Imperfect credit markets and the transmission of macroeconomic shocks

Gertjan W. Vlieghe*
Bank of England and London School of Economics

Preliminary and incomplete, do not cite.
2 March 2004 (first version January 2003)

Abstract

This paper outlines a monetary model of a production economy with an explicit role for credit in allocating investment funds to the agents with the most productive projects. Due to limited commitment, credit markets are imperfect and collateral is required. This provides a role for asset prices and borrower net worth in investment decisions. In particular, the wealth distribution directly affects the productive capacity of the economy, by influencing the respective holdings of capital by agents with high and low productivity. Small, temporary shocks that affect output or asset prices can have large and persistent effects on current and future output. The interaction between the wealth distribution and the productive capacity of the economy has important implications for the role of monetary policy. Since some of the output variability is the result of credit frictions, it is not efficient. In contrast to standard sticky-price models, it may not be not optimal for monetary policy to try and achieve the flexible-price level of output.

*I thank Nobuhiro Kiyotaki for invaluable advice and encouragement. I also thank David Aikman, Kosuke Aoki, Kalin Nikolov, Thomas Sargent, Andrei Sarychev, Lars Svensson, Tony Yates and participants at the London School of Economics Money and Macro seminar and the Bank of England seminar for helpful comments. This paper does not reflect the opinion of the Bank of England or the Monetary Policy Committee. All errors are solely the author's responsibility.

1 Introduction

This paper aims to address the following questions. If credit market imperfections are an important feature of the economy, how might they affect the economy's response to shocks? Furthermore, if monetary policy can influence real outcomes in the short run, how do credit market frictions alter the effect of systematic monetary policy?

Any model to address these questions needs to have the following features: a role for credit and a role for monetary policy. To generate a role for credit in the economy, it is necessary to introduce some imperfection so that heterogeneity across agents matters. The model in this paper will feature heterogeneous agents who operate in a credit market where enforcement problems exist, and only a limited set of securities are available. In such a setting, the distribution of wealth across agents will affect aggregate outcomes.

To allow monetary policy to influence aggregate real outcomes, there has to be some friction, or non-neutrality, preventing instantaneous adjustment of prices, wages, debt contracts or asset portfolios. My approach is to assume that product prices cannot fully adjust, but the results of the paper do not hinge crucially on this particular choice of non-neutrality.

The model economy consists of ex-ante identical entrepreneurs who can produce intermediate goods using capital, which is in fixed supply (e.g. land), and a variable input. Using the approach of Kiyotaki (1998), I assume that some entrepreneurs are more productive than others, but spells of high productivity do not last, and arrive randomly. While an entrepreneur is highly productive, he will want to invest as much as possible in his own technology. Entrepreneurs with low productivity, on the other hand, would rather invest in the technology of high productivity entrepreneurs, as this generates superior returns. Let us therefore call the entrepreneurs that currently have high productivity 'producers', and the entrepreneurs with low productivity 'investors'. In principle, investors could lend to producers so that producers end up applying their technology to the entire capital stock. This would be the first-best outcome. But it is assumed that there are credit market imperfections, so borrowing is permitted against collateral. The larger the net worth of the borrower, the more capital he can buy. Moreover, since capital serves as collateral as well as a factor of production, an increase in the value of capital will increase the net worth of a producer who already had some capital installed and therefore allow him to buy more capital. The model also features workers, who provide labour to entrepreneurs. Workers do not have access to productive technology. They therefore do not hold capital. This also means that they do not hold any collateral, so they are not able to borrow. Finally, while entrepreneurs sell their intermediate goods output in competitive markets, there is a monopolistically competitive sector that buys intermediate inputs and produces diversified final consumption goods. It is assumed that not all final goods producers can adjust the nominal price of their output in each period.

In the baseline model, I assume that some fraction of final goods producers have to set prices one period in advance. Not all prices can therefore adjust instantaneously, and nominal changes can therefore have short-run real effects. In traditional models with this type of price stickiness, most or all of the short-run real effects die out when all agents have been able to change their prices. But in this model, the redistribution of wealth caused by any nominal shock will continue to have real effects even after all prices have adjusted, because the wealth distribution across agents, which affects aggregate outcomes, only returns to its stationary distribution slowly as producers rebuild their share of wealth. Monetary policy therefore works through wealth redistribution as well as through sticky prices, a powerful mechanism emphasised by Fisher (1933).

The effect of the wealth distribution on aggregate output works as follows. Following a shock that reduces current output and/or the price of capital, the net worth of producers falls by more than the net worth of investors, because producers are highly leveraged. This means that producers can only afford to buy a lower share of the total capital stock for production in the following period. Because capital shifts to those with lower productivity, this reduces expected future returns, which depresses the value of capital today, and exacerbates the initial redistribution of wealth from producers to investors. If the difference in productivity between investors and producers is high enough, output falls further in the subsequent period, as the capital stock is now used much less efficiently. The model is therefore able to generate a 'hump-shaped' response of output, i.e. one that gets amplified further following the initial shock. It takes time for the producers to rebuild their share of the wealth distribution to its steady-state level, and output is therefore below its steady-state level for many periods, even if the initial disturbance only lasted a single period.

The mechanism described so far is entirely real, i.e. operates even in an environment where monetary policy has no real effects. So what is the effect of monetary policy? Sticky prices reduce the initial redistribution following a productivity shock: when output is temporarily lower, nominal goods prices need to rise for a given systematic monetary policy response that does not fully accommodate the fall in output. But nominal prices cannot rise enough, because they are sticky, so output increases relative to the case where prices are fully flexible. So while the direct effect of an adverse productivity shock is obviously to lower output, the effect of sticky prices is to mitigate this fall somewhat. Since the initial output effect is smaller under sticky prices, the redistribution from producers to investors is also smaller, and the price of capital will fall by less. The entire credit mechanism is therefore weakened.

Relative to the existing literature on monetary policy and credit frictions, the modeloffers the following insights. First, credit frictions are a potential source of persistence in the output response to shocks. Such endogenous persistence is usually absent from existing models [1] Note that the persistence manifests itself as persistent variation in aggregate total factor productivity, even if actually total factor productivity in the model is white noise. And unlike models where total factor productivity is entirely exogenous, in this model aggregate total factor productivity is driven not only by exogenous shocks to firm-level total factor productivity, but by anything that affects credit and asset prices, such as monetary policy. Second, the fact that credit frictions affect not only demand, but can affect aggregate supply as well, has important consequences for the desirable systemic response of monetary policy to shocks. If credit frictions affect aggregate supply, aggressive systematic monetary policy can generate an inefficiently large output response. A trade-off therefore exists between deviations of output from its efficient level and deviations of inflation from its efficient level. Such a trade-off is not generally present in traditional monetary models, unless one considers shocks that hit the price level directly.[2]

The remainder of this paper is organised as follows. Section (2) presents

[1] King, Plosser, Rebelo (1999) document the absence of endogenous persistence in the real business cycle model, and Woodford (2003) and many others discuss the absence of endogenous persistence in the baseline so-called Dynamic New-Keynesian models.

[2] In models such as those discussed by Clarida, Gali and Gertler (1999) and Woodford (2003), the level of output that prevails under flexible prices is the appropriate target for monetary policy, and this level can theoretically be achieved as long as there are no direct shocks to the price level. For the case of productivity shocks, there is therefore no trade-off between output fluctuations from their flex-price level and inflation deviations from target. This is not the case if other frictions are added. For example, Erceg, Henderson and Levin (2000) show that a trade-off also exists both wages and prices are sticky.

the model in detail. Section (3) outlines the competitive equilibrium. Section (4) presents quantitative results, section (5) discusses the related literature and section (6) concludes.

2 The environment

The model features a basic credit frictions mechanism due to Kiyotaki (1998), which is extended to allow for endogenous labour supply, monopolistic competition and a role for monetary policy.

There is a continuum of entrepreneurs. They are identical in terms of preferences. Their production technology is also identical, up to a productivity factor, which randomly switches between high (α) and low (γ). Denote those who currently have high productivity 'producers', and those who currently have low productivity 'investors'. The productivity factor follows an exogenous Markov process with probability matrix

$$P = \begin{bmatrix} 1-\delta & \delta \\ n\delta & 1-n\delta \end{bmatrix}$$

so the probability of switching from high productivity to low productivity is δ, and the probability of switching from low productivity to high productivity is $1 - n\delta$. This probability matrix implies that from any initial distribution, the distribution will converge to a stationary distribution with a ratio of productive to unproductive agents of n. In addition to the random fluctuation that each agent experiences between high and low productivity, there are aggregate productivity shocks, which affect all agents equally. To reflect these aggregate fluctuations I will put a time subscript on the productivity levels, α_t and γ_t.

Producers maximise life-time utility given by

$$\max_{c_t} \sum_{t=0}^{\infty} \beta^t \ln c_t$$

s.t. budget constraint,

$$c_t + x_t + q_t(k_t - k_{t-1}) + w_t l_t = \frac{y_t}{\varphi_t} + \frac{b_{t+1}}{r_t} - b_t$$

[add nominal bonds to budget constraint] production technology,

$$y_t = \alpha_t \left(\frac{k_{t-1}}{\sigma}\right)^{\sigma} \left(\frac{x_{t-1}}{\eta}\right)^{\eta} \left(\frac{l_t}{1-\eta-\sigma}\right)^{1-\eta-\sigma}$$

and borrowing constraint

$$b_{t+1} \leqslant E_t q_{t+1} k_t$$

The variable c_t denotes consumption, x_t denotes a non-durable input (eg inventories), k_t denotes durable capital, w_t denotes the wage paid, l_t denotes the quantity of labour employed, b_{t+1} denotes the amount of real borrowing taken out at time t and repayable at time $t+1$, and q_t is the price of capital.

It is assumed that producers do not consume their output directly, but sell it to a monopolistically competitive retailer, who then offers the diversified goods back to producers, investors and workers with a markup of φ_t. All variables are denominated in terms of a consumption index. Define a Dixit-Stiglitz (1977) aggregate of a continuum of differentiated goods of type $z \in [0,1]$ each with price $p(z)$

$$c_t = \left[\int_0^1 c_t(z)^{\frac{\theta-1}{\theta}} dz\right]^{\frac{\theta}{\theta-1}}$$

The corresponding price index, defined as the minimum cost of a unit of the consumption aggregate, is defined as

$$p_t = \left[\int_0^1 p_t(z)^{1-\theta}\right]^{\frac{1}{1-\theta}}$$

For simplicity, it is assumed that inventories are costlessly created from the consumption goods and used in the same Dixit-Stiglitz aggregator, so that their relative price in terms of the consumption index is 1.

Following Kiyotaki and Moore (1997), borrowing constraints are interpreted as follows: it is assumed that when an entrepreneur has installed some capital, he invests some specific skill into that capital to generate output. The total value of his project is therefore the next period resale value of the installed capital plus the value of the output that can be generated using his specific skill. But he cannot commit to investing his specific skill: once the capital is in place, he can always choose to walk away. Because of this inability to commit to full repayment, the investor will never lend more than the resale value of capital. It is assumed that, should the value of collateral fall short of what was expected at the time the loan was taken out, the entrepreneur still repays the borrowing in full, because by the time he finds out about the realisation of the aggregate shock, he has already produced, and no longer has the opportunity to walk away.[3] Also following Kiyotaki and Moore (1997), it is assumed that, after the initial uncertainty about aggregate productivity is resolved, agents assume that future aggregate productivity is constant. In other words, their decisions are assumed to be unaffected by aggregate uncertainty. This certainty-equivalence principle can also obtained if a quadratic utility function is considered. I do not take this route, however, because I want to exploit particular functional forms to obtain very simple decision rules, which are exact if there is no aggregate uncertainty, and which will be a reasonable approximation if aggregate uncertainty is small. Although in such an environment agents are not strictly evaluating the mathematical expectation of variables with respect to the distribution of aggregate shocks, I will retain the mathematical expectations notation to highlight which variables are not known at time t.

It is useful to define $u_t \equiv q_t - E_t \frac{q_{t+1}}{r_t}$, the user cost of a unit of capital.

If we assume the borrowing constraint is binding, which will be verified later, we can rewrite this problem as

$$c_t + x_t + u_t k_t + w_t l_t = \frac{\alpha_t}{\varphi_t}\left(\frac{k_{t-1}}{\sigma}\right)^{\sigma}\left(\frac{x_{t-1}}{\eta}\right)^{\eta}\left(\frac{l_t}{1-\eta-\sigma}\right)^{1-\eta-\sigma} + q_t k_{t-1} - b_t$$

To solve this, we break up the problem into two steps. First, given last period's capital and intermediate goods, what is the optimal demand for labour?

$$\pi_t = \max_{l_t}\left\{\frac{\alpha_t}{\varphi_t}\left(\frac{k_{t-1}}{\sigma}\right)^{\sigma}\left(\frac{x_{t-1}}{\eta}\right)^{\eta}\left(\frac{l_t}{1-\eta-\sigma}\right)^{1-\eta-\sigma} - w_t l_t\right\}$$

This leads to the first-order condition

$$w_t = (1-\eta-\sigma)\frac{\alpha_t}{\varphi_t}\left(\frac{k_{t-1}}{\sigma}\right)^{\sigma}\left(\frac{x_{t-1}}{\eta}\right)^{\eta}\frac{l_t^{-\eta-\sigma}}{(1-\eta-\sigma)^{1-\eta-\sigma}}$$

[3] He could still have an incentive to walk away if the the debt burden exceeds not only the value of his collateral, but exceeds the value of his collateral plus current output. It is assumed that shocks are never that large.

which can also be written in the familiar form

$$w_t l_t = (1 - \eta - \sigma)\frac{y_t}{\varphi_t}$$

The maximised profit after paying for labour input is therefore

$$\pi_t = (\eta + \sigma)\frac{y_t}{\varphi_t}$$

For the second step of the producer's problem, we analyse what combination of capital and inventories he should buy to minimise expenditure, given a desired level of profits.

$$z_t = \min_{k_t, x_t} \{u_t k_t + x_t\}$$

$$s.t. \pi_{t+1} \geqslant \overline{\pi}$$

Let λ_t denote the Lagrangian multiplier on the profit constraint. Substituting the optimal level of labour demanded into the production function, the first-order conditions become

$$u_t = E_t \left\{ \lambda_t \left(\frac{\alpha_{t+1}}{\varphi_{t+1}} \right)^{\frac{1}{\eta+\sigma}} w_{t+1}^{-\frac{1-\eta-\sigma}{\eta+\sigma}} \left(\frac{\sigma}{\eta} \right)^{\frac{\eta}{\eta+\sigma}} \left(\frac{x_t}{k_t} \right)^{\frac{\eta}{\eta+\sigma}} \right\}$$

$$1 = E_t \left\{ \lambda_t \left(\frac{\alpha_{t+1}}{\varphi_{t+1}} \right)^{\frac{1}{\eta+\sigma}} w_{t+1}^{-\frac{1-\eta-\sigma}{\eta+\sigma}} \left(\frac{\sigma}{\eta} \right)^{-\frac{\sigma}{\eta+\sigma}} \left(\frac{x_t}{k_t} \right)^{-\frac{\sigma}{\eta+\sigma}} \right\}$$

This can be simplified to

$$u_t = \frac{\sigma x_t}{\eta k_t}$$

This optimal combination of inputs yields the minimised expenditure function

$$z_t = \frac{\eta + \sigma}{\sigma} u_t k_t$$

Note that λ_t is the resource cost of another unit of profit, or, in other words, $1/\lambda_t$ is the return on an investment of z_t. For convenience we define this as a new variable:

$$r_t^p \equiv E_t \left\{ \left(\frac{\alpha_{t+1}}{\varphi_{t+1}} \right)^{\frac{1}{\eta+\sigma}} w_{t+1}^{-\frac{1-\eta-\sigma}{\eta+\sigma}} u_t^{-\frac{\sigma}{\eta+\sigma}} \right\}$$

Substituting these optimal labour demand and factor demand conditions into the production function, we can now write the budget constraint as

$$c_t + z_t = r_{t-1}^p z_{t-1} + q_t k_{t-1} - b_t$$

This can be interpreted as a savings problem with uncertain returns (eg Sargent (1987)). The optimal decision rules for consumption and investment are linear in wealth:

$$c_t = (1-\beta)(r_{t-1}^p z_{t-1} + q_t k_{t-1} - b_t)$$

$$z_t = \beta(r_{t-1}^p z_{t-1} + q_t k_{t-1} - b_t)$$

2.1 Investors

Let lower-case variables with a prime denote the choices of an individual investor. The labour demand conditions facing the agents with low productivity, i.e. the investors, are the same as those for the producers, so the maximised profits after paying the wage bill are

$$\pi_t' = (\eta + \sigma)\frac{y_t'}{\varphi_t}$$

The second step of the problem, minimising the expenditure on x_t' and k_t', is solved by maximising

$$\min_{x_t', k_t'} \left(q_t - E_t \frac{q_{t+1}}{r_t} \right) k_t' + x_t'$$

$$s.t. \pi_{t+1}' \geqslant \overline{\pi}$$

Using our earlier definition of u_t, this problem is again parallel to that faced by producers, except that the rate of return for investors is

$$r_t^i \equiv E_t \left\{ \left(\frac{\gamma_{t+1}}{\varphi_{t+1}} \right)^{\frac{1}{\eta+\sigma}} w_{t+1}^{-\frac{1-\eta-\sigma}{\eta+\sigma}} u_t^{-\frac{\sigma}{\eta+\sigma}} \right\}$$

The decision rule for investors is therefore

$$c'_t = (1-\beta)(r^i_{t-1} z_{t-1} + q_t k_{t-1} - b'_t)$$

$$z'_t = \beta(r^p_{t-1} z'_{t-1} + q_t k'_{t-1} - b'_t)$$

2.2 Retailers

Retailers buy output and use a costless technology to turn output goods into differentiated consumption or input goods, which they sell onwards. The separation of producers and retailers is a modelling choice similar to Bernanke, Gertler and Gilchrist (1999) and is chosen to introduce monopolistic competition while maintaining tractable aggregation of producers. If producers operate directly in monopolistically competitive markets, the choice of the input ratio $\frac{x_t}{k_t}$ depend on the individual output level, which greatly complicates aggregation across producers and investors. Per period real profits for the retailers are given by

$$\Pi_t(p_t(z)) = \frac{(p_t(z) - p^p_t)}{p_t} y^R_t(z)$$

where p^p_t is the nominal price of output goods, so that $\frac{p^p_t}{p_t} = \frac{1}{\varphi_t}$. In other words, φ_t is the retail sector's average markup. Retailer output is denoted $y^R_t(z)$.

Demand for each retailer's output is given by

$$y^R_t(z) = \left(\frac{p_t(z)}{p_t}\right)^{-\theta} Y^R_t$$

where Y^R_t is aggregate demand for retail goods, which is given by

$$Y^R_t = \left[\int_0^1 y^R_t(z)^{\frac{\theta-1}{\theta}} dz\right]^{\frac{\theta}{\theta-1}}$$

In the baseline model, it is assumed that some fraction κ of retailers must set their price, $p_{2,t}(z)$, one period in advance, while the remainder can change their price, $p_{1,t}(z)$ each period. Each type of retailer maximises profits, leading to the following first order conditions:

$$\frac{p_{1,t}(z)}{p_t} = \frac{\theta}{\theta - 1}\frac{1}{\varphi_t}$$

$$E_{t-1}\left\{\Lambda_{t-1,t}\frac{Y_t^R}{p_t^{-\theta}}\left[\frac{p_{2,t}(z)}{p_t} - \frac{\theta}{\theta - 1}\frac{1}{\varphi_t}\right]\right\} = 0$$

The term $\Lambda_{t-1,t}$ is a discount factor applied at time $t-1$ to profits earned at time t. It is assumed that retailers are owned by workers, so it is the workers' discount factor that is relevant here. The aggregate price level evolves according to:

$$p_t = \left[(1-\kappa)p_{1,t}^{1-\theta} + \kappa p_{2,t}^{1-\theta}\right]^{\frac{1}{1-\theta}}$$

I will end up working with a linearised model, and it is convenient to note already that the first-order conditions for retailer profit maximisation, combined with the evolution of the aggregate price level, once linearised, will give the following pricing equation:

$$\widehat{\pi}_t = E_{t-1}\widehat{\pi}_t - \frac{1-\kappa}{\kappa}\widehat{\varphi}_t$$

where $\widehat{x}_t \equiv \frac{x_t - \overline{x}}{\overline{x}}$ denotes proportional deviations from the steady-state.

In an extension of the model, I consider an environment where retailers face opportunities for price changes that arrive randomly, so that price setting follows a discrete time version of the model proposed by Calvo (1983), as described, for example, in Woodford (1995), Yun (1996), Clarida, Gali and Gertler (1999) and many others. The implication is that actual prices can deviate from their optimally chosen level for more than one period following a shock, which allows for richer inflation and mark-up dynamics. The probability for each retailer of being able to reset their price equals $(1-\kappa)$ in each period, and is independent of when the last price change occurred. The retailers who can set a price at time s will maximise the intertemporal objective function:

$$E_s\sum_{t=s}^{\infty}\Lambda_{s,t}\kappa^{t-s}\left[\Pi_t(p_s^*(z))\right]$$

where $\Lambda_{s,t}$ is a discount factor applied in period s to profits expected in period t, and $p_s^*(z)$ is the optimal price chosen. Retailers are owned by workers. It is assumed that retailers (but not entrepreneurs) form a cooperative that redistributes income between those who were able to change their price and those who were not able to do so. This assumption implies that retailers do not face idiosyncratic risk. This in turn implies that all retailers who are able to change their price will set the same price, regardless of their history. This greatly facilitates aggregation across retailers.

The first-order condition for retailers who are able to change their price in period s is:

$$E_s \sum_{t=s} \Lambda_{s,t} \kappa^{t-s} \frac{Y_t^R}{p_t^{-\theta}} \left\{ \frac{p_s^*(z)}{p_t} - \frac{\theta}{(\theta-1)} \frac{1}{\varphi_t} \right\} = 0$$

The aggregate price level evolves according to.

$$p_t = \left[(1-\kappa) p_t^{*1-\theta} + \kappa p_{t-1}^{1-\theta} \right]^{\frac{1}{1-\theta}}$$

The linearised aggregate pricing condition now becomes:

$$\widehat{\pi}_t = \beta E_t \widehat{\pi}_{t+1} - \frac{(1-\kappa)(1-\beta\kappa)}{\kappa} \widehat{\varphi}_t$$

2.3 Workers

There is a set of agents in the economy who have no access to productive technology, but who can work for the producers and investors. They derive utility from consumption and leisure, and their objective is to maximise

$$\max_{c_t, l_t} \sum_{t=0}^{\infty} \beta^t \ln \left(c_t - \frac{\chi}{1+\tau} l_t^{1+\tau} \right)$$

$$s.t. c_t^w + \frac{b_{t+1}^w}{r_t} = w_t l_t + b_t^w + \Pi_t$$

where l_t is the fraction of time spent on work, and Π_t are the profits from the retail sector, which is owned by the workers. Setting the marginal utility of leisure equal to the marginal utility of consumption, the labour supply decision is

$$w_t = \chi l_t^{1+\tau}$$

It is to be verified later that the interest rate on bonds is below the rate of time preference $1/\beta$. This implies that, near the stationary state, the workers will choose not to hold any bonds, and simply consume their wage and profit income. Their consumption therefore becomes:

$$c_t^w = w_t l_t + \Pi_t$$

2.4 Monetary authorities

Prices in the economy are set in money terms. As described in Woodford (2003), it is not necessary for agents to have a well-behaved demand for money balances in order for the monetary authorities to have control of the nominal interest rate. All that is necessary is for agents to have some, possibly infinitely small, demand for money balance. I assume such a 'cashless limit' (Woodford (2003)) here, so that money balances, and therefore the central bank's balance sheet, approach zero. Given this assumption, it is a reasonable approximation to omit money from the agents' utility function and budget constraint. A similar approach is used, for example, by Aoki (2001) who also omits money balances from a model that allows the central bank to set nominal interest rates. The central bank simply announces the one-period nominal interest rate R_t, which means that it stands ready to deposit or lend any amount[4] the private sector desires at this rate, subject to a (infinitely small) spread. The spread ensures that the private sector will attempt to clear the loan market first without resorting to the central bank. The influence of the central bank on the market for loanable funds is therefore unrelated to the amount of base money, but instead works via arbitrage with the private market for loanable funds. No private agent would be willing to borrow at a rate higher than that offered by the central bank, and no private agents would deposit funds that receive a lower return that that offered by the central bank. This arbitrage mechanism is similar to the way actual monetary policy operates in countries such as New Zealand, Canada, the United Kingdom and Scandinavian countries, although in practice the spreads are of course not infinitely small. This environment gives rise to an arbitrage condition based on the marginal utility of the investors.

$$E_t \left\{ \beta R_t \frac{P_t}{P_{t+1}} \frac{1}{c'_{t+1}} \right\} = E_t \left\{ \beta r_t \frac{1}{c'_{t+1}} \right\}$$

[4]The central bank does not have better enforcement mechanisms for the collection of loan repayments than does the private sector. It will therefore not lend any funds to a producer who is already at the binding borrowing constraint.

The central bank is assumed to follow a simple rule for setting monetary policy, for example by responding to current inflation. There are also random deviations from the rule, which we will interpret as monetary policy shocks.

$$R_t = \pi_t^{\lambda} \exp(\varepsilon_t^R)$$

3 Competitive Equilibrium

We now look for a competitive rational expectations equilibrium for this model economy. This will consist of aggregate decision rules for consumption, investment, labour supply and asset holdings, and aggregate laws of motion so that market clearing and individual optimality conditions hold. Because the distribution of wealth directly affects aggregate outcomes, it becomes a state variable. As will be shown, the distribution of wealth can be summarised by the share of wealth owned by producers. While in model simulations we will consider a stochastic process for aggregate productivity α_t and γ_t, we look for a certainty-equivalent equilibrium, in the sense that agents behave as if they expect aggregate exogenous random variables to be fixed at their mean values in the future. Let capital letters denote aggregate variables. The market clearing conditions are that

$$B_t + B_t' + B_t^W = 0$$

$$K_t + K_t' = \overline{K}$$

and that labour supply equals labour demand. For the goods market, the following must hold. It is assumed that each retailer buys a single output good, turns it into a single diversified consumption/inventory good and sells it back to producers. The market clearing condition for each good is then

$$y_t(z) = y_t^R(z), \forall z, t$$

Recall that aggregate output is given by the sum across all identical output goods produced by the entrepreneurial sector:

$$Y_t + Y_t' = \int_0^1 y_t(z)dz$$

and aggregate demand for retail goods is given by

$$Y_t^R = \left[\int_0^1 y_t^R(z)^{\frac{\theta-1}{\theta}} dz \right]^{\frac{\theta}{\theta-1}}$$

In general, it is not the case that $Y_t^R = Y_t + Y_t'$, but this will be true in a neighbourhood of the steady state. It is understood that the following condition only applies in such a neighbourhood:

$$C_t + C_t' + X_t + X_t' + C_t^w = \frac{Y_t + Y_t'}{\varphi_t} + \Pi_t$$

Aggregate retailers' profits will be equal to

$$\Pi_t = \left(1 - \frac{1}{\varphi_t}\right)(Y_t + Y_t')$$

Note that the individual decision rules for consumption and investment are all linear, so that we can simply sum them to obtain aggregate decision rules and laws of motion:

$$C_t = (1-\beta)((\eta+\sigma)\frac{Y_t}{\varphi_t} + q_t K_t - B_t)$$

$$C_t' = (1-\beta)((\eta+\sigma)\frac{Y_t'}{\varphi_t} + q_t K_t' + B_t)$$

$$Z_t = \beta(r_{t-1}^p Z_{t-1} + q_t K_{t-1} - B_t)$$

$$Z_t^{'} = \beta(r_{t-1}^i Z_{t-1}^{'} + q_t K_{t-1}^{'} + B_t)$$

where the bond market clearing condition has been used, together with the fact that workers will hold no bonds near the steady-state. The following is asserted, to be verified later: I am interested in equilibria near a steady-state where the investors hold some capital. This has two implications. First, investors must then be indifferent between holding capital for production and bonds, so that they equalise the expected return to each

$$r_t^i = r_t$$

Second, because we have shown that

$$r^p = \frac{\alpha}{\gamma} r^i > r^i$$

it follows that the borrowing constraint is indeed binding near the steady-state, since producers achieve a larger return on their own productive investment than the interest rate they have to pay on the bonds they issue.

Along the certainty-equivalent path, using the fact that the borrowing constraint is always expected to bind, the expected law of motion for producers becomes

$$Z_{t+1} = \beta r_t^p Z_t$$

For investors,

$$Z'_{t+1} = \beta r_t^i Z'_t$$

Next, it is useful to define aggregate wealth as

$$W_t \equiv Z_t + Z'_t$$

We also define the share of wealth held by producers as

$$s_t \equiv \frac{Z_t}{Z_t + Z'_t}$$

We can now write a law of motion for aggregate wealth as

$$W_{t+1} = \left[r_t^p s_t + r_t^i (1 - s_t) \right] \beta W_t$$

Using the Markov-process for the way agents switch between having high and low productivity, the law of motion for the share of wealth can be written as

$$s_{t+1} = \frac{(1-\delta) Z_{t+1} + n\delta Z'_{t+1}}{W_{t+1}}$$

This can be simplified to

$$s_{t+1} = \frac{(1-\delta)\widetilde{\alpha}_{t+1} s_t + n\delta\widetilde{\gamma}_{t+1}(1-s_t)}{\widetilde{\alpha}_{t+1} s_t + \widetilde{\gamma}_{t+1}(1-s_t)} \tag{1}$$

where $\widetilde{\alpha}_{t+1} = \alpha_{t+1}^{\frac{1}{\eta+\sigma}}$ and similarly for $\widetilde{\gamma}_{t+1}$.

Using the expressions for r_t^i and r_t^p derived earlier, the law of motion for wealth can be written as

$$W_{t+1} = [\widetilde{\alpha}_{t+1} s_t + \widetilde{\gamma}_{t+1}(1-s_t)]\, \varphi_{t+1}^{-\frac{1}{\eta+\sigma}} w_{t+1}^{-\frac{1-\eta-\sigma}{\eta+\sigma}} u_t^{\frac{-\sigma}{\eta+\sigma}} \beta W_t \tag{2}$$

To complete the model, we use the aggregate budget constraint, substitute the decision rules for consumption, investment, labour, and use the fact that $W_t = (\eta+\sigma)\,(\frac{Y_t+Y_t'}{\varphi_t}) + q_t\overline{K}$. This can be then be written as two equilibrium conditions linking the user cost and the wage to wealth and asset prices:

$$(1-\beta)W_t + \frac{\eta}{\sigma} u_t \overline{K} = \left(W_t - q_t\overline{K}\right) \tag{3}$$

and

$$w_t^{\frac{1+\tau}{\tau}} \left(\frac{1}{\chi}\right)^{1/\tau} = \frac{1-\eta-\sigma}{\eta+\sigma}\left(W_t - q_t\overline{K}\right) \tag{4}$$

The asset pricing equation is given by

$$q_t = u_t + E_t\left(\frac{q_{t+1}}{r_t}\right) \tag{5}$$

combined with the condition

$$r_t = E_t\left\{\widetilde{\gamma}_{t+1}\varphi_{t+1}^{-\frac{1}{\eta+\sigma}} w_{t+1}^{-\frac{1-\eta-\sigma}{\eta+\sigma}} u_t^{\frac{-\sigma}{\eta+\sigma}}\right\} \tag{6}$$

We now need to complete the model by adding a set of equations describing the role of monetary policy. Note that the arbitrage equation for nominal bonds, when considered along the certainty-equivalent path, is just a Fisher equation:

$$r_t = \frac{R_t}{E_t \pi_{t+1}}$$

Combined with the monetary policy rule, this can be written as

$$r_t = \frac{\pi_t^{\lambda} \exp(\varepsilon_t^R)}{E_t \pi_{t+1}} \tag{7}$$

Note that u_t and w_t can be eliminated using (3) and (4), and r_t can be eliminated using (6). This leaves a system of 4 dynamic equations (1),(2),(5), (7) in $\{s_t, W_t, q_t, \pi_t\}$, 3 initial initial conditions

$$W_0 s_0 = (1-\delta)((\eta+\sigma)\frac{Y_0}{\varphi_0}+q_0 K_{-1}-B_0)+n\delta((\eta+\sigma)\frac{Y_0'}{\varphi_0}+q_0(\overline{K}-K_{-1})+B_0) \quad (8)$$

$$W_0 = (\eta+\sigma)\left(\frac{Y_0+Y_0'}{\varphi_0}\right)+q_0\overline{K} \quad (9)$$

$$\widehat{\pi}_0 = E_{-1}\widehat{\pi}_0 - \frac{1-\kappa}{\kappa}\widehat{\varphi}_0 \quad (10)$$

The stochastic processes for the productivity of producers and investors are assumed to be identical, so $\widehat{\alpha}_{t+1} = \widehat{\gamma}_{t+1}$and they follow an autogressive process:

$$\widehat{\gamma}_{t+1} = \rho\widehat{\gamma}_t + \varepsilon_{t+1} \quad (11)$$

4 Model solution

4.1 Dynamics

The system of 4 equations and 3 initial conditions is solved as follows. First, we take a linear approximation of all the equations around the steady state. The steady state is the level that aggregate variables tend to when there are no aggregate shocks. Associated with these levels for aggregate variables is a stationary wealth distribution summarised by the share of wealth owned by producers, $s_t = \overline{s}$.

Suppressing the expectations notation, the linearised system can be written as

$$AX_{t+1} = BX_t$$

$$X_t = \begin{bmatrix} \widehat{q}_t \\ \widehat{\pi}_t \\ \widehat{s}_t \\ \widehat{W}_t \\ \widehat{\gamma}_t \end{bmatrix}$$

This system can then be written as:

$$X_{t+1} = FX_t \quad (12)$$

where $F = A^{-1}B$.

Using a simple eigenvalue decomposition of $F = P\Lambda P^{-1}$ this can be written as a new system

$$Y_{t+1} = \Lambda Y_t$$

where $Y_t = P^{-1}X_t$. This system is 'uncoupled' as Λ is a diagonal matrix containing the eigenvalues of F. I am interested in non-explosive, determinate solutions. Order the eigenvalues in decreasing absolute magnitude, and let n be the number of eigenvalues outside the unit circle. Let P_1^{-1} denote the upper n rows of P^{-1}. For a solution to be non-explosive, it is necessary for $P_1^{-1}X_t$ to be zero for all t. For a solution to be determinate (following Blanchard and Kahn (1980)), it is necessary for $n = 2$ eigenvalues (corresponding to the number of 'jump' variables q_t, π_t) to lie outside the unit circle and for the remaining eigenvalues to lie inside the unit circle. After some re-arranging, the non-explosive condition can then be rewritten as

$$\begin{bmatrix} \widehat{q}_t \\ \widehat{\pi}_t \end{bmatrix} = P_{12}\left(P_{22}\right)^{-1} \begin{bmatrix} \widehat{s}_t \\ \widehat{W}_t \\ \widehat{\gamma}_t \end{bmatrix} \tag{13}$$

where P_{21} denotes the first n rows and the left $(5-n)$ columns of P, and P_{22} denotes the bottom right $(5-n)\times(5-n)$ block of P. Given this relationship, the initial response to any shock at time 0 can be found by substituting out the jump variables from the system of initial conditions, which can then be solved for $\widehat{W}_0$, $\widehat{s}_0, \widehat{\varphi}_0$. This then gives the initial response to a shock. From the dynamic system (12), again with the jump variables substituted out using (13), the remaining dynamic path of all the variables can be computed, noting that $\widehat{\varphi}_t = 0, \forall t \geqslant 1$.

It can be shown that the eigenvalues of this system are, in descending order $\frac{\widetilde{\gamma}}{\beta\frac{\eta(1+\tau)}{\tau+\eta+\sigma}?[\widetilde{\alpha}s+\widetilde{\gamma}(1-s)]}$, λ, $\frac{(1-\delta)\widetilde{\alpha}-\widetilde{\gamma}n\delta-(\widetilde{\alpha}-\widetilde{\gamma})s}{\widetilde{\alpha}s+\widetilde{\gamma}(1-s)}$, $\frac{\eta(1+\tau)}{\tau+\eta+\sigma}$, ρ. So for a monetary policy that satisfies the Taylor principle of reacting to inflation by a factor greater than 1, this system has a non-explosive, determinate solution. [discuss conditions on other eigenvalues]

4.2 Steady state

The full steady state of the model is given in the appendix. However, it is instructive to consider the expression for the steady-state interest rate:

$$r = \frac{1}{\beta}\left(\frac{\widetilde{\gamma}}{\widetilde{\alpha}s + \widetilde{\gamma}(1-s)}\right) < \frac{1}{\beta}$$

Since s is the share of wealth owned by the productive agents, and I want to consider the model near a steady-state where productive agents do not hold all of the capital stock, $s < 1$. This in turn means that the real interest rate is strictly lower than the (inverse of) the rate of time preference. At these low interest rates, workers will not wish to save, so workers choose not to participate in the financial asset market. This proves the earlier assertion that workers simply consume their wage and profit income in each period.

4.3 Frictionless model

Before turning to the properties of the full model, I show what the properties of the model would be without binding borrowing constraints. In that case, the efficient allocation would always be reached, in the sense that the most productive agents would always hold the entire capital stock. The full derivation of the model is given in the appendix. I state here the law of motion for aggregate output:

$$Y_{t+1} = \alpha_{t+1}^{\frac{\tau+1}{\tau+\eta+\sigma}} \left(Y_t\right)^{\frac{\eta(\tau+1)}{\tau+\eta+\sigma}} c \tag{14}$$

where c denotes a constant term. This implies that output dynamics are entirely driven by the exogenous process for aggregate productivity and lagged output. There is no feedback from any net worth or asset price variable in the model. The equations for the asset price and wealth are

$$q_t = \frac{\sigma\beta}{\varphi\overline{K}(1-\beta)} Y_t$$

and

$$W_t = \frac{\eta + \sigma - \eta\beta}{\varphi\,(1-\beta)} Y_t$$

So asset prices and entrepreneurial wealth are simply proportional to output.

4.4 Calibration

The model contains 13 parameters. Some of the parameters are standard, in the sense that they can be chosen to match key steady-state ratios in the economy. Other parameters, in particular those specific to the credit mechanism, are more difficult to assign values to. The calibration I have chosen is designed to show how the mechanism might work, not how it most likely does work, as there is little guidance from actual observation in choosing plausible values for these parameters. The following parameter values are chosen for the baseline model.

parameter	assigned value
β	0.99
η	0.1
σ	0.3
τ	0.5
χ	0.29
γ	0.12
κ	0.5
θ	11
λ	1.5
α/γ	1.034
n	0.0073
δ	0.5

The model is calibrated so that each period can be interpreted as on quarter of a year. The discount factor $\beta = 0.99$ is a standard choice in many general equilibrium macromodels (see e.g. Cooley and Prescott (1995)). Together with the other parameters in the model, it results in an annual real interest rate of just under 4%. The values for $\eta, \sigma, \tau, \chi, \gamma$ were chosen to achieve a capital to output ratio of 10, a labour share in output of 0.6, hours worked of 0.31 as a fraction of total available time, and a wage elasticity of labour supply of 2, values very close again to those in Cooley and Prescott (1995). The monetary policy reaction function parameter λ is set at the value used by Taylor (1993), although the reaction function does not have exactly the same form. The rule used in this paper is certainly too simplistic to be realistic, and is for illustrative purposes only. The elasticity parameter θ determines a steady-state net mark-up for consumption goods of 0.10, corresponding to the empirical findings by Basu and Fernald (1997). The share of prices that are set one period in advance, κ, is set at 0.5. In the extended model, which features staggered pricing, the probability for each firm of not being able to reset their price is 2/3, implying that firms change their price on average every 3 quarters, in line with the estimates in Sbordone (2002). The extended model also features a more realistic monetary policy rule, which is necessary in order to obtain plausible inflation dynamics.[5] The form of the rule in the extended model is

$$\widehat{R}_t = (1 - \rho_R)\,\lambda_\pi \widehat{\pi}_t + (1 - \rho_R)\,\lambda_\varphi \widehat{\varphi}_t + \rho_R \widehat{R}_{t-1} + \varepsilon_{R,t} \tag{15}$$

In other words, monetary policy now responds gradually to inflation, and also responds to the mark-up, which is a proxy for the deviation of output from the level of output that would prevail under flexible prices (when the markup is constant). The calibrated values for $\{\lambda_\pi, \lambda_\varphi, \rho_R\}$ are $\{1.5, 2, 0.9\}$.

The crucial parameters for the strength of the credit mechanism are the productivity difference between producers and investors α/γ, the steady-state ratio of productive to unproductive agents n, and the probability of a highly productive agent becoming less productive, δ. The paramters n and α/γ were chosen so that productive agents hold about 2/3 of the capital stock in steady state, the same value as that in Kiyotaki and Moore (1997). But other combinations of these parameters could achieve the same ratio, and generate either more or less persistence. The parameter δ was chosen to be low enough so that the credit mechanism generates substantial persistence, while still producing model responses that appear well behaved.

4.5 Response to aggregate productivity shock

In this section I consider the response of the model economy to aggregate productivity shocks. I compare these responses with the responses of a 'flexible price' version of the model (with $\kappa = 0$), and also with the response of the fully efficient model, outlined in section (4.3). Figure 1 shows the response of output, the price of capital, and aggregate entrepreneurial wealth response. The units on the vertical axes are percentage deviations from steady state.

[5] For a monetary policy rule that only reacts to contemporaneous variables, a monetary policy contraction causes a rise in inflation, because the 'supply' effect of the reduction in future aggregate productive capacity dominates the 'demand' effect of the monetary policy shock. By making the policy rule more gradual, the policy contraction is longer lasting, and the demand effect is stronger.

The units on the horizontal axes are quarters, with the shock taking place in quarter 1. The productivity shock is a 0.25 per cent fall in aggregate productivity, which lasts only for a single period. In other words, aggregate productivity follows a white noise process. Output in the efficient model falls by about 1.7 times the fall in productivity, which is the combined effect of lower productivity and lower labour inputs. After the shock, output returns fairly quickly to its steady state value. We know from equation (14) that, if productivity follows a white noise process, the persistence of output, mas measured by the autocorrelation coefficient, is equal to $\frac{\eta(\tau+1)}{\tau+\eta+\sigma}$. Using the baseline calibration, this is equal to 0.17. Asset prices and aggregate wealth respond with the same proportional magnitudes as output. For the flexible price model with credit frictions, the initial output response is the same as the efficient response, because all determinants of output other than labour (i.e. last period's borrowing decision, the share of capital held by productive agents, and investment in inventories) are predetermined. But note that the asset price falls more than twice as much. This amplification is due to the following mechanism. In period 1, producers and investors experience an unanticipated loss of output, as well as an unanticipated reduction in the value of producers' collateral. This means that in period 1, producers cannot maintain their share of the capital stock: they can now afford less than the steady-state share, because they buy capital with the reinvested share of output and with collateralised borrowing. This means that capital will be less efficiently used for production from period 2 onwards. Because today's capital price is the present discounted value of all future marginal returns to capital, which will fall by more in the credit-constrained economy, the price of capital falls by more than in the efficient model, and this fall further exacerbates the reduction in producers' net worth. Output in period 2, rather than returning to steady-state, falls further due to the shift in capital from highly productive to less productive entrepreneurs. After period 2, it takes time for the most productive agents to rebuild their share of wealth, and it therefore takes time for asset prices and output to return to their steady-state values.

In the full model, with sticky prices as well, the initial fall in aggregate output is slightly muted relative to the efficient and flexible price models. As output falls, the nominal price level needs to rise for any given monetary policy stance that does not fully accommodate the output fall. But prices are sticky, so they do not rise enough. This causes the real marginal cost of the retail sector to rise, as not all retailers are able to charge their desired markup.

For the entrepreneurs, however, the paying a lower markup is beneficial: it increases the value of their output in consumption terms, which in turn increases the amount of labour they want to hire, relative to the amount of labour they would want to hire with constant markups. This mechanism, while appearing perhaps non-standard, is simply the New Keynesian channel whereby those who cannot change prices change output to meet demand, if we consider the entpreneurs and the retailers are one single sector. So aggregate output falls by less in the period of the shock. This has important consequences for output dynamics in future periods. Because output falls by less, there is a smaller redistribution of wealth from producers to investors. There is therefore a smaller response of asset prices and aggregate wealth, because less of the capital stock shifts from producers to investors during the transmission of the shock. The entire credit - asset price effect has been dampened by the stickiness of prices. The response of inflation, nominal interest rates and the markup in the sticky price model are shown in figure 2.

Does this effect depend on the particular modelling choice of paying retail profits to workers? After all, if profits of the retail sector were to be paid to entrepreneurs, there would be an offsetting effect: the beneficial effect on entrepreneurs' net worth of the fall in markups would be offset by the adverse effect of the fall in retailer profits that are paid back. But the quantity of labour demanded by entrepreneurs would still push output towards offsetting the effect of the productivity shock, because it is not affected by the flow of profits, only by the marginal product of labour. So net worth of entrepreneurs would still fall by less than under flexible prices, although the difference would be smaller, because the direct effect of the change in markup and the change in profit would cancel eachother out.

The key difference, relative to standard sticky-price monetary models, is that the flexible price fall in output from period 2 onwards following an adverse productivity shock is no longer efficient, that it does not correspond to a social planner solution. This can be seen from the fact that the no-frictions level of output, which corresponds to a social planner solution in the absence of all frictions, lies strictly above the flexible-price level of output from period 2 onwards. In standard sticky-price monetary models, it is considered desirable for monetary policy to respond aggressively to inflation following a productivity shock, as this will simultaneously reduce inflation and ensure that output follows the same path as a model without price stickiness. In those models, as soon as productivity has returned to its steady-state level, so does the flexible price level of output. But in the credit frictions model considered in this paper, only the initial fall in output is an efficient response to a change in aggregate productivity. The subsequent further fall, and the slow return to steady state are the result of inefficiencies in the credit market.

How large the dampening effect of sticky prices will be depends on how aggressively monetary policy responds to inflation. As the adverse productivity shock puts upward pressure on inflation, the monetary policy reaction function dictates that the nominal interest rate should rise. The more aggressive the rise in interest rates, the smaller the resulting increase in inflation, and the smaller the reduction in mark-ups. As monetary policy becomes sufficiently aggressive in its response to inflation, the economy's response to productivity shocks approaches that of the flexible price economy, where markups are constant.

4.6 Response to monetary policy shock

Figure 2 shows the model economy's response to a temporary white noise shock to the monetary policy rule, where the model now features staggered prices and the monetary policy rule (15)[6]. The shock is calibrated to cause a 0.25 per cent rise in the annualised nominal interest rate. The discussion here is brief, because most of the mechanism is similar to that in the case of a productivity shock. Only the initial cause and transmission of the disturbance differs. Nominal interest rates rise in response to the shock. Because retailers are unable to lower their prices sufficiently in response to the monetary contraction, their markups rise. Entrepreneurs therefore face a fall in the consumption value of their output, which reduces net worth both via a direct effect of the markup and via a further reduction in labour inputs. Because of the leverage effect, producers suffer a larger fall in net worth than investors, and once again the wealth distribution is shifted from those with high productivity to those with low productivity. This lowers return on capital in future periods, which causes a fall in the price of capital today, resulting in a further reduction of net worth. Output in the following period is lower still, because capital is now being used less efficiently. The return to the steady-state happens gradually, as producers rebuild their share of wealth, so that the wealth distribution returns to its stationary distribution.

[6] For completeness, the response of this staggered pricing version of the model to productivity shocks is given in figure 3.

Note that in this case the efficient path of output remains constant, because monetary policy would have no effect in this model absent sticky prices.

5 Related literature and further discussion [to do]

Bernanke and Gertler (1989), Kiyotaki and Moore (1997), Kiyotaki (1998), Kocherlakota (2000), Carlstrom and Fuerst (1997,1998,2000,2001), Bernanke, Gertler and Gilchrist (1999), Iacoviello (2002), Cooley and Quadrini (1999), Cooley, Marimon and Quadrini (2001).

Autocorrelation properties of output (King, Plosser, Rebelo and Cogley and Mason). Shocks to future productivity. Nominal contracts. State contingent borrowing and the optimal contracts literature. Total factor productivity.

The simulations presented in this paper are for a linearised version of the model, in the neighborhood of a steady state with a binding borrowing constraint. But the process driving the model implies a potential asymmetry. If enough borrowing is allowed in the economy, or many agents experience a sufficiently long spell of high productivity, the economy can reach an unconstrained steady-state. In this steady-state, the wealth distribution still fluctuates in response to shocks, but no longer causes any feedback to real outcomes. Productive agents who experience a small enough negative shock can still borrow enough so that they achieve their desired level of investment without hitting the borrowing constraint. The economy's response to small negative productivity and monetary policy shocks will be small and transient. Positive shocks to their net worth, no matter how large, will never result in hitting the borrowing constraint. But if any of the adverse shocks are large enough, they can cause the borrowing constraint to become binding again. In that case, the wealth distribution will once again feed back to the real economy, and the response to both negative and positive shocks will be larger and more persistent. The intuition for this asymmetry is similar to that in Kocherlakota (2000), although his model is much simpler.

6 Conclusion

I have outlined a macroeconomic model where credit markets operate less than perfectly due to enforcement problems, and I have used this model to discuss the interaction between aggregate output dyamics, the wealth distribution and the effect of monetary policy. None of the building blocks of the model are new. The idea that monetary policy works through a redistribution of wealth between highly productive and less productive agents is very much in the spirit of Fisher (1933). The notion that the net worth of agents affects the quantity of investment is a common theme in the macro-economic 'credit-channel' literature, reviewed by Gertler (1988) and Bernanke and Gertler (1995). And the idea that the wealth distribution can have a first-order effect on aggregate output via the efficiency with which capital is used was formalised in Kiyotaki and Moore (1997) and Kiyotaki (1998). The contribution of this paper is to put these elements together in an internally consistent, tractable model. The analysis has shown that the credit mechanims can amplify shocks and make them highly persistent, so that small, temporary disturbances to productivity or monetary policy have large and persistent effects on output. The basic mechanism is that, because highly productive agents find it optimal to borrow from less productive agents, they are leveraged. Any aggregate disturbance will affect borrowers' net worth more than lenders' net worth due to leverage, and so will affect the wealth distribution. The most productive agents will end up holding less of the economy's productive resources, which lowers aggregate output and further depresses the price of capital, exacerbating the shift in the wealth distribution. It takes time for the most productive agents to rebuild their share of wealth, and output therefore deviates from its steady-state level for many periods. I have also shown that sticky prices not only dampen the output effect of productivity shocks, which is not new, but that they bring the output effect of productivity shocks closer to efficient levels - which is new. This casts new light on the trade-off between output and inflation variability that systematic monetary policy aims to balance. The flexible-price response of the economy to productivity shocks is no longer efficient. And by allowing some inflation variability, monetary policy can achieve lower output variability around the efficient level. These ideas are pursued further in a another paper (Vlieghe (2004)), where I consider how monetary policy should optimal react to productivity shocks, given the trade-off created by credit frictions.

References

[1] Aoki, K. Optimal monetary policy responses to relative-price changes. *Journal of Monetary Economics 48* (2001), 55–80.

[2] Basu, S., and Fernald, J. Returns to scale in u.s. production: Estimates and implications. *Journal of Political Economy 105* (1997), 249–283.

[3] Bernanke, B., Gertler, M., and Gilchrist, S. The financial accelerator and the flight to quality. *Review of Economics and Statistics 78*, 1 (February 1996), 1–15.

[4] Bernanke, B. S., and Gertler, M. Agency costs, net worth and business fluctuations. *American Economic Review 79*, 1 (1989), 14–31.

[5] Blanchard, O., and Kahn, C. The solution of linear difference models under rational expectations. *Econometrica 48* (1980), 1305–1311.

[6] Calvo, G. Staggered prices in a utility-maximising framework. *Journal of Monetary Economics 12* (1983), 383–398.

[7] Carlstrom, C. T., and Fuerst, T. S. Agency costs, net worth, and business fluctuations: A computable general equilibrium analysis. *American Economic Review 87*, 5 (1997), 893–910.

[8] Carlstrom, C. T., and Fuerst, T. S. Monetary shocks, agency costs and business cycles. *Carnegie Rochester Conference Series on Public Policy 54* (2001), 1–27.

[9] Clarida, R., Gali, J., and Gertler, M. The science of monetary policy: A new Keynesian perspective. *Journal of Economic Literature 37*, 4 (1999), 1661–1707.

[10] Cooley, T., Marimon, R., and Quadrini, V. Aggregate consequences of limited contract enforceability. *mimeo, New York University* (June 2001).

[11] Cooley, T., and Prescott, E. Economic growth and business cycles. In *Frontiers of Business Cycle Research*, T. Cooley, Ed. Princeton University Press, Princeton, 1995, pp. 1–38.

[12] Cooley, T. F., and Quadrini, V. Monetary policy and the financial decisions of firms. *mimeo, New York University* (December 1999).

[13] Erceg, C., Henderson, D., and Levin, A. Optimal monetary policy with staggered wage and price contracts. *Journal of Monetary Economics 46* (2000), 281–313.

[14] Fisher, I. The debt-deflation theory of great depressions. *Econometrica 1*, 4 (1999), 337–357.

[15] Hart, O., and Moore, J. A theory of debt based on the inalienability of human capital. *Quarterly Journal of Economics 109*, 4 (1994), 841–879.

[16] King, R. G., and Rebelo, S. T. Resuscitating real business cycles. *Handbook of Macroeconomics 1* (1999), 927–1007.

[17] Kiyotaki, N. Credit and business cycles. *Japanese Economic Review 49*, 1 (1998), 19–36.

[18] Kiyotaki, N., and Moore, J. Credit cycles. *Journal of Political Economy 105* (1997), 211–248.

[19] Kocherlakota, N. R. Creating business cycles through credit constraints. *Federal Reserve Bank of Minneapolis Quarterly Review 24*, 3 (2000), 2–10.

[20] Sbordone, A. Prices and unit labour costs: a new test for price stickiness. *Journal of Monetary Economics 49* (2002), 265–292.

[21] Schleifer, A., and Vishny, R. W. Liquidation values and debt capacity: A market equilibrium approach. *Journal of Finance 47*, 4 (1992), 1343–1366.

[22] Vlieghe, G. Optimal monetary policy with credit market imperfections. *mimeo* (2004).

[23] Woodford, M. *Interest and Prices: foundation of a theory of monetary policy.* Princeton University Press, 2003.

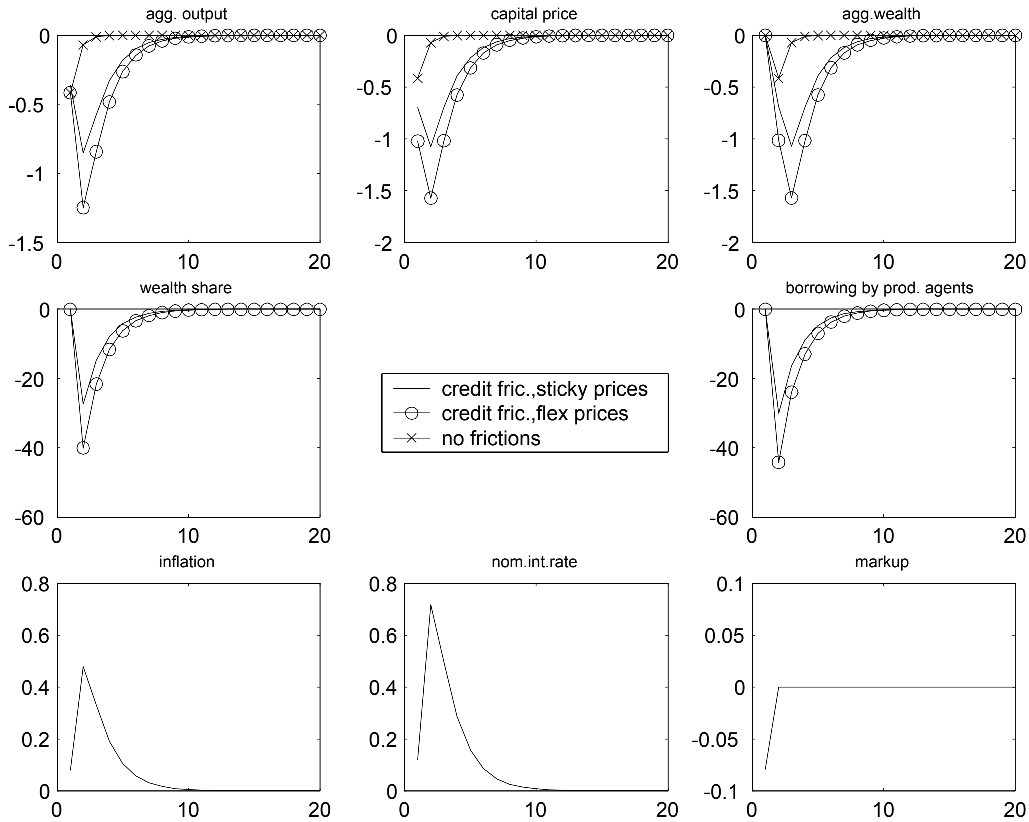

Figure 1: Response to productivity shock (baseline model)

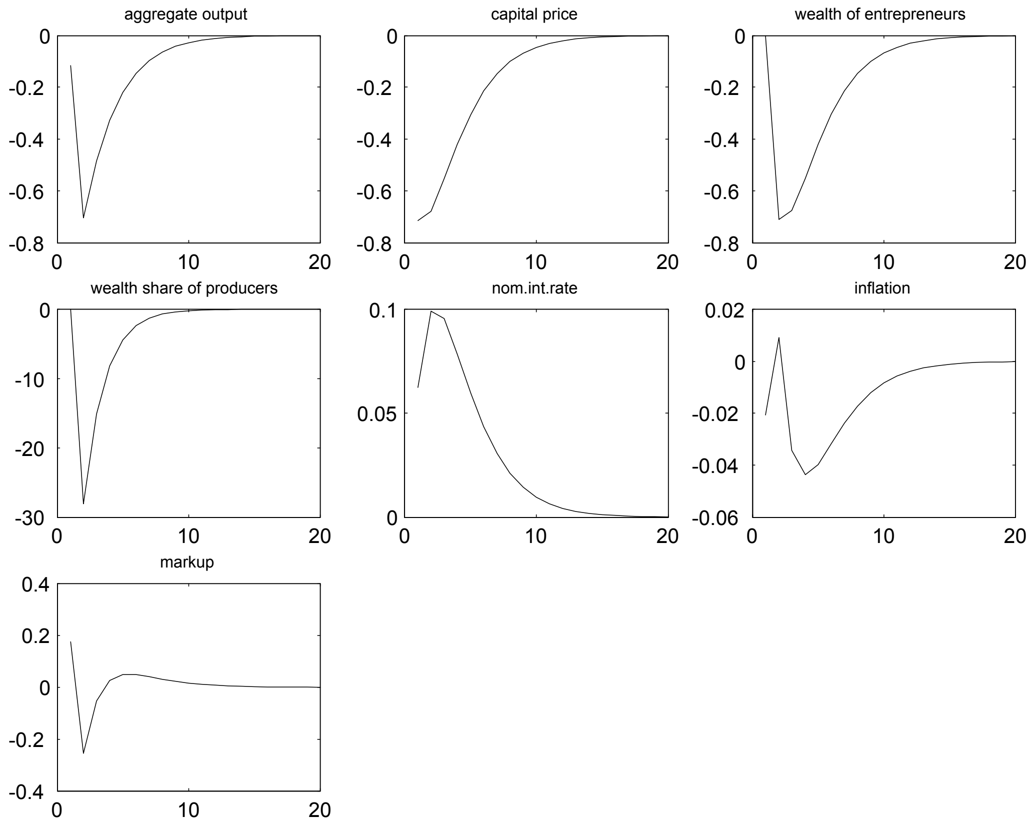

Figure 2: Response to monetary policy shock (staggered pricing model)

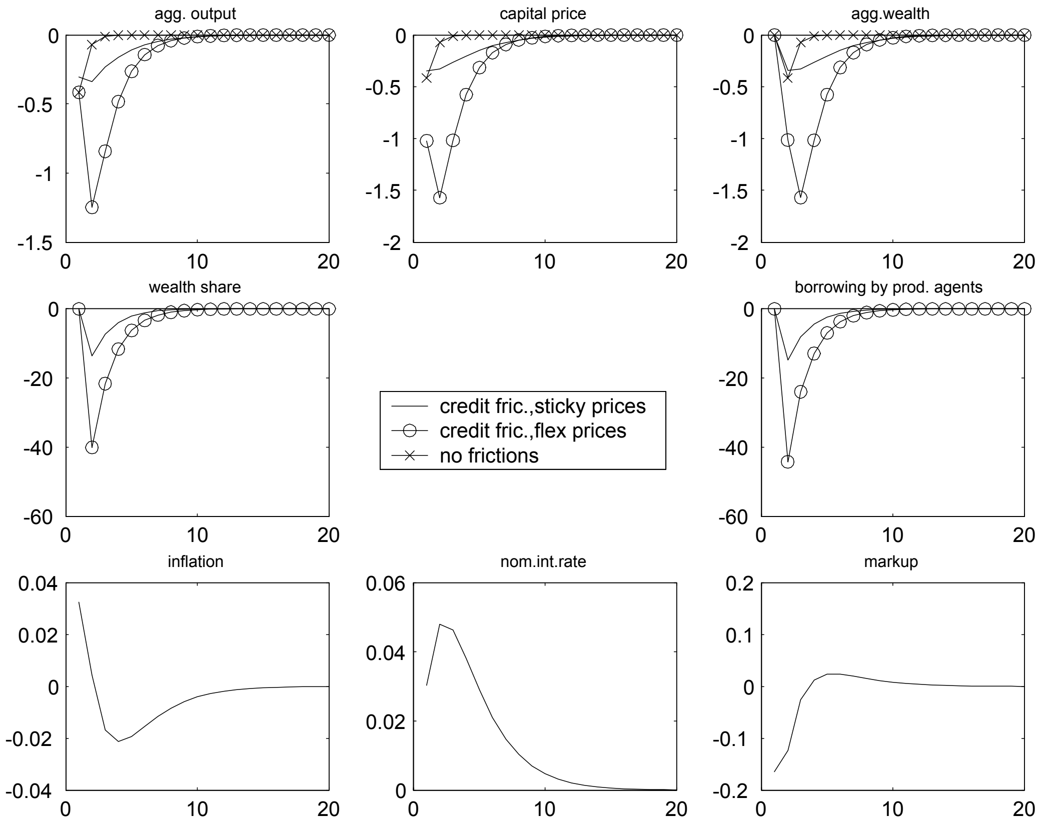

Figure 3: Response to productivity shock (staggered pricing model)