University of Heidelberg

Department of Economics

Discussion Paper Series | No. 537

Heterogeneous consumers, segmented asset markets, and the effects of monetary policy

Zeno Enders

December 2012

Heterogeneous consumers, segmented asset markets, and the effects of monetary policy*

Zeno Enders
University of Heidelberg

September 22, 2012

Abstract

This paper examines how segmented asset markets can generate real and nominal effects of monetary policy. I develop a model, in which varieties of consumption bundles are purchased sequentially. Newly injected money thus disseminates slowly through the economy via second-round effects and induces a longer-lasting, non-degenerate wealth distribution. As a result, the demand elasticity differs across consumers, affecting optimal markups chosen by producers. The model predicts a short-term inflation-output trade-off, a liquidity effect, countercyclical markups, and procyclical wages and expenditure dispersion across consumers after monetary shocks. Including a modest degree of real or nominal wage rigidity yields responses that are also quantitatively in line with empirical evidence.

Keywords: Segmented Asset Markets, Monetary Policy, Countercyclical Markups, Liquidity Effect, Segmented Asset Markets, Expenditure Dispersion
JEL-Codes: E31, E32, E51

*I want to thank Jordi Galí, Stefano Gnocchi, Jonathan Heathcote, Giovanni Lombardo, Gernot Müller, Stefan Niemann, and Gerald Seidel for helpful discussions and valuable comments. Part of this research was conducted while Enders was a visiting scholar at the IMF's Research Department, whose hospitality is gratefully acknowledged. The views expressed in this paper are solely those of the author and do not necessarily reflect those of the IMF. Please address correspondence to zeno.enders@uni-heidelberg.de.

1 Introduction

Which role does heterogeneity of economic agents play in the transmission of monetary policy? Standard models of the monetary transmission mechanism use a representative agent and thus ignore this question. Instead, they implicitly assume that either all agents are affected in the same way by actions of the monetary authority or that firms do not pay attention to the potential heterogeneity of their customer base when setting prices.[1] In this paper, I explicitly account for heterogeneity of firms and consumers and its implications for monetary non-neutrality. I do so by developing a heterogeneous-agents model of segmented asset markets and overlapping shopping sequences. The resulting time-varying distribution of money across agents and its effects on optimal markups turn out to be important dimensions in the transmission of monetary policy, yielding a short-term inflation trade-off. A calibrated version of the model that includes a modest degree of real or nominal wage rigidity accounts well for the empirically estimated dynamics of output, inflation, hours, interest rates, profits, and expenditure dispersion across consumers after a monetary policy shock.

Monetary non-neutrality follows from the assumption that agents manage their asset portfolio only infrequently, generating heterogenous cash holdings.[2] Consumers divide their labor and financial income between an interest-bearing illiquid and a liquid asset, which is needed for purchasing consumption goods. They acquire their consumption bundle on shopping trips, visiting one shop after the other. Since consumers start shopping at different times, their sequences overlap, resulting in a heterogeneous customer base faced by each shop. In particular, customers at the beginning of their shopping sequence have a higher demand elasticity because they can substitute with more shops further down the shopping trip. Since producers cannot price-discriminate, they face a trade-off between extracting a higher profit from low-elasticity customers and attracting more sales from high-elasticity customers.[3] The trade-off is altered if the distribution of money holdings in the population changes, affecting the aggregate demand elasticity, which in turn gives rise to optimally time-varying markups. As a result, producers avoid being first to increase nominal prices to the new steady state following monetary easing. Instead, they compete for the customers who benefited first from the monetary easing by keeping relatively low prices. Specifically, the markup is countercyclical because of the following reason.[4] Monetary injections reach only those agents currently participating in the asset market (results are similar if the other agents also benefit when participating later). These agents will receive a higher weight, as they account for a larger share of sales. Since they are in the beginning of their shopping sequence, this raises the effective elasticity of substitution, leading to a lower markup. A lower markup implies higher output, such that a short-term inflation-output trade-off obtains. Countercycli-

[1] Textbook examples of these kind of models are presented in Woodford (2003) and Galí (2008).

[2] Jovanovic (1982) derive optimality conditions for this behavior in a general equilibrium model of the Baumol-Tobin type, while Christiano et al. (1996) provide empirical support. Appendix D shows that relatively low costs of managing assets imply infrequent asset optimizations in the present model.

[3] This aspect is related to Bils (1989), where a monopolist faces a trade-off between extracting profits from loyal customers and attracting new ones.

[4] When using the term 'countercyclical' in this context, I refer to the a negative correlation between output and markups conditional on monetary policy shocks.

cal markups are empirically supported by Rotemberg and Woodford (1999) (see also references therein), and Campello (2003) at an industry-level. Chevalier and Scharfstein (1996) confirm that prices are strategic complements since they depend positively on the prices of competitors, as in the present model. Note that because of the sequential structure, the model predicts an increase in the dispersion of prices after a monetary shock for a finite elasticity of substitution, as empirically observed by Balke and Wynne (2007). Since only a fraction of agents receive the injection, also expenditure of agents is predicted to be more dispersed. I present novel empirical evidence confirming this reaction.

While the predictions of the model after monetary shocks are qualitatively in line with empirical observations, the friction on the demand side does not prevent firms' marginal costs from rising relatively quickly. In order to generate also quantitatively plausible results, I combine the above mechanism with modest degrees of real or nominal wage rigidities. While rigid nominal wages prevent nominal marginal costs directly from rising swiftly, real wage rigidity alone leaves real variables unaffected after a monetary shock.[5] Since wages and prices are directly linked in this case, the above described dampening effect on prices is amplified. This results in a slower adjustment to the new equilibrium and higher initial spending. The increased spending translates into higher income of workers and business owners. They react by also raising their subsequent expenditure that is spent partly in the same period, while prices are still comparatively low. Hence, the sequential structure of the model provides another amplification mechanism. The transmission of the changing wealth distribution on real variables via heterogenous labor-supply and demand decisions turns out to be of limited importance.

In order to establish empirical evidence, I estimate the dynamic responses to a monetary expansion of a range of variables. A comparison of the model responses to their empirical counterparts shows that the model does well in reproducing the impulse-response functions of these variables. Specifically, output, inflation, labor, wages, profits, velocity, and expenditure dispersion rise after a monetary expansion, while markups and the interest rate falls, i.e., a liquidity effect is observed. The theoretical prediction of a negative correlation between consumption expenditure dispersion and markups is therefore confirmed.

Models of segmented asset markets in which only a part of the population participates in an open-market operation of the central bank go back to Grossman and Weiss (1983), who develop a Baumol-Tobin-type model of staggered money withdrawals. Subsequent work along these lines focuses on the implications for financial variables. Alvarez and Atkeson (1997) show that such a model of segmented asset markets can generate volatile and persistent real as well as nominal exchange rates. In a similar model of a closed economy, Alvarez et al. (2009) examine the dynamics of money, velocity, and prices. Alvarez et al. (2002) develop a model of endogenous asset market segmentation and find plausible implications for interest rates, expected inflation and exchange rates. Occhino (2004) uses a model where a part of the population is constantly excluded from asset trading, and studies the implications for money and interest rates. Common to these models is the exogeneity of output. An exception is Rotemberg (1984), who combines

[5] Blanchard and Galí (2007) discuss extensively the case of real wage rigidities and argue that they are an important factor in shaping cyclical fluctuations. Among others, also Hall (2005) employs them to explain characteristics of empirical labor markets.

segmented asset markets with production based on capital and a fixed labor supply. He finds that after a simultaneous increase in money and governmental holdings of capital, output increases and returns slowly to the steady state. However, because of perfect competition optimal price setting is not considered. This implies that firms continue to ignore the potentially heterogeneous composition of their customer base.

The implications of heterogeneous agents for price setting and labor-supply decisions were often neglected because of complicated wealth effects, which arise after monetary injections that affect only a part of the population. One solution to this problem was proposed by Lucas (1990). In his model, the economy consists of families that pool their resources at the end of the period. A large body of literature uses this approach to build and simulate models of the transmission of monetary policy, including Fuerst (1992) and Christiano et al. (1997). While tractability is reached with this method, the heterogeneity of money holdings is limited to the period of the shock, eliminating longer-lasting wealth effects. Similarly, Alvarez et al. (2009) remove wealth effects by allowing for trade in a complete set of state-contingent assets. However, as also argued by Menzio et al. (2011) in the context of a search model of money, long-lasting non-degenerate wealth distributions can have potentially important effects. In the present model, tractability is reached despite unrestricted money distributions by a finite number of agents and an ownership structure of shops that leads to a slow dissemination of newly injected money throughout the economy, as agents who did not benefit directly from the monetary injection nevertheless receive higher future income following such an injection. This mechanism gives rise to persistent effects of monetary shocks due to second-round effects and the implied long-lasting changes in the wealth distribution. Because over time all agents in the economy benefit from the monetary injection via increased profits and wages, the wealth distribution returns to its pre-shock level in the long run, thereby guaranteeing stationarity. Hence, the model can be analyzed with standard tools for the simulation of dynamic stochastic general equilibrium models.

The remainder of this paper is organized as follows. The model is developed in section 2. Its implications for the inflation-output trade-off are discussed in section 3. I calculate empirical impulse-response functions in section 4, and compare them to predictions of the model in section 5. Section 6 concludes the paper. Appendix A derives housholds' optimality conditions, in appendix B the velocity in steady state is calculated, while appendix C isolates the pure demand effect for $n=2$. Finally, appendix D derives the optimal number of bank trips in steady state and appendix E lists data sources.

2 A model of sequential purchases

Standard models of monopolistic competition assume that each agent is consuming an infinite number of different varieties. Furthermore, although one period is assumed to be of considerable length, all actions of the agents are done simultaneously, including buying the varieties. If one is to relax these assumptions, important changes for optimal price setting will emerge. In the following model purchasing consumption bundles takes time and customers spend positive amounts of resources on each purchase. To account for these points, I change the standard model setup as follows. The economy is populated by a continuum of consumers and firms. All consumers and firm belongs to one of n subgroups that comprise a unit measure of agents each. The model features shopping sequences similar to Grossman and Weiss (1983) and Rotemberg (1984). Instead of visiting all shops simultaneously, each consumer visits n shops, one after another. After having acquired all goods that enter the consumption bundle, consumers aggregate and consume their bundles. As in standard models, it takes the length of one period to buy a complete bundle. The number of shops visited per consumer is thus finite, where each shop sells a differentiated good.[6] Note that this does not imply that the total number of shops in the economy is finite, but merely that each consumer spends a positive amount of money on each good in a given period. Furthermore, consumers cannot visit several shops simultaneously. This, in turn, implies that shops can influence the average price of their customers' consumption bundle and therefore customers' consumption. However, because there is a continuum of each type of shop, a single shop has no impact on the economy-wide price level and serves only a infinitesimal fraction of the total population. Assuming additionally that each agent visits a random new shop in her next stage of the shopping sequence entails that there is no strategic interaction between individual shops, i.e., shop owners take the prices of other shops as given.

Before starting their shopping sequences, consumers visit the bank, where they have access to their account. All income from labor and dividends up to this point were transferred on this account. At the bank, agents can participate without costs in the asset market, dividing their wealth in liquid and interest-bearing illiquid assets.[7] As in, e.g., Grossman and Weiss (1983) and Alvarez et al. (2002), only those agents currently participating in the asset market receive monetary injections from the central bank.[8] After having settled their financial transactions, consumers start a new shopping sequence, using the liquid assets for payments. Each consumer works in the last shop of her shopping sequence, receiving wage income on her bank account.[9] In addition, the consumer owns the shares of the same shop, such that the corresponding profits also get paid to her account. After having worked, the consumer visits the bank, has access to her income, and the sequence starts over again.

If it takes some time to acquire a consumption bundle, it is unlikely that all consumers start and finish their shopping sequences and adjust their financial assets at the same dates. I therefore assume that the above explained sequence starts at different points in time for each consumer. Specifically, each of the n types of consumers is at a different stage of the sequence. All consumers visit a particular type of shop at the same time, where the shops cannot price discriminate. This assumption has the advantage that from the the shops' perspective, the setup is equivalent to an economy with a representative consumer and uncertainty about the current stage of the shopping sequence of this consumer. The timing of the model is visualized in figure 1 for $n = 3$. One type of shop after the other is serving all customers, while in between the visits there is always

[6]The case of a finite number of varieties was already discussed by Dixit and Stiglitz (1977).

[7]For the results it does not matter if the liquid asset also yields some return. In the linearized version of the model it is only important that the illiquid asset dominates the liquid asset in the rate of return.

[8]I also consider a version of the model in which all agents receive a part of the injection, but access their accounts at different times. Results are similar.

[9]Alternatively, one could assume that the consumer works in the first shop of the sequence. While this adds an additional channel of internal propagation to the model, it has the disadvantage of assuming that considerable time passes until the agents have access to their wage income, which was transferred to their accounts.

one type of agent consuming the bundle and passing by the bank, and another one is working for the next shop. Heterogeneity of agents arises endogenously because of the different points in time when agents visit the asset market, resulting in potentially different money holdings.
As visible in the figure, I make the following assumptions regarding the timing of information in between the visits to two subsequent shops. First, one type of agent is consuming its bundle—acquired over the course of the last shopping sequence—visits the bank and participates in the asset market, where it receives a potential monetary injection. The amount of this injection is instantaneously common knowledge to all agents in the model. The agents at the bank divide their assets in liquid and illiquid assets, and leave the bank. The shops that are going to be visited next subsequently produce goods using labor input of the agents with the next higher index, set their prices and sell the produced goods to the customers. Since the shop owners are free to adjust prices and no new information arrives between production, price setting, and sales, only the amount demanded will be produced. Concerning notation, agents are ordered such that the agents with index i start their shopping sequence at the shops with index $j = i$. In the following, I will model representative consumers and firms of each of the n subgroups.

Figure 1 about here

2.1 Setup

Households Agent i maximizes her expected value of lifetime utility, which depends positively on consumption C, negatively on labor L, and is non-separable in consumption and leisure[10]

$$U_t = E_t \sum_{s=t}^{\infty} \beta^s \frac{1}{1-\sigma} \left[C_{i,s}(1 - L_{i,s})^{\mu} \right]^{1-\sigma} , \tag{1}$$

where $C_{i,t}$ is a consumption bundle consisting of n different goods:

$$C_{i,t} = \frac{1}{n^{\frac{1}{\gamma-1}}} \left(\sum_{j=i}^{n} C_{i,t-1}^{\frac{\gamma-1}{\gamma}}(j) + \sum_{j=1}^{i-1} C_{i,t}^{\frac{\gamma-1}{\gamma}}(j) \right)^{\frac{\gamma}{\gamma-1}} \qquad \gamma > 1, \tag{2}$$

with $C_{i,t}(j)$ being the consumption of agent i of good j. If the consumer happens to start her shopping sequence at the beginning of a period, she acquires the complete consumption bundle in the course of a single period and consumes in the beginning of the next period. This is the case for agent 1 only, who is the first in the period to visit the bank and start shopping. The other agents started somewhere in the middle of last period and consume this period. This implies that they buy a specific good j either in period $t-1$ or t. The period changes between shops $j = n$ and $j = 1$.
While being at the bank, i.e., after having visited shop $j = i-1$ (shop $j = n$ for agent $i = 1$), the agent has access to her account. Her nominal labor income $W_{i,t}L_{i,t}$, a fixed cost of production ϕ, and the dividends $\Pi_{i,t}$ of the shop of which she owns the shares have been transferred to this account.[11] Furthermore, she can participate in the asset market, i.e., divide her assets into illiquid

[10] For a discussion of the properties (including balanced growth) of this kind of utility functions, see King et al. (1988).

[11] In this setup, the fixed cost can be interpreted as a base salary for the worker.

assets $B_{i,t}$ (bonds etc.) and liquid assets $M_{i,t}(j)$ (money/checking account). $M_{i,t}(j) \geq 0$ denotes agent i's holdings of the liquid asset after having acquired good j. Hence, after having used the liquid asset for shopping in her first shop after the bank, an amount of $M_{i,t}(i)$ remains. The illiquid assets from last period pay the amount $(1+r_{i,t})B_{i,t}$. Finally, the agent may also receive a monetary injection $S_{i,t}$. The budget constraint of the agent who participates in the asset market ($i\!=\!j$) is therefore

$$M_{i,t}(j)+B_{i,t+1}+P_t(j)C_{i,t}(j) = (1+r_{i,t})B_{i,t}+\Pi_{i,t}+W_{i,t}L_{i,t}+\phi+S_{i,t}+M_{i,t}(j-1) \quad i = j. \tag{3}$$

The liquid asset can then be used for purchasing consumption, where the price of good j is $P_t(j)$. During the shopping sequence the agent has to obey a series of cash-in-advance constraints

$$\begin{aligned} M_{i,t}(j) + P_t(j)C_{i,t}(j) &= M_{i,t}(j-1) \qquad i \neq j, \\ \text{with } M_{i,t}(0) &\equiv M_{i,t-1}(n). \end{aligned} \tag{4}$$

If a change of period lies between two visits of shops, the time index of the liquid asset changes as well, as described in the last equation. I solve the model under the assumption that all liquid assets are spent during the shopping sequence, i.e., $M_{i,t}(i-1) = 0$.[12] As, e.g., Grossman and Weiss (1983), Rotemberg (1984), and Alvarez et al. (2009), I make the assumption that inter-household borrowing and lending is not possible. This would contradict the structure of the model, in which consumers are not visiting the bank during their shopping sequence. Hence, consumers currently at the bank do not engage in borrowing and lending with the consumers not at the bank.

Shops Producer j maximizes the profit function

$$\Pi_t(j) = Y_t(j)P_t(j) - W_t(j)L_t(j),$$

where the wage can differ across firms because each shop employs a different worker. However, the shop takes the wage as given, i.e., each worker stands for a continuum of workers of the same type, just as each consumer stands for a continuum of consumers of the same type. The maximization problem is subject to a production function that features labor as the sole input

$$Y_t(j) = A_t L_t(j) - \phi,$$

[12] This spending pattern is optimal if the following holds

$$\frac{U_{C_{i,t}}}{P_t(i-1)} \frac{\partial C_{i,t}}{\partial C_{i,t}(i-1)} > E_t \frac{U_{C_{i,t+1}}}{P_{i,t+1}} \qquad i \neq 1,$$

with a corresponding restriction for $i = 1$. The price index P_i of agent i's consumption bundle C_i is defined via $P_i C_i = \sum_{j=1}^{n} P_i(j)C_i(j)$. In order to support the above assumption, I check that this condition is fulfilled for each agent in all shopping sequences when calculating impulse-response functions. A similar approach is used by Alvarez et al. (2009). Under normal circumstances, this inequality is always satisfied, since it is clearly not optimal to carry over non-interest bearing liquid asset holdings between visits to the bank. The condition is violated only for large shocks (more than +4.5 or less than -2.4 standard deviations of the empirically estimated monetary shock under all considered calibrations). Including a positive steady-state inflation rate would discourage carrying cash over to the next period even further. However, in times of high deflation, e.g., due to a strong negative demand shock, agents would postpone their consumption. The model would thus endogenously generate a liquidity trap. I do not consider this kind of shocks in the present paper, but leave this possibility for future research.

where ϕ represents the fixed cost of production, see Christiano et al. (1997). The technology level A_t is common to all firms.

Monetary authority The central bank controls the money supply. It does so by setting the monetary injections S_t according to a money growth rule

$$S_t = \eta_s S_{t-1} + \epsilon_t, \tag{5}$$

which is the same as specifying a movement of the total money stock M_t according to $\Delta M_t = \eta_s \Delta M_{t-1} + \epsilon_t$. I assume that the central bank injects money only at the beginning of the period, simplifying the exposition. In the baseline scenario I assume that the complete injection is transferred to the account of the agent who starts her shopping sequence at the beginning of the period, i.e., $S_{1,t} = S_t$ and $S_{i,t} = 0\ ; \forall\ i \neq 1$. As a sensitivity analysis, I also consider the case of an equal transfer to the accounts of all agents in the economy, i.e., $S_{i,t} = S_t/n\ \forall\ i$. This implies that all agents benefit from the monetary injection but access it at different points in time, namely when visiting the bank. In this case, the customer base of the first shop after an expansionary monetary shock consists of one agent that has already received and withdrawn her part of the injection, while all other agents did not have access to their accounts yet. The second shop faces two agents that have already withdrawn their part of the injection and so forth.
In equilibrium, the aggregate money stock M_t has to equal money demand by the households. This yields for the end of period t

$$M_t = \sum_{i=1}^{n} M_{i,t}(n). \tag{6}$$

Timing and ownership structure As described above, each agent receives dividends from the shop where she has worked and shopped before entering the bank, i.e., agent i receives her wage and profits from shop $i-1$. In addition, she also receives the fixed cost ϕ. Since dividends and wages are paid on the account before the worker has access to the account, the time index changes if the period ends in between. This is the case for agent 1, who receives the profits of shop n. Hence in terms of notation we have

$$\Pi_{i,t} = \Pi_t(i-1) \quad i \neq 1 \qquad\qquad \Pi_{1,t} = \Pi_{t-1}(n).$$

For the same reason

$$\begin{aligned} W_{i,t} &= W_t(i-1) \quad i \neq 1 \qquad\qquad & W_{1,t} &= W_{t-1}(n), \\ L_{i,t} &= L_t(i-1) \quad i \neq 1 \qquad\qquad & L_{1,t} &= L_{t-1}(n). \end{aligned}$$

2.2 First-order conditions

Because of the timing assumptions, some differences in the first-order conditions arise relative to a standard model. Notably, the consumers are heterogeneous with respect to their money holdings, which changes the aggregate demand elasticity faced by the producers. Furthermore, besides their influence on nominal marginal costs, average prices of competitors affects individual optimal prices also directly because each consumer buys at a finite number of shops. Due to this different consumption behavior, price setting of firms is affected. For ease of exposition, I assume perfect foresight in the following. Due to certainty equivalence of the linearized system, this does not change the results after a one-time shock. It simplifies, however, many expression that would involve expected values in a non-linear way.[13] Furthermore, in order to present a concise exposition only the equations regarding the case of $j < i$ are presented.

Households While being at the bank, each agent has to decide how much of the liquid asset to hold for the next shopping sequence, and how much to invest into the illiquid asset for saving, resulting in a bond Euler equation.

$$\lambda_{i,t+1} = \beta(1 + r_{i,t+1}) \left(\frac{P_{i,t+1}}{P_{i,t+2}} \lambda_{i,t+2} \right).$$

The expected marginal utility of consumption is

$$\lambda_{i,t+1} = C_{i,t+1}^{-\sigma}(1 - L_{i,t+1})^{\mu(1-\sigma)}.$$

Note that the agent decides on holdings of the liquid asset that she then uses for shopping, resulting in consumption in the following period. The first-order condition concerning the labor-leisure trade-off is

$$\mu C_{i,t}^{1-\sigma}(1 - L_{i,t})^{\mu(1-\sigma)-1} = \beta W_{i,t} \left(\frac{\lambda_{i,t+1}}{P_{i,t+1}} \right), \tag{7}$$

where the left hand side is the marginal disutility of working, and the future price level and $\lambda_{i,t+1}$ enter because today's wage can only be used for the coming shopping sequence.
Appendix A derives the demand elasticity of agent i for good j with respect to the price as

$$\varepsilon_{C_{i,t}(j),P_t(j)} = -\gamma + \varepsilon_{\bar{P}_{i,t}(j),P_t(j)}(\gamma - 1), \tag{8}$$

where $\varepsilon_{\bar{P}_{i,t}(j),P_t(j)}$ is the elasticity of the individual price index for the remaining shopping sequence with respect to the price of good j, also defined in appendix A.

Shops The first-order condition for the producer is

$$\frac{\partial Y_t(j)}{\partial P_t(j)}[MC_t(j) - P_t(j)] = Y_t(j),$$

where $Y_t(j)$ is the demand function, derived in appendix A. As usual, the optimal price results as a time-varying markup over marginal costs[14]

$$P_t(j) = \frac{\varepsilon_{C_t(j),P_t(j)}}{\varepsilon_{C_t(j),P_t(j)} - 1} W_t(j)/A_t, \tag{9}$$

[13]The model equations under uncertainty are available upon request.

[14]Note that shops never want to charge an infinite price, even though customer n spends all her remaining cash. Starting from a very high value, setting a slightly lower price increases sales only marginally. This raises production costs just a little bit but increases revenues a lot, as the profit per unit sold is very high.

with the absolute value of the aggregate elasticity being

$$\varepsilon_{C_t(j),P_t(j)} = -\sum_{i=1}^{n} \frac{C_{i,t}(j)}{C_t(j)} \varepsilon_{C_{i,t}(j),P_t(j)}. \tag{10}$$

Equation (8) shows that the demand elasticity of an individual agent lies between $-\gamma$ and -1, depending on the number of remaining goods in the consumption bundle. It follows from equation (10) that the aggregate elasticity is a weighted average of individual elasticities, with the weights being determined by the consumption share of the respective consumer. Finally, equation (9) relates the markup of the firm to the aggregate elasticity in the usual way. The optimal markup is higher relative to the standard case of infinitely many goods. Note that as in standard models the firm is taking household expectations about future prices as given, i.e., a single firm does not assume that its price setting affects future prices. The implications of the above pricing rule are discussed in section 3.

Pre-set wages In the same section, I will also discuss the implications of nominal and real wage rigidities, as explored by Erceg et al. (2000) and suggested by Christiano et al. (1997) for enhancing the empirical success of limited participation models. Assuming that the first ξ^n workers after a monetary injection cannot re-negotiate their nominal wages, equation (7) is replaced by

$$W_t(i) = W \qquad i = 1, \ldots, \xi^n,$$

where variables without time indexes denote steady-state values.[15] Because of the muted response of marginal costs, a stronger output response and higher profits at the time of the shock are generated under pre-set wages, as explained in more detail below. If I assume pre-set real instead of nominal wages, equation (7) is replaced by

$$\frac{W_t(i)}{P_t(i)} = \frac{W}{P} \qquad i = 1, \ldots, \xi^r, \tag{11}$$

where ξ^r denotes the number of workers that cannot change their real wages after a monetary shock. Pre-set real wages alone do not generate monetary non-neutrality, see also Blanchard and Galí (2007). As under flexible wages, simultaneous monetary transfers to all agents in the economy—independently if they are currently at the bank or not, i.e., without asset market segmentation—lead to an increase in the price level without any real effects since no heterogeneous wealth levels arise. This heterogeneity thus remains the cause for monetary non-neutrality under pre-set real wages.

2.3 Aggregation

Aggregation concerns the question how to derive aggregate variables from the heterogeneous agents in the model. Aggregate output is defined as the sum of this variable over all producers in

[15] Note that pre-set wages can be introduced like this in the context of impulse-response functions, where the economy is at its steady state when the shock occurs. For a simulation exercise, it is relatively easy to derive the required equations.

one period. Since there is no government nor investment, consumption equals output. Note that by this convention aggregate consumption is not the consumption bundle of the utility function but real consumption expenditure, as in official statistics. Concerning wages, prices, marginal costs, labor, profits, and the markup, I use averages over all producers in one period. All these variables are counted in the period when production takes place. Since the agents participate in the asset market at different times in one period, they are offered potentially different interest rates. The aggregate interest rate is defined as the average. Total money supply is the total amount of the liquid asset in the economy at the end of the period.[16] Velocity can then be calculated given aggregate output, the price level, and the money supply.

2.4 Steady state

The steady state is characterized by a fixed money stock and a constant technology level. Since these are the only exogenous driving forces in the model, all other variables are also constant. The only steady-state variable that will play a role later on (in the calibration section) is the velocity of money, which is derived in appendix B.

3 The inflation-output trade-off

To generate a sizable inflation-output trade-off, nominal shocks need to have an impact on real variables. Furthermore, this impact might need to be amplified to be quantitatively relevant. This section shows how the heterogenous wealth distribution is responsible for generating real effects of monetary shocks. The sequential structure of the model together with rigid real wages then delivers the needed amplification, as discussed in section 3.2. As an alternative, I will also consider the case of modestly rigid nominal wages, which by themselves create real effects of nominal shocks. They too are amplified by the sequential structure.

Under flexible prices and wages, monetary policy affects real variables only by changing the wealth distribution via segmented asset markets. While the resulting impact on household's heterogenous demand and labor-supply decisions results from the underlying Baumol-Tobin structure, the influence via its impact on firm's pricing decisions is due to the novel form of endogenous markups. Price setters face a trade-off between extracting more profits from the customers with a low elasticity, and loosing profits from the customers at the beginning of the sequence, who might substitute to shops that come later in the row. In this decision context, a monetary shock influences the markup in the following way. A cash injection reaches only those agents currently visiting the asset market (or, alternatively, reaches these agents earlier than others). After having received the injection on the asset market, the agents start a new shopping sequence. Thus, their demand elasticity is high. Furthermore, their relative weight rises because of their increased consumption share. The aggregate demand elasticity increases, leading to a countercyclical markup after expansionary monetary shocks. A countercyclical markup is crucial for achieving procyclical real marginal costs (wages). It also dampens the

[16]This ensures comparability with the data, which measures also the end-of-period money stock.

initial inflation response and thereby increases demand. These mechanisms generate the initial short-term inflation-output trade-off. Put differently, firms avoid being first to raise prices to the new steady-state level to attract more of the richer (and higher-elasticity) customers. Over time, more and more agents benefit from the initial injection via elevated nominal wages and profits, which are higher for those shops that employ agents with an increased labor supply. Since the dispersion of income from wages and profits levels off only slowly, the wealth distribution remains heterogenous for a prolonged period, leading to long-lasting responses. The risen money supply depresses initial interest rates because agents currently at the bank have to be induced to hold more money, causing a liquidity effect.

In order to demonstrate that this channel is the most important one, I additionally lay out the remaining two alternative transmission mechanisms via demand and labor supply. The effect of a changing wealth distribution on households' demand—even without any price movements—can be isolated in a thought experiment in which all prices jump up directly to the new steady-state value after a monetary shock. Equal prices between all firms eliminate any impact of heterogeneous labor supplies on the distribution of final goods prices.[17] With prices being the same for all producers, changes in demand are only due to wealth effects. The resulting effect on aggregate output is actually (small and) negative. The agents that receive the injection spend the extra amount during the curse of their shopping sequences. Initially, however, all other agents cannot increase their spending as they did not yet benefit from the injection. This missing expenditure hinders total period spending to immediately reach its new steady-state level. Hence, while prices have already jumped up to the new level, nominal expenditure is below its new long-run value. This decreases output.[18] Hence, the effect of the monetary injection on heterogenous demand per se cannot explain the inflation-output trade-off, as it predicts the wrong sign. A more detailed demonstration for $n=2$ is given in appendix C.

The heterogenous wealth distribution can have an impact on real variables also via its effects on labor supply. Depending on the size of the individual wealth effects compared to the substitution effects, the heterogenous labor supplies of relatively richer and poorer workers can push aggregate output up or down. While this is an interesting aspect in itself, I skip an extensive discussion because the quantitative effect is relatively small. Sensitivity analyzes later in this section and in section 5 of changing the intertemporal elasticity of substitution, thereby also changing the size of the wealth effect, show that the wealth effect's impact on heterogenous labor-supply decisions has a very limited influence on the maximum response of real and nominal variables. As argued above, the largest effect thus stems from pricing decisions. A sensitivity analysis in section 5 shows that fixing the markup, i.e., allowing only for the remaining two transmission channels, reduces the impact of monetary policy drastically.

For all of the considered channel, the time-varying wealth distribution—created by the segmented asset markets—is necessary to generate an inflation-output trade-off. If a monetary injection reaches all agents independently if they are currently at the bank or not, the money

[17] In fact, the labor-supply equation cannot be observed in this case (e.g., by imposing rigid real wages for a long period), as heterogenous labor-supply decisions can generally not be squared with equal prices.

[18] Note that the dispersion of money holdings still prevails. In particular, since only few agents participate in the asset market at the time of the monetary injection, the basic limited participation mechanism is effective, yielding a liquidity effect.

distribution is merely shifted upwards and nominal variables jump to a higher level while real variables are not affected. This can be seen by multiplying all nominal variables, including the cash-in-advance constraints (4) of agents currently not trading, with a scalar (observing that in equilibrium $B = 0$). Note that this is also the case under pre-set real wages.

3.1 Impulse-response functions for the basic setup

In order to demonstrate the basic mechanism of the model, figure 2 shows the impulse-response functions after an unanticipated monetary policy shock of 0.55% to the money supply at $t = 0$ for the simplest case, namely $n = 2$, flexible wages, and $\rho_M = 0$. A lower number of shops visited leads, ceteris paribus, to a lower elasticity of substitution. To achieve a steady-state markup of 20%, the parameter γ has therefore to be set to 21. The remaining calibration targets are as in table 1 in section 5. The figure compares the baseline calibration of an intertemporal elasticity of substitution ($1/\sigma$) of 1/3 and a Frisch elasticity of 1/2 (black solid lines) with the cases of a Frisch elasticity of 1/3 (red dashed-dotted lines), $\sigma = 5$ (blue dashed lines), and $\sigma = 2$ (green dashed-dotted lines), each with a Frisch elasticity of 1/2. The results are similar across calibrations. Except for profits, the model does qualitatively well in reproducing the empirical impulse-response functions of section 4. Profits fall due to a larger increase in the real wage. They rise after a monetary injection for higher n or sticky wages, though. As in the empirical counterpart, velocity falls on impact but fails to rise above zero in subsequent periods.

Figure 2 about here

Quantitatively, however, the model fails to deliver empirical plausible results if compared with the empirical evidence of the next section. In particular, nominal costs (i.e., wages) increase relatively quickly. I therefore introduce modest wage rigidities, whose interaction with the sequential structure and the endogenous markups strongly amplifies the responses. I begin with the description of the effects of nominal wage rigidities and consider real wage rigidities next.

3.2 Wage rigidities

If the first ξ^n shops after a monetary shock face constant nominal wages, nominal marginal costs and therefore nominal prices charged will remain lower than in the flexible-wage case. Also modest degrees of wage rigidities have a large impact on output owing to the sequential structure of the model. Customers anticipate that prices will eventually reach the new equilibrium level and therefore spend more in the early shops with low prices. The higher revenues raise income of workers and business owners during this initial subperiod, who increase their expenditure in the next shops to open (potentially still in the same time period).

While pre-set nominal wages alone generate real effects of nominal shocks, this is not the case for rigid real wages. In this case, the described impact of a changing wealth distribution are responsible for real effects, while the combination of pre-set real wages with endogenous markups amplifies the responses. Initially, the changed wealth distribution exerts a negative pressure on markups and induces shops to reduce prices. With pre-set real wages, nominal wages are directly tied to prices, keeping prices at an even lower level. As in the case of rigid nominal wages, lower wages stimulate initial spending and therefore business income and subsequent spending due to the sequential structure. The downward spiral of lower prices and wages reaches an equilibrium because of the following counteracting force on the endogenous markups. A lower price increases the expenditure share of the respective good in individual consumers' baskets. This raises the market power of the corresponding shop, which has a positive influence on markups.[19] Consequently, prices stabilize at a lower level, where these two effects counterbalance each other. Hence, although markups do not move very much—they are in fact constant during the period of pre-set real wages—their endogeneity in the price-setting problem generates large effects; it implies that low initial prices are consistent with the optimal markup decision of firms after a monetary injection.

Figure 3 about here

To illustrate the above discussed mechanisms, figure 3 plots the responses of prices and markups of individual shops after a monetary injection. The size of this injection and all other parameters are as in figure 2. For demonstrational purposes shop number 1, owned by agent 1, faces a rigid real wage after the injection, while the other does not. Since a fixed real wage implies a fixed markup, the first shop keeps it constant in the first period (reducing the movement of the average markup) and charges a relatively low price, as explained above. The second shop reduces its markup and also charges a price below the new steady-state price. Because of the low prices, output and nominal revenues are above the new steady-state level. The latter are paid to the agents that own and work in the respective shops, which increases subsequent spending (still in the first period in case of agent 2) and prolongs the heterogeneous wealth distribution. In the following period, the first shop faces a customer with relatively high money holdings in the last part of her shopping sequence, namely agent 2, who received high revenues due to the pre-set wage in her shop. Her spending of all remaining cash in this shop creates an incentive for higher markups. However, since the shop does not want to forego sales to the other customer who is in the first stage of her shopping sequences and has therefore higher absolute money holdings and a higher elasticity of substitution, the increase in the markup is tiny. Nominal wages are still below the new steady state, as the price level needs more time to fully adjust, such that shop 1 still sets a comparatively low price. Shop number 2 keeps its markup reduced because of the heterogenous wealth distribution but faces a risen nominal wage, which increases gradually. Hence, output is still comparatively high for both shops. This continues until prices have converged to the new steady-state level. The same pattern also emerges for higher n. The shop that faces the richest

[19] Specifically, lower prices increase purchases and therefore the relative weight of the specific good in customers' baskets and their individual price indexes. Price increases of low-price firms thus lead to larger reactions of individual price indexes $\bar{P}_{i,t}(j)$ (see equation A-5) and thereby to a muted reaction of the ratio $P_t(j)/\bar{P}_{i,t}(j)$ and a smaller demand response (see equation 8). This reduced demand elasticity increases optimal markups for lower relativ prices. Equation (11) then states that firms which cannot re-set their real wages keep the same markup as before the shock. Keeping a constant optimal markup can thus only be reached via lower prices. Hence, prices and nominal wages rise more slowly to the new equilibrium and firms increase sales and output. Furthermore, since markups (and, as usual, wage demand) depend positively on competitors prices, prices are strategic complements.

agent in the last part of her shopping sequence sets a relatively high markup, while all other unconstrained firms lower markups in the period after a monetary expansion. All firms, however, raise prices only slowly to the new long-run level.
Introducing wage rigidity can therefore deliver results that are also quantitatively in line with empirical evidence. To this end, section 5 brings the model to the data by using plausible values for wage stickiness and the number of bank visits. Before this the next section establishes empirical evidence.

4 Empirical evidence

To compare the predictions of the model to their empirical counterparts, I calculate impulse-response functions to monetary shocks based on time series for the United States.

4.1 Data and estimation procedure

The series employed are the log of the gross domestic product (GDP), the change in the log of the GDP deflator (inflation), corporate profits of non-financial firms, hours worked, real wages, velocity, M1, and the federal funds rate (FFR). Additionally, the inverse of real unit labor costs is used as a proxy for the markup, see Galí et al. (2007).[20] Following Clarida et al. (1999), the data start in 1979Q3, the date when Paul Volcker was appointed chairman of the Fed, and run through 2009Q4. Finally, in order to investigate the heterogenous impact of a monetary shock on consumers, I include the standard deviation over consumers' total consumption expenditure.[21] For sources and details of the data, see appendix E. The identification scheme follows standard techniques. Specifically, I estimate a VAR of the form

$$A(L)Y_t = \epsilon_t,$$

where $A(L)$ denotes a matrix polynominal in the lag operator L. A constant and a linear trend is omitted to simplify the exposition. In the baseline regression, the lag length is four and the vector Y_t includes four variables

$$Y_t = \begin{pmatrix} \ln(\text{GDP}_t) \\ \text{Inflation}_t \\ \ln(\text{Profits}_t) \\ \text{FFR}_t \end{pmatrix}.$$

Identification is achieved by the assumption that a change in the federal funds rate has no impact on real variables in the same quarter. This implies that $A(0)$ is lower-triangular and the interest

[20]This approximation holds in the model, as flexible prices imply that output prices are set as a markup over marginal costs.

[21]This variable is calculated from the panel of households constructed in Krueger and Perri (2006). I also include an impulse dummy in 1986Q1 because all households of the sample change at that date. The series starts in 1980Q1 and ends in 2004Q4, such that the VAR has to be adjusted accordingly when this variable is used.

rate is ordered last, or second-to-last if M1 or velocity are included. See Christiano et al. (1996) for further details. In order to economize on the degrees of freedom, I re-estimate the VAR six more times, replacing in turn profits with the logs of hours, the inverse of real unit labor costs, real wages, velocity, the monetary base, and consumption expenditure dispersion.

Figure 4 about here

Figure 5 about here

4.2 Impulse-response functions

The estimated responses of the variables under consideration are plotted in figures 4 and 5. Dashed lines represent bootstrapped 90% confidence intervals based on 1000 replications. The results are in line with established views in the literature.[22] After an unexpected fall in the federal funds rate of 100 basis points, output, inflation, hours worked, unit labor costs, velocity, M1, and profits increase. While inflation and output rise by around the same amount, real wages increase by much less. The finding of an increase in the monetary base after a fall in the interest rate documents a liquidity effect. As discussed in Christiano et al. (1997), rising profits constitute a problem for standard sticky-price models. Additionally, figure 5 presents novel evidence on consumption expenditure dispersion. As visible, this variable changes significantly, documenting a heterogenous impact of a monetary-policy shock on expenditure. The increase in dispersion shows that mainly consumers with high expenditure levels benefit initially. The response returns to its pre-shock level after around one year.

5 Simulation

After having established empirical evidence, I compute the impulse-response functions of the model and compare them to their empirical counterparts. In order to do so, I linearize the model around its symmetric (and unique) non-stochastic steady state and solve the resulting system of linear equations using standard techniques.

5.1 Calibration

The baseline parameters used for the simulation of the model are summarized in table 1. The elasticity of substitution between the varieties γ is chosen such that the markup in steady state is 20%, see Rotemberg and Woodford (1993).[23] Different values are used in the literature for

[22] See Christiano et al. (1997), who report similar findings for the responses of output, inflation, interest rates, wages, and profits. Altig et al. (2011) include velocity as well, yielding almost the same picture as here. Galí et al. (2007) also report a falling markup after an expansionary monetary shock.

[23] Rotemberg and Woodford (1993) report values between 20% and 40%. Due to the finite number of goods in the consumption bundle, the monopoly power of firms for a given γ is higher relative to the case of infinitely many goods. With infinitely many goods the markup that corresponds to the chosen γ would be 15%.

the coefficient of relative risk aversion σ. Basu and Kimball (2002) report empirical findings for its inverse, the intertemporal elasticity of substitution, ranging from 0.2-0.75. The Frisch elasticity of labor supply was estimated between 1/3 and 1/2 by Domeij and Flodén (2006). I choose a parameter constellation in the baseline calibration with $\sigma = 3$ and a Frisch elasticity of 1/2 ($\mu = 0.65$). Later in this section I conduct a robustness check regarding these parameters, employing 2 and 5 for σ and 1/3 for the Frisch elasticity. The fixed cost is set such that the steady-state profit share corresponds to the empirical average of 5.1% over the sample period.[24] Concerning the length of one period, note that in this model each agent visits the asset market once every period. Hence, the length of one period determines how often agents re-optimize their asset holdings. I follow Alvarez et al. (2009) and use one year as the length of one period.[25] The latter authors refer to Vissing-Jørgensen (2003), who shows that around 1/2 to 1/3 of households trade in asset markets in a given year, which would correspond to even longer periods of 2-3 years. Christiano et al. (1996) find that households' assets do not change significantly for one year after a monetary policy shock, such that the choice of one year seems appropriate. Furthermore, appendix D shows that this frequency of asset reoptimization turns out to be optimal in steady state for relatively small costs of reoptimizing asset holdings. The discount factor is therefore set to 0.96, implying an annual steady-state interest rate of four percent. The parameter n determines how often the bank is visited by different agents in one period, and thus governs velocity. Choosing $n = 14$ implies, according to equation (B-2) in appendix B, a steady-state velocity of 1.87, corresponding to the mean over the empirical sample. The money growth rate after a monetary policy shock is estimated in the VAR model of section 4 to be 0.36 in quarterly terms, implying an annual value for ρ_M of 0.36^4 since the model does not allow for intra-period injections.[26]

Table 1 about here

Concerning the degree of wage stickiness, a large body of literature employs a Calvo-lottery scheme for generating a slow adjustment of nominal wages. The values used for the corresponding Calvo parameter range from the estimates of 0.64 in Christiano et al. (2005) to values of 0.72 in Altig et al. (2011) and 0.75 in Erceg et al. (2000). I convert them to pre-set wages along the following thought. During the time of pre-set wages, firms cannot adjust at all, while afterwards firms are free to adjust fully. I therefore set the length of the pre-set wage period such that it corresponds to the time when half of the wage setters can adjust after a shock in a Calvo-style model. With a Calvo parameter of 0.7, this period is around one quarter.[27] I will therefore consider a small friction of nominal wages being pre-set for slightly above one quarter. With $n = 14$

[24] Again, see the appendix for data and their sources.

[25] Alvarez et al. (2009) use values between 11 and 38 for their variable N, assuming that each month a fraction $1/N$ of households are active in the asset market. In the present model, each household participates in the asset market in every period. This implies that one period has a length of N months.

[26] The responses do not change if alternatively each agent receives a monetary injection of 0.36 times the injection that was received by the agent who visited the bank last. Only dispersions increase somewhat. However, notation would become more cumbersome with intra-period money injections.

[27] Letting ξ^C denote the quarterly Calvo parameter, a fraction of $1 - \xi^C$ adjusts in the period of the shock. One quarter later, this fraction reaches $(1-\xi^C)(1+\xi^C)$, which is $1/2$ for $\xi^C = 0.707$ and 0.48 for the value of Altig et al. (2011). Thus, a little bit less than half of the price setters adjust after one quarter.

this implies $\xi^n = 4$, i.e., the first four shops in the period cannot change their nominal wage after a monetary injection. Furthermore, I will use $\xi^n = 3$ as a robustness check, such that wages are pre-set slightly below one quarter, as well as $\xi^r = 3$ for a further investigation of the model's mechanics.

Figure 6 about here

5.2 Impulse-response functions

Figure 6 shows the theoretical responses to an unanticipated, positive shock to the total money supply of 0.55%, corresponding to the observed change of the money stock in the first period after an expansionary shock in section 4. I consider several cases for the labor market frictions, described in the previous section. The baseline calibration with $\xi^n = 4$ (wages pre-set for 1.14 quarters) is plotted with a solid black line. A shorter duration of $\xi^n = 3$ (wages pre-set for 0.86 quarters) is depicted by the red dashed-dotted line. The resulting impulse-response functions are quite similar. In order to isolate the effect of asset market segmentation I also explore the case of pre-set real wages, as discussed in section 3.2. The corresponding impulse-response functions for $\xi^r = 3$ are plotted with blue dashed lines in the same figure. While pre-set nominal wages create another channel through which monetary policy can affect real variables, pre-set real wages do not. This friction alone does not create monetary non-neutrality, as shown above. Combined with the sequential structure of the model, however, a significant inflation-output trade-off is created. Additionally, the green dashed-dotted lines show the the endogenos markup is crucial for generating sizable respones. They represent a scenario in which firms ignore the heterogeneity of their customer base and set constant markups, i.e., the markup in equation (9) is fixed to its steady-state value.

As in the basic scenario in section 3.1, prices rise only slowly, thereby increasing demand. This reaction in sales raises profits, despite the falling markup. Real wages increase by a small amount. The higher money supply depresses interest rates since agents currently at the bank have to be induced to hold more money, resulting in a liquidity effect.

Figure 7 about here

Comparing figures 4 and 5 with figure 6 shows that the model with modest wage rigidities performs fairly well in replicating the empirical responses. Output, inflation, profits, and hours increase by around the same amount as found in the data. Also velocity rises by an empirical plausible value, without the initial fall. An exception is the real wage, which responds much too little in the model compared with the point estimate in section 4. Also the markup responds more strongly in the data, potentially indicating that there might be more influences on markups than considered here. However, the estimated confidence intervals of both variables are very wide and include the theoretical responses. Furthermore, the interest rate falls less then the corresponding reaction in the data. In terms of persistence, the model does reasonably well in generating an internal propagation mechanism. The responses of many variables are similarly long-lived as their empirical counterparts. Notable exceptions are inflation, velocity, and hours, which return to their steady-state values quicker than the corresponding responses of the VAR. Considering the stylized structure of the model without capital and further features that would add additional persistence, the proximity of most responses to their empirical counterparts in terms of size and length is quite satisfying. Note that the model is able to deliver quantitatively plausible results without resorting to high markups and/or a high labor-supply elasticity, which Christiano et al. (1997) report as crucial for the empirical success of a basic limited participation model. The biggest failings are the small impact of monetary shocks on the real wage and the short response of velocity.

Figure 8 about here

Figure 7 plots the standard deviations of selected variables across consumers or firms after the same shock as in the previous exercise. Again, the black line stands for $\xi^n = 4$, the red dashed-dotted line for $\xi^n = 3$, and the blue dashed one for $\xi^r = 3$. The values for money holdings and (consumption) expenditure refer to dispersions across consumers. The remaining plots depict dispersions across shops, where this measure coincides with dispersions across consumers for wages and hours. Except for the nominal wage, variables are in real terms. As mentioned before, the increased dispersion of money holdings, i.e., money withdrawn from the bank for shopping trips, is important for generating real effects. But since firms are visited sequentially, also output and markups are dispersed over firms, leading to quite large differences in the reaction of profits. While the real wage develops similarly for all workers, hours worked differ to a larger extent because of the heterogeneous wealth distribution. The prediction of an increase in the dispersion of prices after a monetary shock if empirically supported by Balke and Wynne (2007). Also the dispersion of consumption expenditure across individual consumers increases significantly, in line with the estimate in figure 5. In the model, a part of the population benefits (or benefits earlier) from such a shock and increases expenditures, while the remaining population profits later via second-round effects, leading to a subsequent reduction in expenditure dispersion. The empirical response is a bit shorter lived, though. In sum, the model does satisfactorily in generating dispersions that are consistent with the sparse evidence, i.e., it predicts a crucial interaction between the level of aggregate variables and their dispersions.

5.3 Sensitivity analysis

As discussed in the calibration section, values for the intertemporal elasticity of substitution (IES) and the Frisch elasticity of labor supply are estimated within broad ranges in the empirical literature. I therefore calculate the impulse-response functions for four different parameter constellations in figure 8. The black lines reproduce the baseline calibration ($\sigma = 3, \mu = 0.65$, i.e., IES=1/3, Frisch elasticity=1/2), while the red dashed-dotted lines depict the case of $\sigma = 3$ and $\mu = 0.38$, corresponding to an IES and a Frisch elasticity of 1/3 each. The blue dashed lines plot the case of $\sigma = 5$ and $\mu = 0.71$, implying an IES of 1/5 and a Frisch elasticity of 1/2. Finally, the green dashed-dotted lines result from $\sigma = 2$ and $\mu = 0.59$, that is an IES and a Frisch elasticity of 1/2 each. As visible in the picture, the model predicts very similar results for all considered cases. Since the intertemporal elasticity of substitution governs the reaction of the marginal utility to changes in consumption, variations in σ change the wealth effect on (heterogenous) labor-supply decisions. The impact response of GDP and hours worked are unaltered and the responses of the remaining variables change little, with a reduced persistence for lower values of σ. Note that during the period of pre-set wages hours worked are determined by demand, which dampens the effective wealth effect on labor supply.

Figure 9 about here

I also explore the alternative distribution mechanism for the monetary injection described in section 2. In this scenario, the central bank transfers equal amounts of money on all accounts in the economy ($S_{i,t} = S_t/n \; \forall \; i$), where the total increase in the money stock is as before. Because of the staggered bank visits, each agent has access to her share of the injection at different points in time, i.e., when visiting the asset market. This mechanism generates the impulse-response functions in figure 9, showing that it is not crucial that the monetary injection is concentrated in the hand of a single agent for a sizeable inflation-output trade-off to emerge. I consider the same parameter variations as in figure 8. Slightly hump-shaped responses for output, inflation, hours, and profits emerge, in line with the empirical evidence. Furthermore, velocity now falls on impact and then rises, also a feature of the empirical impulse-response function in figure 6. On the other hand, profits and the interest rate react less than before. The lower response of output is due to the lower money supply during the initial period of pre-set wages and low prices.

6 Conclusion

Introducing the slow spreading of newly injected money and its effects on price setting and labor supply in a model of segmented asset markets with modest wage rigidities (real or nominal) can replicate several empirical observations: 1) a short-term inflation-output trade-off after a monetary injection, 2) quantitatively empirical plausible impulse-response functions for output, inflation, hours worked, profits, expenditure dispersion, and velocity after monetary injections, 3) a liquidity effect, 4) a countercyclical markup at the firm level, and 5) procyclical wages after monetary shocks. Without wage rigidities, the impulse-response functions for most variables are qualitatively in line with the evidence. The model generates a microfounded, internal propagation mechanism which does not rely on capital or sticky prices, but on the slow spreading of newly inserted money. This can be seen as a way of describing the effects of central bank actions, where only parts of the population benefit through first-round effects, while others are affected indirectly and later. Because shops and consumers take future prices and quantities into account in an overlapping manner, forward-looking behavior of both groups results even without capital, sticky prices or wages. Furthermore, the distribution of money holdings represents another state variable. The sequential structure of the model is therefore responsible for richer dynamics, which could also be interesting for the analysis of other kinds of shocks or effects of anticipation.

References

Altig, D., Christiano, L. J., Eichenbaum, M., and Lindé, J. (2011). Firm specific capital, nominal rigidities and the business cycle. *Review of Economic Dynamics*, 14(2):225–247.

Alvarez, F. and Atkeson, A. (1997). Money and exchange rates in the Grossman-Weiss-Rotemberg model. *Journal of Monetary Economics*, 40(3):619 – 640.

Alvarez, F., Atkeson, A., and Edmond, C. (2009). Sluggish responses of prices and inflation to monetary shocks in an inventory model of money demand. *Quarterly Journal of Economics*, 124(3):911–967.

Alvarez, F., Atkeson, A., and Kehoe, P. J. (2002). Money, interest rates, and exchange rates with endogenously segmented markets. *Journal of Political Economy*, 110(1):73–112.

Balke, N. S. and Wynne, M. A. (2007). The relative price effects of monetary shocks. *Journal of Macroeconomics*, 29:19–36.

Basu, S. and Kimball, M. (2002). Long-run labor supply and the elasticity of intertemporal substitution of consumption. Mimeo, University of Chicago.

Bils, M. (1989). Pricing in a customer market. *Quarterly Journal of Economics*, 104(4):699–718.

Blanchard, O. and Galí, J. (2007). Real wage rigidities and the new Keynesian model. *Journal of Money, Credit and Banking*, 39(s1):35–65.

Campello, M. (2003). Capital structure and product markets interactions: evidence from business cycles. *Journal of Financial Economics*, 68:353–378.

Chevalier, J. A. and Scharfstein, D. S. (1996). Capital-market imperfections and countercyclical markups: Theory and evidence. *American Economic Review*, 86(4):703–725.

Christiano, L., Eichenbaum, M., and Evans, C. (2005). Nominal rigidities and the dynamic effects of a shock to monetary policy. *Journal of Political Economy*, 113(1):1–45.

Christiano, L. J., Eichenbaum, M., and Evans, C. (1996). The effects of monetary policy schocks: Evidence from the flow of funds. *Review of Economics and Statistics*, 78(1):16–34.

Christiano, L. J., Eichenbaum, M., and Evans, C. (1997). Sticky price and limited participation models: a comparison. *European Economic Review*, 41(6):1201–1249.

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

Dixit, A. and Stiglitz, J. (1977). Monopolistic competition and optimum product diversity. *American Economic Review*, 67:297–308.

Domeij, D. and Flodén, M. (2006). The labor-supply elasticity and borrowing constraints: Why estimates are biased. *Review of Economic Dynamics*, 9(2):242–262.

Erceg, C. J., Henderson, D. W., and Levin, A. T. (2000). Optimal monetary policy with staggered wage and price contracts. *Journal of Monetary Economics*, 46(2):281–313.

Fuerst, T. S. (1992). Liquidity, loanable funds, and real activity. *Journal of Monetary Economics*, 29:3–24.

Galí, J. (2008). *Monetary Policy, Inflation, and the Business Cycle: An Introduction to the New Keynesian Framework*. Princeton University Press.

Galí, J., Gertler, M., and López-Salido, J. (2007). Markups, gaps, and the welfare costs of business flucturations. *Review of Economics and Statistics*, 89(1):44–59.

Grossman, S. J. and Weiss, L. (1983). A transactions-based model of the monetary transmission mechanism. *American Economic Review*, 73(5):871–880.

Jovanovic, B. (1982). Inflation and welfare in the steady state. *Journal of Political Economy*, 90(3):561–577.

King, R. G., Plosser, C. I., and Rebelo, S. T. (1988). Production, growth and business cycles. *Journal of Monetary Economics*, 21:195–232.

Krueger, D. and Perri, F. (2006). Does income inequality lead to consumption inequality? Evidence and theory. *Review of Economic Studies*, 73:163–193.

Lucas, R. E. (1990). Liquidity and interest rates. *Journal of Economic Theory*, 50(2):237–264.

Menzio, G., Shi, S., and Sun, H. (2011). Monetary theory with non-degenerate distributions. Queens economics department working paper no. 1264.

Occhino, F. (2004). Modeling the response of money and interest rates tomonetary policy shocks: a segmented markets approach. *Review of Economic Dynamics*, 7(1):181 – 197.

OECD (2010a). Economic Outlook 87, Main Economic Indicators vol. 2009. Available via SourceOECD.

OECD (2010b). OECD.Stat. Available via http://stats.oecd.org.

Rotemberg, J. (1984). A monetary equilibrium model with transactions costs. *Journal of Political Economy*, 92(1):40–58.

Rotemberg, J. and Woodford, M. (1993). Dynamic general equilibrium models with imperfecly comptetitive product markets. NBER Working Paper Nr. 4502.

Rotemberg, J. and Woodford, M. (1999). The cyclical behavior of prices and goods. In Taylor, J. and Woodford, M., editors, *Handbook of Macroeconomics*. Amsterdam: North Holland.

Vissing-Jørgensen, A. (2003). Perspectives on beharioral finance: Does ”irrationality” disappear with wealth? Evidence from expectations and actions. *NBER Macroeconomics Annual*, pages 139–200.

Woodford, M. (2003). *Interest & Prices*. Princeton University Press, Princeton, New Jersey.

Tables and Figures

Parameter		Value	Calibration Target	Value
Intratemporal elasticity of subst.	γ	7.51	SS Markup	20%
Coefficient of rel. risk aversion	σ	3	Intertemp. elasticity of subst.	1/3
Weight on leisure	μ	0.65	Frisch Elasticity	1/2
Fixed costs	ϕ	0.071	Profit share	5.1%
Discount factor	β	0.96	SS interest rate	4%
Total # visits to the bank	n	14	Average velocity	1.87
Autocorrelation of money shock	ρ_M	0.36^4	Quarterly autocorrelation	0.36
Wage stickiness	ξ^n	4	Time until 50% of all shops adjust	1.14 Q.

Table 1: Baseline calibration of the model

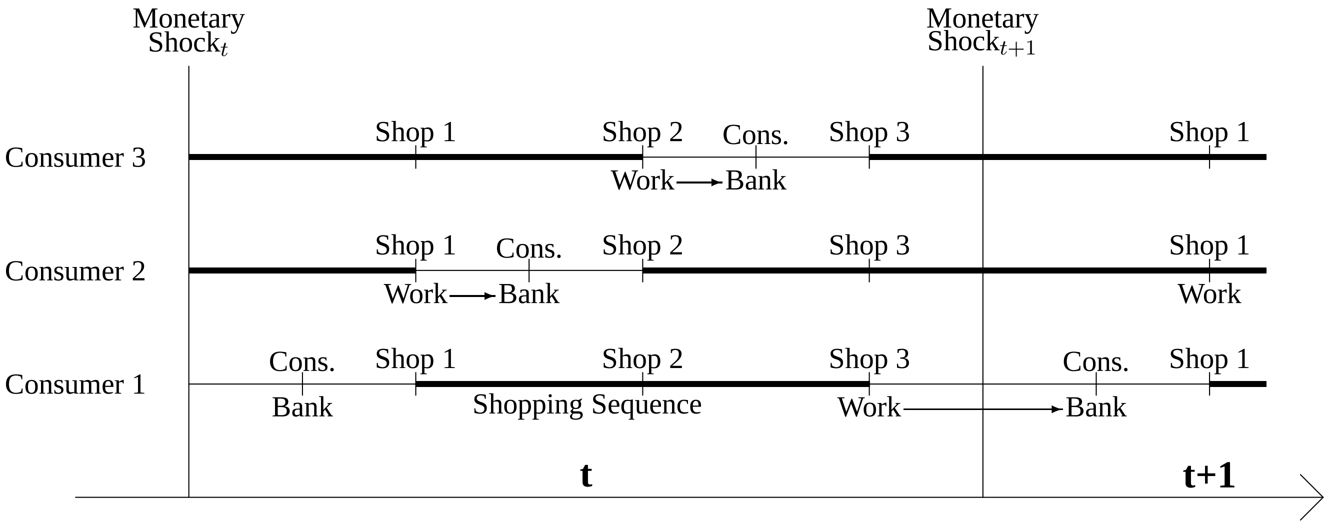

Figure 1: Timing of the model. Notes: 'Shop j' denotes purchases at shop of type j, 'Bank' the participation in the asset market. 'Cons.' stands for consumption of the previously bought bundle, while arrows depict the transfer of income from labor and business activity to the account of the respective agents. Thick lines represent shopping sequences.

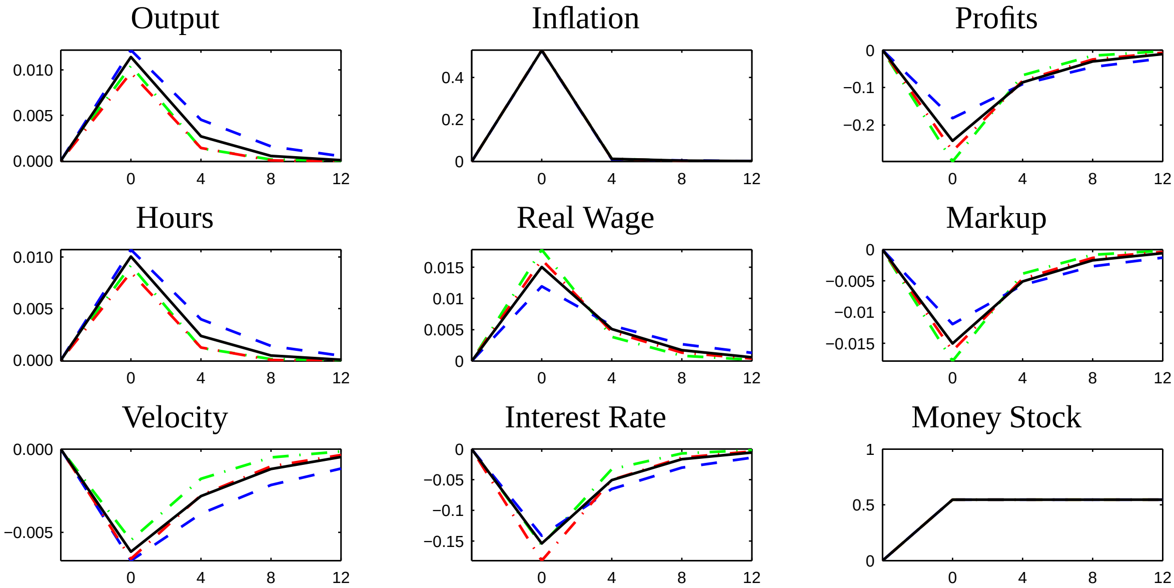

Figure 2: Theoretical responses to an unanticipated expansionary monetary policy shock at t=0 under flexible wages for n=2. Black solid lines: σ=3, Frisch elasticity=1/2. Red dashed-dotted lines: Frisch elasticity=1/3. Blue dashed lines: σ=5. Green dashed-dotted lines: σ=2. Notes: Horizontal axis denotes quarters, vertical axis shows log deviations from steady state.

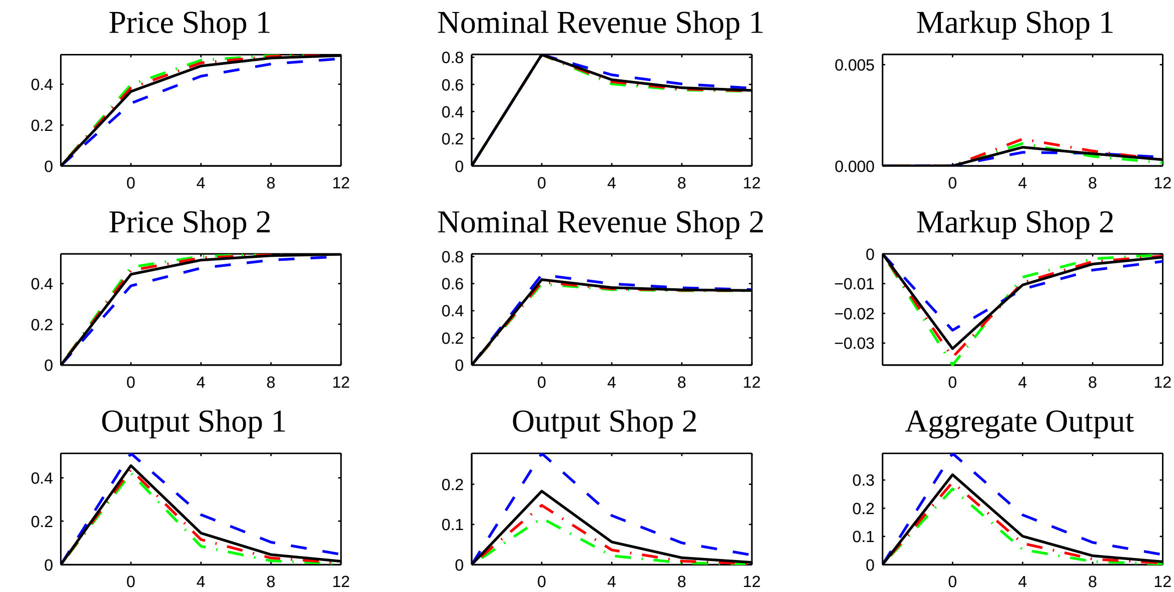

Figure 3: Theoretical responses to an unanticipated expansionary monetary policy shock at t=0 of individual shops for n=2 with real wages set in advance for one shop. For description of different lines see figure 2. Notes: Horizontal axis denotes quarters, vertical axis shows log deviations from old steady state.

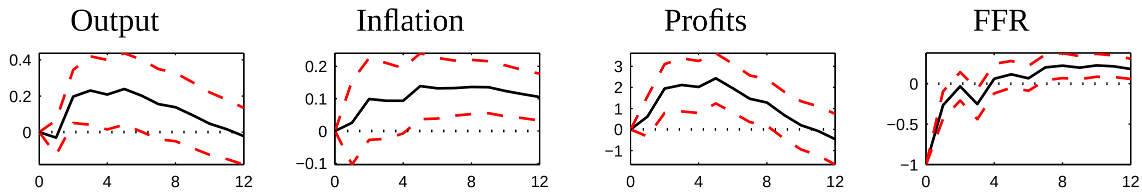

Figure 4: Empirical responses to an unanticipated expansionary monetary policy shock at t=0. Solid line: point estimate. Dashed red lines: bootstrapped 90% confidence intervals based on 1000 replications. Notes: Horizontal axis denotes quarters, vertical axis shows log deviations. For description of the data, see appendix E.

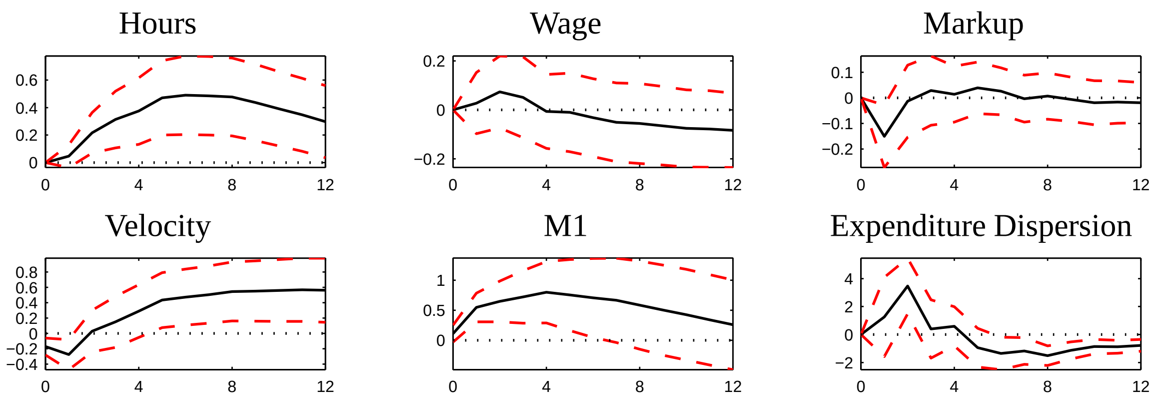

Figure 5: Empirical responses to an unanticipated expansionary monetary policy shock at t=0. For description of different lines see figure 4. Notes: Horizontal axis denotes quarters, vertical axis shows log deviations. For description of the data, see appendix E.

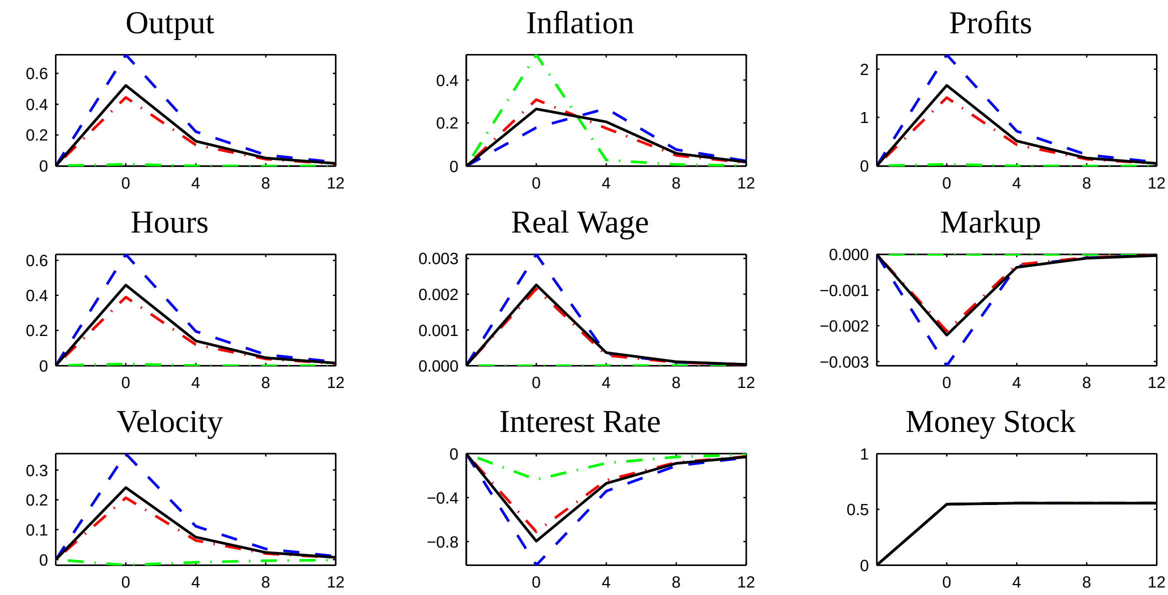

Figure 6: Effects of different wage rigidities. Theoretical responses to an unanticipated expansionary monetary policy shock at t=0. Black solid lines: nominal wages set in advance for four shops (baseline). Red dashed-dotted lines: nominal wages set in advance for three shops. Blue dashed lines: real wages set in advance for three shops. Green dashed-dotted lines: constant markups. Notes: Horizontal axis denotes quarters, vertical axis shows log deviations from steady state.

Figure 7: Theoretical responses of dispersion to an unanticipated expansionary monetary policy shock at t=0. For description of different lines see figure 6. Notes: Horizontal axis denotes quarters, vertical axis shows standard deviations of percentage deviations from steady state for individual agents.

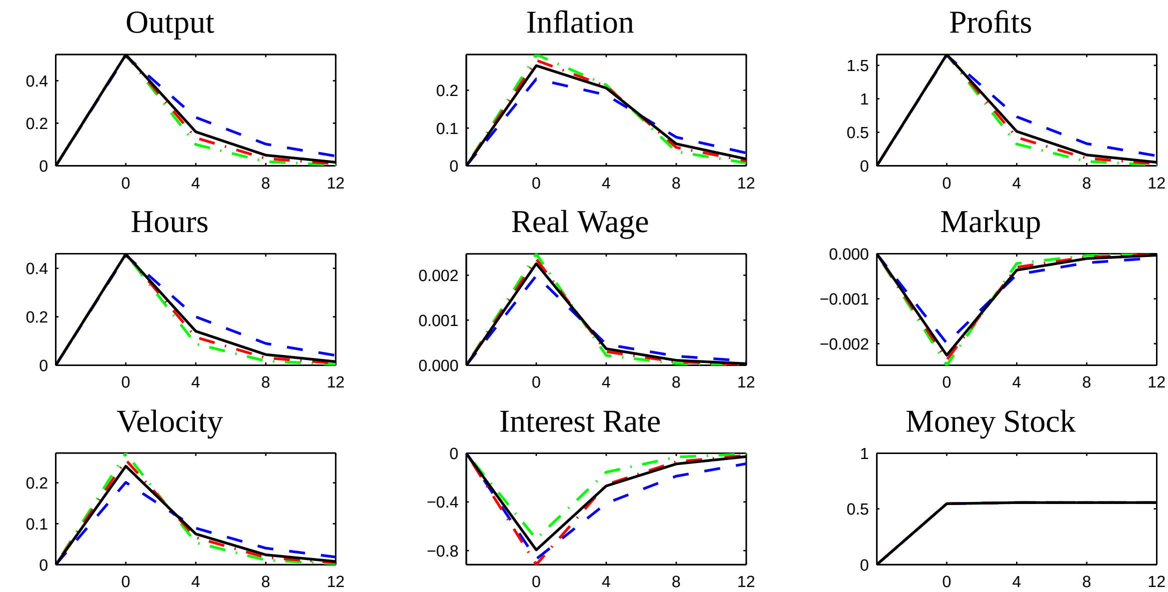

Figure 8: Effects of different elasticities. Theoretical responses to an unanticipated expansionary monetary policy shock at t=0. Black solid lines: baseline calibration. Red dashed-dotted lines: Frisch elasticity=1/3. Blue dashed lines: σ=5. Green dashed-dotted lines: σ=2. Notes: Horizontal axis denotes quarters, vertical axis shows log deviations from steady state.

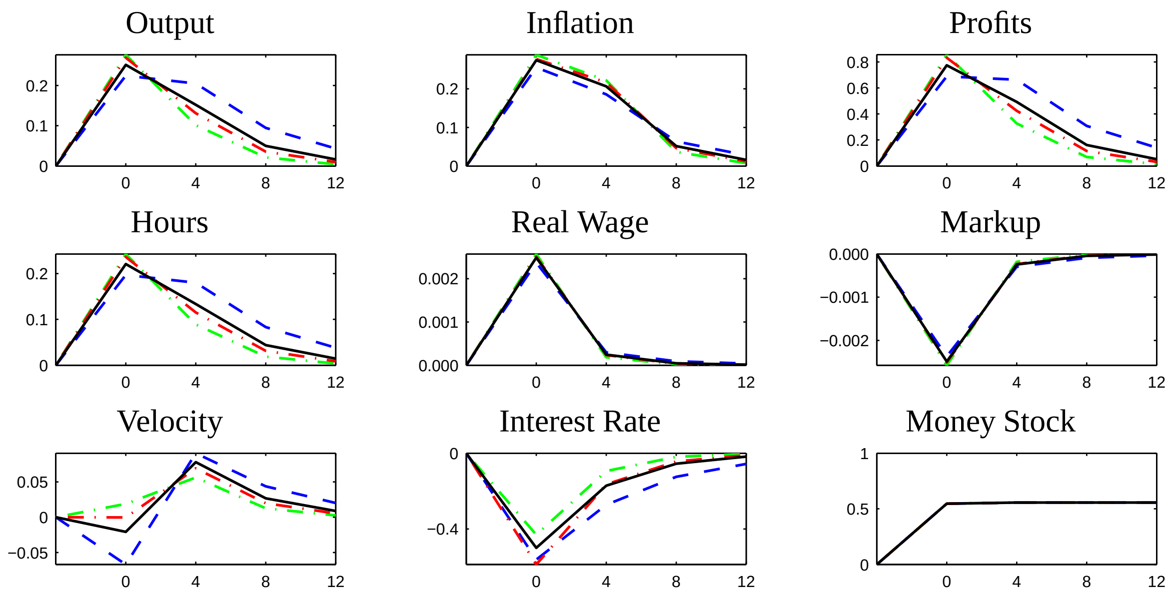

Figure 9: Theoretical responses to an unanticipated expansionary monetary policy shock at t=0 with $S_{i,t}$=S_t/n $\forall$ i. For description of different lines see figure 8. Notes: Horizontal axis denotes quarters, vertical axis shows log deviations from steady state.

A Derivation of households' optimality conditions

This appendix derives equation (8) in the main text. During the shopping sequence, the consumer is optimizing the value of her consumption bundle. When deciding about the amount of consumption of good j, this yields the condition

$$C_{i,t}(j) = \frac{P_t^{-\gamma}(j)}{\sum_{k=j}^{i-1} P_t(k)^{1-\gamma}} M_{i,t}(j-1). \tag{A-1}$$

Let $n_{i,t}(j)$ denote the number of remaining goods in the bundle of agent i, starting at good j. Now define the corresponding price index of agent i *for the remaining shopping sequence* as

$$\bar{P}_{i,t}(j) \equiv \left(\frac{1}{n_{i,t}(j)} \sum_{k=j}^{i-1} P_{i,t}^{1-\gamma}(k) \right)^{\frac{1}{1-\gamma}}. \tag{A-2}$$

The binding CIA constraint for the remaining shopping sequence is thus

$$\bar{C}_{i,t}(j)\bar{P}_{i,t}(j) = M_{i,t}(j-1), \tag{A-3}$$

where $\bar{C}_{i,t}(j)$ is the aggregate of the remaining goods of the sequence of agent i

$$\bar{C}_{i,t}(j) \equiv \left(\frac{1}{n_{i,t}^{\frac{1}{\gamma}}(j)} \sum_{k=j}^{i-1} C_{i,t}^{\frac{\gamma-1}{\gamma}}(k) \right)^{\frac{\gamma}{\gamma-1}}.$$

The demand of agent i for variety j, equation (A-1), is then

$$C_{i,t}(j) = \left(\frac{P_t(j)}{\bar{P}_{i,t}(j)} \right)^{-\gamma} \frac{\bar{C}_{i,t}(j)}{n_{i,t}(j)}.$$

The demand elasticity of agent i for good j with respect to the price, $\varepsilon_{C_{i,t}(j),P_t(j)}$, can be derived from this equation. Note that because of equation (A-3) we have $\varepsilon_{\bar{C}_{i,t}(j),\bar{P}_{i,t}(j)} = -1$, such that

$$\varepsilon_{C_{i,t}(j),P_t(j)} = -\gamma + \varepsilon_{\bar{P}_{i,t}(j),P_t(j)}(\gamma - 1), \tag{A-4}$$

where

$$\varepsilon_{\bar{P}_{i,t}(j),P_t(j)} = \frac{1}{n_{i,t}(j)} \left(\frac{P_t(j)}{\bar{P}_{i,t}(j)} \right)^{1-\gamma} \tag{A-5}$$

is the elasticity of the individual price index with respect to the price of good j, see equation (A-2).

Since shopping periods overlap, shops face consumers in different stages of their shopping sequence. Market clearing requires that production equals total demand, which is for good j at time t

$$Y_t(j) = \sum_{i=1}^{n} C_{i,t}(j) = \sum_{i=1}^{n} \left(\frac{P_t(j)}{\bar{P}_{i,t}(j)} \right)^{-\gamma} \frac{\bar{C}_{i,t}(j)}{n_{i,t}(j)}. \tag{A-6}$$

B Derivation of velocity in steady state

Because n measures the total number of bank visits of all agents during one period, velocity depends on this parameter. In any moment of time there is one agent in each stage of the shopping sequence. Money held by the agent when entering the last shop of her sequence, $M(i–2)$, divided by the steady-state price level equals per capita consumption per shop. Total output is per capita output per shop times n^2, since there are n agents and n shops. Hence,

$$Y = \frac{n^2 M(i-2)}{P}.$$

To relate $M(i-2)$ to the total money supply M, note that in steady state—according to equations (4) and (6)—the following holds

$$M = \sum_{j=1}^{n} M(n) = \sum_{k=1}^{n} kM(i-2) = \frac{n(n+1)}{2} M(i-2).$$

Hence,

$$Y = \frac{2n^2}{n(n+1)} \frac{M}{P}, \tag{B-1}$$

and steady-state velocity is given by

$$V = \frac{2n^2}{n(n-1)}. \tag{B-2}$$

C Pure demand effect

As mentioned in the main text, the case in which prices jump up directly to the new steady state level allows for isolating the pure demand effect. For ease of exposition, I will use the simple version of $n=2$ and an injection equal to 1% of the old period-expenditure level, corresponding to an increase in the money stock of 1.33%, see equation (B-1). Agent 1 receives the injection and spends half of it in both shops of her shopping sequence, as prices are equal. Agent 2 spends what she has left from the previous period, i.e., the old steady-state cash level in the second stage of a shopping sequence, $M(i-2)$. Taken together, this increases business income by 0.5% of the old steady-state expenditure level in the first shop to open (figure 1 illustrates the sequences for $n=3$), received by agent 2. This consumer will spend half of it in the second shop, which corresponds to 0.25%. Agent one spends her remaining 1/2 of the injection, increasing total expenditure in the second shop by 0.75%. Total period expenditure is therefore 1.25% above the old steady state.

In the long run prices move one-to-one with the money stock, i.e., they increase by 1.33%. The mentioned injection thus increases prices to 1.33% while, as seen above, initial expenditure increases only by 1.25%. Hence, aggregate output falls by a small amount.

D Optimal number of bank visits in steady state

In this appendix I calculate the optimal number of bank visits in steady state. Using a slight modification of the model, one can show that the assumed frequency of bank trips—besides being in line with empirical evidence—can be justified by small costs of optimizing asset holdings. In the following, I assume that agents have the possibility to visit the asset market several times during their shopping trips. Furthermore, they receive an interest rate from the central bank on their accounts that offsets the steady-state inflation rate. By this this assumption, the money supply grows at the inflation rate (the real money supply is constant in steady state) and monetary neutrality would obtain in the benchmark case of no asset market segmentation, i.e., free withdrawals at all points in time. In this case, agents would each time withdraw just as much money as needed for the next shop. With a positive steady-state inflation rate, longer shopping trips reduce the purchasing power for a given withdrawn nominal money balance. Introducing a cost of visiting the asset market generates a trade-off between paying this cost for obtaining liquid assets and suffering the reduced purchasing power due to inflation. Otherwise, the model is as described in the paper. In the analysis here, I implicitly assume that agents do not change their habits in the short run, i.e., the optimal number of bank trips depends on steady-state inflation.
I consider a simple modification of the model by subtracting a cost K for visiting the asset market to re-optimize asset holdings from the utility of consumption activity. The cost represents the required time and computing costs for an optimal portfolio choice.[28] This gives the following utility function

$$U_i = \sum_{s=t}^{\infty} \beta^s \frac{1}{1-\sigma} \left[(C_{i,s} - xK) (1 - L_{i,s})^{\mu} \right]^{1-\sigma}, \tag{C-1}$$

where the consumption bundle C_i consists of several subbundles $\underline{C}_i(j)$ in the following way

$$C_i = \left(\frac{1}{n^{\frac{1}{\gamma}}} \sum_{k=0,m,2m\ldots}^{n-m} \underline{C}_i(k+1) \right)^{\frac{\gamma}{\gamma-1}}.$$

Here, x is the number of visits to the bank in one period and m is the number of goods in each subbundle. Since x then also denotes the number of subbundles, we get $n/x = m$. Assume for simplicity that subbundles consist of the same amount of goods, i.e., n/x is an integer. The subbundle $\underline{C}_i(j)$ of agent i consists of individual goods starting at shop j

$$\underline{C}_i(j) = \sum_{k=j}^{j+m-1} C_i^{\frac{\gamma-1}{\gamma}}(k).$$

Now define[29]

$$\underline{P}_{i,t}(j) = \left(\frac{1}{m} \sum_{k=j}^{j+m-1} P_t^{1-\gamma}(k) \right)^{\frac{1}{1-\gamma}}$$

[28]Very similar results obtain if the cost is assumed to be a resource loss which reduces available funds for consumption.

[29]I add a time index to variables that exhibit a trend in steady state. The equations are for agent $i = 1$.

as the corresponding price index of the subbundle. The steady-state gross inflation between each pair of shops is denoted by Π (annual inflation then amounts to $\prod_{i=1}^{n}\Pi$). Hence, $P_t(j+1) = \Pi P_t(j)$. We therefore get

$$\underline{P}_{i,t}(j) = P_t(j)\left(\frac{1}{m}\sum_{k=0}^{m-1}\Pi^{k(1-\gamma)}\right)^{\frac{1}{1-\gamma}} \equiv P_t(j)\varphi(x). \tag{C-2}$$

The CIA constraint for the subbundle reads as

$$m^{\frac{1}{1-\gamma}}\underline{C}_i^{\frac{\gamma}{\gamma-1}}(j)\underline{P}_{i,t}(j) = \underline{M}_{i,t}(j-1), \tag{C-3}$$

where $\underline{M}_{i,t}(j-1)$ is money held after the bank was visited (prior to shop j). In order to assess the loss of purchasing power due to infrequent visits to the asset market, consider the case of zero steady-state inflation. In such a situation, prices of goods in the subbundle are equal, and

$$\underline{M}_{i,t}(j-1) = P_t(j)m\frac{C_i^0}{n},$$

defines C_i^0/n as the (equal) real amount per good that the agent would purchase in this case. Inserting this into equation (C-3), using equation (C-2), yields

$$\underline{C}_i(j) = \left(\frac{C_i^0}{n\varphi(x)}\right)^{\frac{\gamma-1}{\gamma}} m$$

and

$$C_i = \frac{C_i^0}{\varphi(x)} \equiv g(x). \tag{C-4}$$

For the zero-inflation case $\Pi = 1$, we get $\varphi = 1$ and $C_i = C_i^0$. Higher inflation rates reduce purchasing power, such that consumption under a positive steady-state inflation equals consumption C_i^0 in the case that goods of each bundle are equally priced, divided by $\varphi(x)$ as defined in equation (C-2). For high values of the elasticity of substitution γ, agents buy larger amounts of the goods in the beginning of the shopping sequence because of a higher willingness to substitute between goods, thereby avoiding coming price increases. This lowers φ for a given value of Π. $g(x) - g(x-1)$ is positive and increasing in Π, and decreasing in x for $\Pi > 1$. The first-order condition for the optimal number of trips to the bank x^*, resulting from the utility function (C-1), is then

$$g(x^*+1) - g(x^*) < K < g(x^*) - g(x^*-1).$$

This equation implicitly determines the optimal number of bank visits x^*, given steady-state inflation Π. A lower steady-state inflation lowers the optimal number of trips to the bank, therefore increasing the number of goods in each subbundle between which the consumer effectively substitutes. The average demand elasticity thus increases via a competition effect, lowering optimal prices. We therefore get, ceteris paribus, a stimulating effect on the economy from low steady-state inflation via enhanced competition (note that this is an effect on the level of economic activity via reduced markups, but not on the growth rate).

Given the above, it is possible to numerically calculate the optimal x^*. Assuming an annual steady-state inflation of 2% (approximate average inflation rate in the U.S. over the last 15 years), each agent's purchasing power in terms of steady-state consumption increases by 0.48% if they divide the shopping sequence into two, i.e., visit the asset market after half the bundle. Hence, the costs K have to be larger than this number in order to get $x^* = 1$, as assumed in the paper. Interestingly, Alvarez et al. (2002) assume a fixed cost of 0.5% for transferring money from the asset to the goods market. In the data of Krueger and Perri (2006), 0.5% of the sum of average annual expenditure for food and nondurables (the most likely cash goods) for an individual is 45 US$, which seems to be a reasonable number for visiting the asset market and optimizing asset holding, once the required time for information gathering and computing costs are considered.

E Data sources

Data for section 4 are taken from the OECD Economic Outlook 87 (OECD 2010a), OECD.Stat (OECD 2010b), and the Bureau of Labor Statistics. All data are for the United States; the time period is as indicated in the main text with four additional quarters for the four lags of the VAR.

From the OECD Economic Outlook: 'Gross domestic product - volume - market prices', 'Gross domestic product - deflator - market prices', 'Velocity of money', 'Wage rate of the private sector' divided by 'Consumer price index', 'Unit labor cost in total economy' divided by 'Consumer price index'.

From OECDStat: 'Narrow Money (M1) Index 2005=100, SA' and 'Immediate interest rates, Call Money, Interbank Rate, Per cent per annum' (quarterly, i.e., mean of last month in quarter).

From the Bureau of Labor Statistics: 'Measure: Hours. Sector: Nonfarm Business, s.a. Series Id: PRS85006033'.

From the Bureau of Economic Analysis: 'Profits before tax (without IVA and CCAdj) (nonfinancial corporate business); Seasonally adjusted at annual rates' (billions of dollar) from NIPA Table 1.14. divided by 'Consumer Price Index'. For the calculation of the profit share: 'Gross domestic product' (billions of dollar).

From the webpage of Fabrizio Perri: 'texp1: Total consumption expenditures' (deflated) divided by 'pers: adult equivalents'. The values are expressed in 1982-1984 constant dollars. The sample runs from 1980Q1 through 2004Q1. A more detailed description can be found in the appendix of Krueger and Perri (2006). The variable used in the VAR is the standard deviation of the resulting series divided by its mean.