear scope for monetary policy as a means to offset shifts in credit risk with undesirable macroeconomic consequences. This consideration is enhanced if account is taken of the empirical finding that credit risk premia tend to be anticyclical (i.e. they rise during downturns; e.g. Marcucci and Quagliariello (2005)), so that they amplify the impact of monetary policy on the economy.

5 Conclusions

In this paper I have put forward a CCC model of monetary policy. The thrust of the model is that firms' reliance on bank loans makes aggregate supply dependent on the official rate controlled by the central bank and a credit risk premium charged by banks on firms. Joint consideration of the two credit and cost channels brings out some attractive features: it may overcome the weaknesses of models that consider each channel separately, it brings the banking sector back to the forefront, and it highlights the role of credit risk at the macroeconomic level.

As far as monetary policy is concerned, it has been shown that under plausible values of the relevant parameters, an exogenous change in the policy interest rate in the CCC model yields a pattern of relationships broadly consistent with the set of empirical regularities today regarded as the *explanandum* of monetary macroeconomics – with particular regard to the labour market – with no recourse to additional goods and labour market imperfections or other *ad hoc* frictions. Moreover, the presumption arises that the CCC may also have permanent, rather than transitory, effects on real variables.

²² Woodford (e.g. 2003, ch. 1) also stresses the change of perspective in the modern theory of monetary policy from shocking the economy unexpectedly to steering the economy by means of systematic, fully anticipated, policy conduct.

Addition of goods or labour market imperfections, however, in particular in the form "real rigidities" in the labour market, may further enhance the explanatory power of the model.

Another line of development concerns policy implications. The CCC model indicates three main issues. First, the need for monetary-policy models to include supply-side effects. Second, the importance of explicit treatment of the banking sector as a link between monetary policy and the supply side. Third, the inclusion of credit-market indicators among the signals to which the central bank is expected to react.

This paper has been devoted to the theoretical assessment of the CCC model. Of course, its applicability and explanatory power in specific economies eventually depend on their structural and institutional features, and should be a matter of empirical investigation using appropriate econometric techniques (e.g. Passamani and Tamborini (2008)).

Appendix

Let us consider the complete model given by the intertemporal equilibrium conditions of the labour and credit markets in each period t , and of the output market in the subsequent period $t+1$.

$$\begin{aligned}
 \text{(A1)} \quad & \text{a) } N^d(\Gamma_t) = N^s(\underline{W}_t, E_t\pi_{t+1}) \\
 & \text{b) } L_t = W_t N_t \\
 & \text{c) } D_t = L_t \\
 & \text{d) } r_t \approx \rho_t + k_t \\
 & \text{e) } Q(N^d(\Gamma_t) = C(\underline{D}_t, E_t\pi_{t+1}) \\
 & \text{f) } E_t\pi_{t+1} = E_t(\tilde{P}_{jt+1}/P_t - 1) = P_{t+1}/P_t - 1
 \end{aligned}$$

We can now examine the response of the system to variations in what we may call the "CCC variables": k_t , which represents the monetary policy variable, and ρ_t , which represents an autonomous component of credit supply. The effects on the real wage rate \underline{W}_t , output $Q(t)_{t+1}$ and the inflation rate π_{t+1} are obtained by totally differentiating the equations of the system around the steady state. This yields the Jacobian matrix of system (A1). It may be convenient to skip the formulation with all generic partial derivatives and move to the formulation in terms of elasticities.

Under suitable conditions (or normalization of initial values) the partial derivatives in the Jacobian matrix of system (A1) can be translated into elasticities, i.e. $Y_x \equiv \partial Y/\partial X \div Y/X$. Accordingly, the appropriate measure of total variations is in relative terms or "rates of change" denoted by $\delta X_t \equiv dX/X$. Secondly, let the production function be of the Cobb-Douglas class, with α denoting the labour-input coefficient. Then, $Q_N = \alpha$, while the total variation of employment is $\delta N^d_t = -N^d_t \delta \Gamma_t = -(1-\alpha)^{-1}(\delta \underline{W}_t + \delta k_t - E_t \delta \pi_{t+1})$. Moreover, as explained above, the total variation of consumption can be split between the income effect (with elasticity C_D) and the intertemporal substitution effect (with elasticity C_π), i.e. $\delta C_{t+1} = C_D(\delta \underline{D}_t - E_t \delta \pi_{t+1}) + C_\pi E_t \delta \pi_{t+1}$. Remember that by definition $\delta \underline{D}_t = \delta \underline{W}_t + \delta N^d_t$. Since the transmission mechanism of the two CCC variables is the same, let us focus on k_t . Imposing the rational expectations constraint, $E_t \delta \pi_{t+1} = \delta \pi_{t+1}$ we obtain

$$\begin{aligned}
 \text{(A2)} \quad & \begin{bmatrix} \delta \underline{W}_t \\ \delta Q(t)_{t+1} \\ \delta \pi_{t+1} \end{bmatrix} = \frac{1}{\Delta} \begin{bmatrix} N_\pi^s(\alpha - C_D) + C_\pi - C_D \\ C_\pi N_w^s - (N_w^s - N_\pi^s)C_D \\ N_w^s(\alpha - C_D) - C_D \end{bmatrix} \delta k_t \\
 & \Delta = \alpha(N_w^s - N_\pi^s)(1 - C_D) - C_\pi(1 + N_w^s(1 - \alpha))
 \end{aligned}$$

The signs of the total variations are ambiguous and depend on the particular values taken by the elasticities. The discussion of the solutions for empirically-based values of elasticities is developed in the paper.

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