The real effects of financial disruptions in a monetary economy

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ABSTRACT

A large literature in macroeconomics reaches the conclusion that disruptions in financial markets have large negative effects on output and (un)employment. Although seemingly diverse, papers in this literature share a common characteristic: they employ frameworks where money is not explicitly modeled. This paper argues that the omission of money may hinder a model's ability to evaluate the real effects of financial shocks, since it deprives agents of a payment instrument that they *could* have used to cope with the resulting liquidity disruption. In a carefully calibrated New-Monetarist model with frictional labor, product, and financial markets we show that output and unemployment respond very modestly to shocks in the ability of agents to trade in the financial market. Explicitly modeling money enables us to show that the size of the transmission mechanism between the financial market shock and the real economy is disciplined by the inflation level.

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1 Introduction

There is a large literature in macroeconomics studying the effects of financial turbulence on the real economy (Bernanke and Gertler, 1989; Kiyotaki and Moore, 1997; Wasmer and Weil, 2004). Many papers in this literature reach the conclusion that disruptions in financial markets have large negative effects on output and employment (Jermann and Quadrini, 2012; Christiano, Motto, and Rostagno, 2014; Petrosky-Nadeau, 2014). Another common thread running through most of these papers is that they employ frameworks where money is not explicitly modeled. However, the absence of money may limit the models' ability to accurately capture the real effects of financial disruptions, for at least two reasons. First, it may overstate the impact of financial turmoil on real variables, since it deprives agents of a payment instrument that they *could* have used to cope with the resulting liquidity disruption. Second, a moneyless model does not allow the study of real-financial linkages under different inflation regimes, a subject that has recently become topical and of policy interest.

In this paper, we study the impact of financial shocks on the real economy in the context of a New Monetarist model with frictional labor, product, and financial markets. As is typical in these models, a medium of exchange is necessary for transactions in the product market and money plays this role. Firms issue corporate bonds to cover their recruitment and operational expenses. Corporate bonds are not directly liquid (i.e., they cannot be used as a medium of exchange) but are *indirectly* liquid, as they can be traded for money in the secondary corporate bond market. As a result, the liquidity services of corporate bonds are reflected in their price, resulting in a liquidity premium. Hence, a more liquid bond market affects firm entry through two channels. First, it enhances the firms' ability to raise funds at more favorable rates, as investors are willing to pay higher prices (in the primary market) for bonds they expect to sell easily "down the road". Second, it raises firms' product market revenue by increasing consumers' effective liquidity, as these consumers have an easier time boosting their money holdings in the secondary market.

In this environment, one would expect a shock that impedes agents' ability to liquidate bonds in the secondary market to have sizeable effects on firm entry, unemployment, and output, very much in line with the aforementioned literature. This expectation, however, is not supported by a careful quantitative analysis of the model. We find that output and unemployment respond very modestly to changes in the ability of agents to meet and trade in the corporate bond market. The reason behind this result is the agents' ability to increase their money holdings and *substitute* the foregone liquidity due to the financial disruption. Hence, working with a moneyless model does not come without loss of generality. Another result highlighting the importance of explicitly modeling money concerns the impact of inflation. We find that the importance of the corporate bond market liquidity and, consequently, the size of the transmission mechanism between the financial market shock and the real economy, is disciplined by the inflation level. Higher inflation makes it more costly for agents to substitute bond market liquidity, thus exacerbating the real effects of financial market disturbances.

To study the issues at hand, we employ the model of Berentsen, Menzio, and Wright (2011) (BMW), extended to include issuance of corporate bonds and a secondary over-the-counter (OTC) market where agents can sell these bonds for money. Firms face costs to enter the labor market (recruiting costs), as well as additional expenses in order to engage in production (operational costs). These costs are covered by the issuance of corporate bonds. Unemployed workers and firms search for counterparties in a Diamond-Mortensen-Pissarides (Diamond, 1982; Mortensen and Pissarides, 1994) labor market. The firms that have been successful in recruiting a worker produce a special good that they sell in a decentralized goods market where a medium of exchange is necessary, following Lagos and Wright (2005). As we have already mentioned, in our model only money can serve as a medium of exchange, but corporate bonds are also indirectly liquid, as they can be sold for cash in the secondary bond market. This *indirect* bond liquidity is crucial, as it ultimately determines the rate at which firms can borrow funds and consumers' effective liquidity, which, in turn, are important drivers of firm entry. Following the influential work of Duffie, Gârleanu, and Pedersen (2005), we model the secondary bond market as an over-the-counter market, characterized by search and bargaining. The number of trades in the OTC market is determined by a matching function, which takes as inputs the masses of buyers and sellers, as well as an exogenous efficiency parameter. Varying the value of this efficiency parameter allows us to capture the notion of "disruptions in financial markets".

We calibrate the model to salient features of US data and study its quantitative implications with a series of comparative statics exercises. Our first quantitative result is that disruptions in financial trade have modest effects on the economy's output and unemployment level. Setting the matching efficiency parameter in the OTC market to zero (an "asset market freeze"; see Gu, Menzio, Wright, and Zhu 2021), results in an unemployment increase of 0.1-0.3 %. We should highlight that this is not an artifact of the "Shimer puzzle" (Shimer, 2005), namely that adverse shocks in frictional models of unemployment do not generate large changes in the unemployment rate. Our second quantitative result falsifies that: we find that changes in the interest rate generate large movements in unemployment and output, in line with the New Monetarist literature. The channel that dampens the effects of financial disruptions is that agents increase their money holdings as a response to changes in the OTC market efficiency. To show this, we offer our third quantitative result: we compute the "money replacement ratio" for different levels of inflation. The money replacement ratio is defined as the additional money holdings agents carry when they know the asset market has shut down relative to the liquidity agents expect to raise by selling bonds in the OTC market when that market operates properly. As expected, when inflation increases and holding money becomes more costly, the money replacement ratio decreases. Even for an annual inflation rate of 11%, however, it does not drop below 0.96, indicating that agents can sufficiently substitute the liquidity provided by bond markets with greater money holdings.

The corporate bond market has almost tripled in size since 2008 (reaching 20% of nominal GDP in 2019; see Kaplan et al. 2019 and Bochner, Wei, and Yang 2020), which indicates that firms rely heavily on bond issuance as a source of funding for new projects and job creation.[1] Moreover, the finance literature has documented that liquidity considerations are of first order importance for explaining corporate bonds yields (Bao, Pan, and Wang, 2011; Lin, Wang, and Wu, 2011; He and Milbradt, 2014; d'Avernas, 2018). For these reasons, the issuance of corporate bonds and the careful consideration of their liquidity aspects are at the core of our analysis. Importantly, there is strong evidence of a positive secular trend in the liquidity of the corporate bonds market over the last thirty years, partly due to technological advances (a close counterpart to the matching efficiency parameter in our model). At the same time, however, it is well known that the unemployment rate does not exhibit any secular trend over time. We view this as suggestive evidence in support of one of our main results, namely, that changes in OTC efficiency do not lead to large changes in the unemployment rate.

Our results highlight the importance of liquidity substitution for a complete understanding of the connection between real and financial variables. Through the lens of the calibrated model, financial crises do not become recessions when there is no binding scarcity of liquid assets. Even if agents routinely rely on the bond market for liquidity, what matters is to be able to substitute this liquidity with something else when needed. In our model, agents achieve this with more money. In this sense, the macroprudential prescription of our model is close to what central banks actually do in times of financial turmoil: flood the balance sheets of market participants with liquid assets to ensure that there is no liquidity scarcity in the system. Our analysis implies that those financial shocks that do result in deep recessions are those in which liquidity dries up so severely

[1] According to balance sheet data from the US Flow of Funds, in the last five years corporate bonds comprised 56% of the total liabilities (debt securities and loans) of nonfinancial corporate businesses.

that agents cannot quickly substitute into different asset classes.

This paper is conceptually related to recent work by Lagos and Zhang (2022) who highlight the importance of explicitly modeling money for macroeconomic outcomes. The authors show that the existence of money provides additional bargaining power to sellers of goods versus financial intermediaries, and that this channel is significant even when the share of monetary transactions in the economy is arbitrarily small. Our question is different, since we focus on the effects of financial disruptions on real economic variables, but our main message is very similar: moneyless models do not come without a loss of generality. Thus, our model delivers a different answer than the papers studying real-financial linkages without explicitly modeling money, such as Monacelli, Quadrini, and Trigari (2011), Jermann and Quadrini (2012), Christiano et al. (2014), Petrosky-Nadeau (2014), Buera, Jaef, and Shin (2015), and Dong (2022).

Our paper belongs to a growing body of work that extends the New Monetarist framework (see Lagos, Rocheteau, and Wright 2017 for a comprehensive review) to include a frictional labor market and study the effects of monetary and financial channels on equilibrium unemployment. The seminal paper in this strand of the literature is Berentsen et al. (2011), which we extend by adding corporate bond issuance, as well as a secondary market in which these bonds are traded. Other papers in this line of work include Rocheteau and Rodriguez-Lopez (2014), Bethune, Rocheteau, and Rupert (2015), Branch, Petrosky-Nadeau, and Rocheteau (2016), Jung and Pyun (2020), Branch and Silva (2021), Bethune and Rocheteau (2021), and Lahcen, Baughman, Rabinovich, and van Buggenum (2022). Moreover, since we perform a careful calibration and numerical analysis of the model, our paper is also linked to several New Monetarist papers with a quantitative focus. Examples include Chiu and Molico (2010), Aruoba and Schorfheide (2011), Aruoba, Waller, and Wright (2011), and Venkateswaran and Wright (2013).

Our paper is also related to the recent New Monetarist literature that highlights the importance of liquidity for the determination of asset prices; see Geromichalos, Licari, and Suárez-Lledó (2007), Lagos (2011), Nosal and Rocheteau (2013), Andolfatto, Berentsen, and Waller (2014), Hu and Rocheteau (2015), and Lee (2020). In contrast to these papers, where assets serve directly as media of exchange or collateral, here we employ the notion of *indirect* liquidity, i.e., the idea that agents can sell assets for money in a secondary asset market. The indirect liquidity approach is explored in several recent papers, such as Berentsen, Huber, and Marchesiani (2014), Mattesini and Nosal (2016), Geromichalos and Herrenbrueck (2016), Geromichalos, Herrenbrueck, and Lee (2018), and Madison (2019). Finally, our work is related to the literature initiated by Duffie, Gârleanu, and Pedersen (2005), which studies how frictions in OTC markets affect asset prices and trade; examples include Weill (2007, 2008), Lagos and Rocheteau (2009), Chang and Zhang (2015), Üslü (2019), and Gabrovski and Kospentaris (2021).

The rest of the paper proceeds as follows. In Section 2, we describe the model environment, and, in Section 3, we analyze the equilibrium of the model. In Section 4, we describe and implement our calibration strategy. In Section 5, we perform the counterfactual exercises in steady state and provide quantitative results. Section 6 concludes the paper. In Appendix A, we provide supplementary steady state results, and, in Appendix B, we perform the counterfactual exercises in the short run.

2 The Model

Time is discrete and the horizon is infinite. Each period consists of four sub-periods where different economic activities take place. In the first sub-period, a labor market resembling that of Pissarides (2000) opens where firms search for workers. In the second sub-period, economic activity takes place in a secondary asset market in the spirit of Duffie et al. (2005), where agents can trade corporate bonds for money. In the third sub-period, agents visit a decentralized goods market à la Kiyotaki and Wright (1993), where frictions, such as anonymity and imperfect commitment, make a medium of exchange (i.e., money) necessary. During the fourth sub-period, economic activity takes place in a Walrasian or centralized market, which is the settlement market of Lagos and Wright (2005) (henceforth, LW). For brevity, we refer to these four markets as LM (labor market), AM (asset market), GM (goods market), and CM (centralized market). There are two distinct types of agents, firms and households. Households are infinitely lived and their measure is normalized to the unit. The measure of firms is determined by free entry.

All agents discount the future between periods (but not sub-periods) at rate $\beta \in (0, 1)$. Households consume in the GM and CM sub-periods and work in the LM and CM sub-period. Their preferences within a period are given by $\mathcal{U}(X, H, q) = X - H + u(q)$, where H represents labor in the CM, X consumption of *general good* in the CM, and q consumption of *special good* in the GM. We assume that households can turn one unit of labor in the CM into one unit of the general good. In contrast, the special good must be purchased from firms in the GM. Firms consume only the general CM good, and they produce both the CM good and the GM good. Their preferences are given by $\mathcal{V}(X, H) = X - H$, where X, H are as above. As is the case with households, firms can turn one unit of labor into one unit of the general good in the CM. However, to produce the GM good firms must hire a worker in the LM. Following Berentsen et al. (2011), we assume that firms who are matched with a worker in the LM produce y units of output, measured in units of the

CM good (the numeraire), which they ultimately use as an input for production in the GM. Specifically, if a firm sells q units in the GM, $y - q$ is left over to bring to the next CM. To finish the description of preferences, assume that u is twice continuously differentiable with $u' > 0$, $u'(0) = \infty$, $u'(\infty) = 0$, and $u'' < 0$. Let q^* denote the optimal level of production in a bilateral meeting in the GM, i.e., $q^* \equiv \{q : u'(q^*) = 1\}$.

With the exception of the CM, which is a frictionless competitive market, all other markets are characterized by *search* and *bargaining*. To ease the notation, we assume that the matching technology in each market is characterized by the function $f_j(b_j, s_j)$, where b_j and s_j represent the measure of buyers and sellers, respectively, searching for a trading partner in market $j \in \{L, A, G\}$ ("L" for Labor market, "A" for Asset market, and "G" for Goods market).[2] We assume that these matching functions exhibit constant returns to scale and are increasing in both arguments. Regarding bargaining, we will adopt the proportional or egalitarian bargaining solution of Kalai (1977), and in line with of our earlier notation choice, we will let $\eta_j \in [0, 1]$ denote the bargaining power of the seller in market $j \in \{L, A, G\}$.

There are two assets in the economy, fiat money and corporate bonds. Agents can choose to hold any amount of money at the (real) ongoing price φ_t. The supply of money is controlled by the monetary authority, and it evolves according to $M_{t+1} = (1 + \mu)M_t$, with $\mu > \beta - 1$. New money is introduced, or withdrawn if $\mu < 0$, via lump-sum transfers to households in the CM. Money has no intrinsic value, but it is portable, storable, and recognizable by all agents, making it an appropriate medium of exchange in the GM. In fact, we will assume that money is the unique medium of exchange in this economy. Corporate bonds are issued by firms in order to fund their recruiting efforts and production. (We describe this process in detail below.) We think of the CM as the *primary* market where these bonds are first issued by the firms and purchased by households. Later, households will have the option to rebalance their portfolios (after receiving idiosyncratic consumption opportunities) by selling bonds for money, and this takes place in the *secondary* AM. In the CM, households can purchase any amount of bonds at the (real) price ψ_t. These are one-period real bonds, i.e., each unit of the bond purchased in period t's CM will deliver one unit of the numeraire in the CM of $t + 1$. The supply of corporate bonds is endogenous, as it depends on the profit maximizing behavior of firms.

[2] Consider for example the LM. In this case, s_L stands for the measure of unemployed workers trying to match with a firm (workers sell their labor), and b_L stands for the measure of vacant firms searching for a worker. In the AM, s_A will be the measure of households trying to sell bonds and b_A the measure of households seeking to buy. (We will describe shortly the shock that induces some households to sell bonds and others to buy.) Finally, in the GM, s_G will be the measure of firms selling the special good, and b_G the measure of households buying that good.

Any given match in period t's LM remains productive in the next period with probability $1-\delta$, or, equivalently, $\delta \in (0,1)$ is the job separation rate in this economy. As is standard in the job search literature, firms whose match got destroyed exit the labor market and can choose to enter again with a new vacancy. Firms that enter the market in order to search for workers must pay a recruiting cost κ_R and an operational cost κ_O, and firms that are already matched with a worker only need to pay the latter. Firms raise funds to cover these costs by issuing bonds in the CM. Since all the action in our paper comes from the liquidity properties of bonds, and how this liquidity affects the firms' entry and production decisions, we assume that firms never default. A straightforward way to obtain this result is to allow firms to repay their debt by working more hours in the next period's CM.[3] Firms that are matched and productive in the LM pay a wage w to the worker. Again following Berentsen et al. (2011), we assume that w is paid in numeraire good in the CM and not in the LM. Unemployed workers enjoy an unemployment benefit b also delivered in the CM.

A unique feature of our model is that the outcome of the endogenous matching process in the GM determines whether households will be active consumers in that market (i.e., matched with a firm) and, consequently, whether they will have a need for cash. We will refer to households who are active in this period's GM as C-types ("consuming"), and to the households who are inactive as N-types ("not consuming"). Since households made their portfolio choices before they knew their types, N-types will typically hold money they will not use in the current period, and C-types will typically not have enough money to carry out the desired transactions (since carrying money is costly). To make things interesting, we assume that the outcome of the GM matching process is revealed before households visit the secondary AM. Thus, in our model the AM plays a special role: it allows money, the unique medium of exchange in the economy, to reach the hands of the households who value it most. Specifically, it allows C-types to boost their money holdings by selling bonds to N-types who will not be needing their money today.[4] This is the essence of asset (bond) liquidity in our model: bonds cannot be used

[3] Consider as an example a firm that just entered the market and issued bonds to fund recruitment and production, and suppose that firm strikes out in the LM and does not match with a worker. With no production in the LM and the GM, it would be impossible for the firm to repay their debt, but in this environment we assume they can do so by working more hours in the CM. This is a simple way to abstract from default which is not central to our question. One can think of this assumption as capturing the idea that firms can sell illiquid assets (such as buildings or machines) to repay their debtors in a parsimonious way.

[4] There is a large literature following LW, where an idiosyncratic consumption shock generates (ex post) heterogeneous money demand, giving rise to a market where the high-demand agents can obtain money from the low-demand agents. In Berentsen, Camera, and Waller (2007) that process takes place though a competitive banking system. In Geromichalos and Herrenbrueck (2016), like in the present paper, it takes

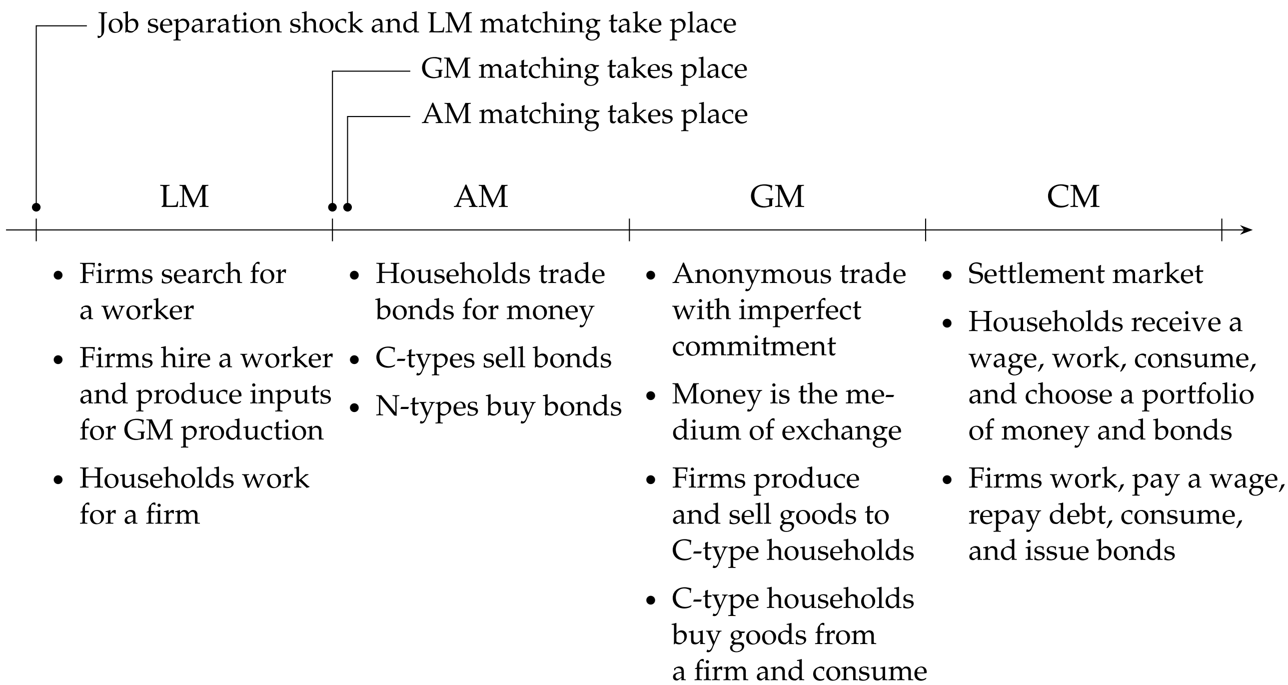

Figure 1: Timing of Events

as means of payment in the GM, but they are *indirectly* liquid, as they can be sold for money in the AM. In terms of the notation introduced earlier, notice that we can denote the measure of C-types by s_A ("selling bonds in the AM"), and the measure of N-types as $b_A = 1 - s_A$.

Figure 1 summarizes the main economic activities in our model and clarifies the timing of the various shocks (which is important in a discrete time model). Notice that the job separation shock and the LM matching take place at the very end of each period (or, equivalently, at the very beginning of the next period).[5] Although this is not important for the results, we assume that the GM matching takes place after the job separation shock (and the LM matching). What does matter for the results, and we have already spelled out, is that the GM matching outcome is known before households visit the AM. (It is precisely what determines whether they will be buyers or sellers in the AM.) We assume that the AM matching takes place immediately after households have entered that market.

place through an over-the-counter asset market. An important difference is that in all these papers the shock that splits agents ex post into active and inactive consumers in the GM is exogenous. But here it depends on the outcome of the matching process in the GM, which, in turn, depends on firm entry. This gives rise to an interesting channel that is unique to our framework.

[5] Let us point out that a worker/household who just lost their job cannot search for a new job right away; they need to wait one period.

3 Analysis of the Model

3.1 Value functions

Households In the CM, a household can be employed ($e = 1$) or unemployed ($e = 0$). For an employed household with m units of money and a units of bonds, the CM value function is

$$W_1^h(m,a) = \max_{X,H,m'\geq 0,a'\geq 0} X - H + \beta\Big[(1-\delta)U_1^h(m',a') + \delta\, U_0^h(m',a')\Big]$$
$$\text{s.t.} \quad X + \varphi m' + \psi a' = H + \varphi m + a + w + T,$$

where m', a' are the optimal money and bond holdings for the next period, and U_e^h is next period's LM value function, where $e = 0, 1$ depends on the outcome of the job separation shock δ. The household also receives the monetary lump-sum transfer T. Moving on to the CM value function of an unemployed household, we have

$$W_0^h(m,a) = \max_{X,H,m'\geq 0,a'\geq 0} X - H + \beta\left[\frac{f_L}{s_L}\, U_1^h(m',a') + \left(1 - \frac{f_L}{s_L}\right) U_0^h(m',a')\right]$$
$$\text{s.t.} \quad X + \varphi m' + \psi a' = H + \varphi m + a + b + T.$$

Notice that in the last expression whether the household will be employed or unemployed in the next period depends on the outcome of the LM matching process. Also, note that the value function W_e^h is linear, that is, $W_e^h(m,a) = \varphi m + a + W_e^h(0,0)$, as is standard in models that built on LW, and this result follows from the (quasi-)linear preferences.

We now move to the LM value functions. For a household at state $e = 0, 1$, we have

$$U_e^h(m,a) = \frac{f_G}{b_G}\, \Omega_e^C(m,a) + \left(1 - \frac{f_G}{b_G}\right)\Omega_e^N(m,a),$$

where Ω_e^k, $k = C, N$, denotes the AM value functions of a k-type household. Whether this household will be C-type or N-type depends on the outcome of the GM matching process.[6] If the household is matched with a firm in the GM it knows it can use some extra liquidity which makes it a natural C-type in the AM market. Conversely, if the household is not matched, it knows it doesn't need to hold money until the CM market so it is a natural N-type in the AM market.

[6] Observe that the Ω value functions are the only ones that do not have the h "for household" superscript. However, it is understood that C-types and N-types are households and that firms never participate in the AM. Thus, there should be no room for confusion.

In the AM, the value function of a C-type (asset seller) is

$$\Omega_e^C(m,a) = \frac{f_A}{s_A} V_e^h(m+\xi, a-\chi) + \left(1 - \frac{f_A}{s_A}\right) V_e^h(m,a), \quad e = 0,1,$$

where V_e^h denotes this household's GM value function, and ξ is the amount of money the household raises by selling χ units of bonds in the AM. Households that do not match in the AM (with probability $1 - f_A/s_A$) continue into the GM with their original portfolio (m,a). Next, consider the AM value function of an N-type (asset buyer):

$$\Omega_e^N(m,a) = \frac{f_A}{b_A} W_e^h(m-\xi, a+\chi) + \left(1 - \frac{f_A}{b_A}\right) W_e^h(m,a), \quad e = 0,1.$$

Notice that N-types move directly to the CM, since, by definition, these types do not get the opportunity to consume in the GM.

In the GM, the value function of a (C-type) household in state e is given by

$$V_e^h(m,a) = u(q) + W_e^h(m-x, a), \quad e = 0,1,$$

where x is the amount of money the household pays to purchase q units of the GM good.

Firms Consider first a firm that just opened a vacancy. The CM value function of that firm is given by

$$W_v^f = \beta\left[\frac{f_L}{b_L} U_1^f(d') + \left(1 - \frac{f_L}{b_L}\right) U_0^f(d')\right], \quad \text{where} \quad d' = \frac{\kappa_R + \kappa_O}{\psi}.$$

U_e^f denotes the LM value function, depending on whether the firm matched with a worker ($e = 1$) or not ($e = 0$). The term d' denotes the firm's debt, which must cover their recruiting and operational cost. In particular, the firm must finance the total costs $\kappa_P + \kappa_O$ by selling bonds at the price ψ. Hence, its resulting debt is $(\kappa_P + \kappa_O)/\psi$.

The CM value function of a firm that is currently matched with a worker is given by

$$W_1^f(n,m,d) = \max_{X,H} X - H + \beta(1-\delta) U_1^f(d')$$
$$\text{s.t.} \quad X = H + n + \varphi m - d - w \quad \text{and} \quad d' = \frac{\kappa_O}{\psi},$$

where n is the amount of the LM production leftover after GM production has concluded (that is, $n = y - q$), m is the amount of money the firm received in the GM, and d is the debt from issuing bonds in the previous period. Observe that this firm needs to raise funds to cover only the operational cost. (There is no recruitment cost since this firm is already matched with a worker.)[7] Also, note that the value function W_1^f is linear, that is, $W_1^f(n,m,d) = n + \varphi m - d + W_1^f(0,0,0)$, as is for the consumer's CM value functions.

These value functions highlight the first channel (discussed in the introduction) whereby a more liquid secondary asset market encourages firm entry: a higher bond market liquidity results into a higher issue price for the bond (ψ), which, in turn, allows firms to "raise funds at more favorable rates", which then lowers their debt and increases profitability, thus, encouraging entry.

The last type of firm we need to consider in the CM is the one that opened a vacancy in the previous period but was not able to find a worker. This firm cannot produce but must still repay its debt, and therefore its CM value function is given by

$$W_0^f(d) = \max_{X,H} X - H$$
$$\text{s.t.} \quad X = H - d.$$

We now move on to the LM. The LM value function of a matched firm is

$$U_1^f(d) = V_1^f(d),$$

where V_1^f is the GM value function of a matched firm, and the LM value function of an entrant firm that did not find a worker is

$$U_0^f(d) = W_0^f(d).$$

Finally, the GM value function of a firm (matched with a worker) is

$$V_1^f(d) = \frac{f_G}{s_G}\left[\frac{f_A}{s_A}W_1^f(y-q^+,x^+,d) + \left(1-\frac{f_A}{s_A}\right)W_1^f(y-q,x,d)\right] + \left(1-\frac{f_G}{s_G}\right)W_1^f(y,0,d).$$

Given that this firm matches with a household/customer (with probability f_G/s_G), the amount of the GM good it will sell depends on the money holdings of that household. This, in turn, depends on whether that household was able to boost their money holdings in the AM. Here, q^+ (q) stands for the amount of the GM good traded if the household was able (not able) to trade in the preceding AM. Similarly, x^+ (x) stands for the amount of money that changes hands in the GM if the household was able (not able) to trade in the preceding AM.

[7] Also, if this firm's job gets destroyed (with probability δ), it will exit the market and get a payoff of 0, which is why the term U_0^f does not appear.

The last value function highlights the second channel (discussed in the introduction) whereby a more liquid secondary asset market encourages firm entry: a higher bond market liquidity increases "consumers' effective liquidity", because it implies that a larger number of C-type households match in the secondary AM and enter the GM with higher amounts of money available for spending, thus, increasing firm profitability.

3.2 Terms of trade

Terms of trade in the GM Consider a meeting between a C-type household with m units of money and a matched firm with y units of LM output. The two parties bargain over the quantity of the GM good q to be produced by the firm and the cash payment x to be made by the household. The household's surplus is

$$S_G^h = u(q) + W_e^h(m - x, a) - W_e^h(m, a) = u(q) - \varphi x,$$

and the firm's surplus is

$$S_G^f = W_1^f(y - q, x, d) - W_1^f(y, 0, d) = -q + \varphi x,$$

where we use the linearity of W_e^h and W_1^f. The terms of GM trade (q, x) are determined by proportional bargaining, where the firm's bargaining power is η_G:

$$\max_{q,x} S_G^f \quad \text{s.t.} \quad S_G^f = \frac{\eta_G}{1 - \eta_G} S_G^h, \;\; x \leq m, \;\; \text{and} \;\; q \leq y.$$

The constraints $x \leq m$ and $q \leq y$ state that the household and the firm cannot leave with a negative amount of money and LM output. We assume, as in Berentsen et al. (2011), that y is sufficiently large and that $q \leq y$ does not bind. The Kalai constraint implies

$$\varphi x = \eta_G \, u(q) + (1 - \eta_G)q \equiv \sigma(q),$$

which means that the household needs to pay $\sigma(q)/\varphi$ units of money, or $\sigma(q)$ units of real balances, to the firm to purchase q units of the GM good. The bargaining solution is given by

$$\begin{aligned} q(m) &= \min\{q^*, \sigma^{-1}(\varphi m)\}, \\ x(m) &= \min\left\{m^* \equiv \frac{\sigma(q^*)}{\varphi}, m\right\} = \frac{\sigma(q(m))}{\varphi}, \end{aligned}$$

where m^* is the amount of money that allows the household to purchase q^*. If the household has enough money to purchase q^*, it will pay m^*; if not, it will spend all her money. Note that, due to the cost of carrying money, the household will never choose to hold $m > m^*$, and the household's liquidity constraint will always bind; hence, we will focus on the binding branch of the bargaining solution:

$$q(m) = \sigma^{-1}(\varphi m), \quad x(m) = m.$$

Terms of trade in the AM Consider a meeting between a C-type household with portfolio (m, a) and a N-type household with portfolio $(\widetilde{m}, \widetilde{a})$. The C-type's surplus is

$$S_A^C = V_e^h(m + \xi, a - \chi) - V_e^h(m, a) = u\big(\sigma^{-1}(\varphi(m + \xi))\big) - u\big(\sigma^{-1}(\varphi m)\big) - \chi,$$

and the N-type's surplus is

$$S_A^N = W_e^h(\widetilde{m} - \xi, \widetilde{a} + \chi) - W_e^h(\widetilde{m}, \widetilde{a}) = -\varphi\xi + \chi,$$

where we use the bargaining solution to GM trade and the linearity of W_e^h. The terms of AM trade (ξ, χ) are determined by the C-type's take-it-or-leave-it offer:

$$\max_{\xi,\chi} S_A^C \quad \text{s.t.} \quad S_A^N = 0, \ \ \chi \leq a, \ \text{ and } \ \xi \leq \widetilde{m}.$$

The first constraint, the participation condition for the N-type, implies $\xi = \chi/\varphi$, that is, χ units of bonds can be traded with ξ units of money. Since carrying money is costly, the C-type will bring $m < m^*$ and want to acquire the amount of money that it is missing in order to reach m^*, namely, $m^* - m$. Whether it will be able to acquire that amount of money depends on her asset holdings a. If a is large enough to acquire $m^* - m$, the C-type will acquire exactly $m^* - m$ by selling $\varphi(m^* - m)$ units of bonds; if not, it will give up all her a and acquire a/φ units of money. However, how much money the C-type can acquire in the AM obviously depends also on the N-type's money holdings $\widetilde{m}$, and the discussion so far has assumed that $m + \widetilde{m} \geq m^*$, that is, the money holdings of the C-type and the N-type pooled together are enough to allow the C-type to achieve m^*. We restrict attention to this case, thereby ignoring the last constraint in the bargaining problem. This will be true in equilibrium as long as inflation is not too large so that all households carry at least $m^*/2$ units of money.[8] Therefore, the bargaining solution is given by

$$\xi(m,a) = \min\left\{m^* - m,\, \frac{a}{\varphi}\right\},$$
$$\chi(m,a) = \min\left\{\varphi(m^* - m),\, a\right\} = \varphi\,\xi(m,a).$$

3.3 Optimal portfolio choice

Households choose their optimal portfolio in the CM independently of their trading histories in previous markets, as is standard in models that build on LW. To analyze the households' optimal behavior, we substitute their GM, AM, LM value functions into their CM value function, collect the terms relevant to the choice variables, and obtain the objective function in the CM:

$$J(m',a') = -\beta\, i\, \varphi' m' - (\psi - \beta)a' + \beta\,\frac{f_G}{b_G}\,S_G^h + \beta\,\frac{f_G}{b_G}\,\frac{f_A}{s_A}\,S_A^C,$$

where

$$S_G^h = u(\sigma^{-1}(\varphi' m')) - \varphi' m',$$
$$S_A^C = u(\sigma^{-1}(\varphi'(m' + \xi))) - u(\sigma^{-1}(\varphi' m')) - \varphi' \xi.$$

The interpretation is straightforward. The first two negative terms represent the cost of choosing portfolio (m', a'), net of their payout in the next period's CM. The portfolio also offers certain liquidity benefits, but these will only be relevant if the household turns out to be a C-type; thus, the rest of the terms are multiplied by f_G/b_G. A C-type can always enjoy at least S_G^h from GM trade. it can further enjoy an additional benefit S_A^C if it has a chance to sell bonds for cash in the AM, which happens with probability f_A/s_A.

3.4 Equilibrium

Before proceeding with the equilibrium analysis, we summarize the money growth rate using the Fisher equation by $i = (1+\mu)/\beta - 1$; this rate will be a useful benchmark as the yield on a completely illiquid asset. (Thus, i should not be thought of as representing, for

[8] Later in the quantitative exercises, we check that $m + \widetilde{m} \geq m^*$ is indeed the relevant case. Moreover, in the equilibrium associated with $m + \widetilde{m} < m^*$, bonds will carry no liquidity premium, a result that is clearly unrealistic. It is simply because in that case the money holdings of the C-type and the N-type pooled together is so scarce that bond holdings become relatively plentiful. For more details, see Geromichalos and Herrenbrueck (2016).

instance, the yield on T-bills; see Geromichalos and Herrenbrueck, 2022.)

Money and bond market equilibrium The households' optimal portfolio choice implies the money and bond demand. The money demand equation is characterized by

$$i = \frac{f_G}{b_G}\left(1 - \frac{f_A}{s_A}\right)\left[\frac{u'(q)}{\sigma'(q)} - 1\right] + \frac{f_G}{b_G}\frac{f_A}{s_A}\left[\frac{u'(q^+)}{\sigma'(q^+)} - 1\right], \tag{1}$$

where the trading protocol in the AM implies

$$q^+ = \min\{q^*;\, \sigma^{-1}(\sigma(q) + a)\}. \tag{2}$$

To see the intuition, express the equation as $\sigma(q^+) = \min\{\sigma(q^*),\, \sigma(q) + a\}$. As a result of trading in the AM, a C-type household acquires the amount of real balances that is enough to purchase q^*, or it boosts her real balances by selling all her bond holdings. The equilibrium price of money solves the money market clearing condition:

$$\varphi M = \sigma(q).$$

The households' bond demand implies the equilibrium bond price:

$$\psi = \beta\left(1 + \frac{f_G}{b_G}\frac{f_A}{s_A}\left[\frac{u'(q^+)}{\sigma'(q^+)} - 1\right]\right). \tag{3}$$

The second term in the parentheses represents the liquidity premium of bonds, which is the product of three terms. First, the probability that a household turns out to be a C-type and thus needs liquidity; second, provided that the household is a C-type, the probability of matching in the AM; third, the marginal surplus of the match, that is, the utility gain in the GM from bringing one more unit of bonds and selling it in the AM, net of what it would have paid out in the following CM. The bonds are supplied according to the following schedule:

$$A = b_L\left[\frac{\kappa_R + \kappa_O}{\psi}\right] + (1 - s_L)(1 - \delta)\frac{\kappa_O}{\psi}, \tag{4}$$

and the bond market clears:

$$a = A.$$

Labor market equilibrium Free entry implies $W_v^f = 0$; that is,

$$0 = \beta\left[\frac{f_L}{b_L} V_1^f\left(\frac{\kappa_R + \kappa_O}{\psi}\right) - \left(1 - \frac{f_L}{b_L}\right)\frac{\kappa_R + \kappa_O}{\psi}\right],$$

where

$$\begin{aligned}
V_1^f(d) &= \frac{f_G}{s_G}\left[\frac{f_A}{s_A} W_1^f(y - q^+, x^+, d) + \left(1 - \frac{f_A}{s_A}\right) W_1^f(y - q, x, d)\right] + \left(1 - \frac{f_G}{s_G}\right) W_1^f(y, 0, d) \\
&= W_1^f(y, 0, d) + \frac{f_G}{s_G}\left[\begin{array}{l} \frac{f_A}{s_A}\Big(W_1^f(y - q^+, x^+, d) - W_1^f(y, 0, d)\Big) \\ + \left(1 - \frac{f_A}{s_A}\right)\Big(W_1^f(y - q, x, d) - W_1^f(y, 0, d)\Big)\end{array}\right] \\
&= y - d - w + \beta(1-\delta) U_1^f\left(\frac{\kappa_O}{\psi}\right) + \frac{f_G}{s_G}\left[\begin{array}{l} \frac{f_A}{s_A}\eta_G(u(q^+) - q^+) \\ + \left(1 - \frac{f_A}{s_A}\right)\eta_G(u(q) - q)\end{array}\right] \\
&= R - d - w + \beta(1-\delta) V_1^f\left(\frac{\kappa_O}{\psi}\right),
\end{aligned}$$

and we define

$$R \equiv y + \frac{f_G}{s_G}\left[\frac{f_A}{s_A}\eta_G(u(q^+) - q^+) + \left(1 - \frac{f_A}{s_A}\right)\eta_G(u(q) - q)\right], \tag{5}$$

which represents the firm's expected revenue. Using this observation, we can solve the free entry condition for $V_1^f(\frac{\kappa_O}{\psi})$:

$$V_1^f\left(\frac{\kappa_O}{\psi}\right) = \frac{R - w - \frac{\kappa_R}{\psi}}{1 - \beta(1-\delta)}.$$

The linearity of $V_1^f(d)$ implies $V_1^f(\frac{\kappa_R+\kappa_O}{\psi}) = V_1^f(\frac{\kappa_O}{\psi}) - \frac{\kappa_R}{\psi}$. Plugging $V_1^f(\frac{\kappa_O}{\psi})$ and $V_1^f(\frac{\kappa_R+\kappa_O}{\psi})$ back to the free entry condition yields the job creation curve:

$$\frac{\kappa_R + \kappa_O}{\psi} + \frac{f_L}{b_L}\frac{\beta(1-\delta)}{1 - \beta(1-\delta)}\frac{\kappa_O}{\psi} = \frac{f_L}{b_L}\frac{R - w}{1 - \beta(1-\delta)}. \tag{6}$$

Notice that ψ, the bond price, appears in the denominators on the left-hand side of the equation. This implies that, as the bond liquidity increases and the price goes up, firms can cover their recruiting and operation costs with less amount of bonds, a channel that encourages more firms to enter the market.

The wage curve is determined through the wage bargaining in the LM. The worker's surplus is

$$U_1^h(m,a) - U_0^h(m,a),$$

while the firm's surplus is

$$U_1^f\left(\frac{\kappa_R + \kappa_O}{\psi}\right) - U_0^f\left(\frac{\kappa_R + \kappa_O}{\psi}\right).$$

Proportional bargaining, where the worker's bargaining power is η_L, implies

$$\eta_L\left[U_1^f\left(\frac{\kappa_R + \kappa_O}{\psi}\right) - U_0^f\left(\frac{\kappa_R + \kappa_O}{\psi}\right)\right] = (1-\eta_L)\Big[U_1^h(m,a) - U_0^h(m,a)\Big].$$

Observe, on the left-hand side, that

$$U_1^f\left(\frac{\kappa_R + \kappa_O}{\psi}\right) - U_0^f\left(\frac{\kappa_R + \kappa_O}{\psi}\right) = V_1^f\left(\frac{\kappa_R + \kappa_O}{\psi}\right) + \frac{\kappa_R + \kappa_O}{\psi} = V_1^f\left(\frac{\kappa_O}{\psi}\right) + \frac{\kappa_O}{\psi},$$

and, on the right-hand side, that

$$U_1^h(m,a) - U_0^h(m,a) = w - b + \beta\left(1 - \delta - \frac{f_L}{s_L}\right)\Big[U_1^h(m',a') - U_0^h(m',a')\Big],$$

from which, using the fact that $U_1^h(m,a) - U_0^h(m,a) = U_1^h(m',a') - U_0^h(m',a')$ in steady state, we can solve for $U_1^h(m,a) - U_0^h(m,a)$. With these two observations, from the bargaining solution, we can derive the wage curve:

$$w = \frac{(1-\eta_L)[1-\beta(1-\delta)]b + \eta_L\left[1 - \beta\left(1 - \delta - \frac{f_L}{s_L}\right)\right]\left[R - \beta(1-\delta)\frac{\kappa_O}{\psi}\right]}{1 - \beta(1-\delta) + \eta_L\,\beta\,\frac{f_L}{s_L}}. \tag{7}$$

Finally, the Beveridge curve is given by

$$(1 - s_L)\delta = f_L. \tag{8}$$

Measures of sellers and buyers The measures of successful matches in the LM, AM, and GM are determined, respectively, by the matching technologies $f_L = f_L(b_L, s_L)$, $f_A = f_A(b_A, s_A)$, and $f_G = f_G(b_G, s_G)$, where $b_A = 1 - f_G$, $s_A = f_G$, $b_G = 1$, and $s_G = 1 - s_L$. The measures of buyers and sellers in the LM, b_L and s_L, are determined in equilibrium.

Parameter	Description	Value
β	Discount Rate	0.9975
δ	Separation Rate	1.3%
i	Nominal Interest Rate	7%
y	Match Output in the LM	1
b	Unemployment Flow Value	0.99

Table 1: Externally Calibrated Parameters

We now define the steady state equilibrium of the model:

Definition 1. The steady state equilibrium of the model corresponds to a constant sequence (b_L, s_L, q, q^+, ψ, A, w) such that equations (1), (2), (3), (4), (6), (7), and (8) hold.

4 Calibration

We set a period in the model to be a month in calendar time. Several parameters with direct empirical counterparts are set exogenously. The discount factor β is set to 0.9975, consistent with a 3% annual real return, as in Bethune, Choi, and Wright (2020) and Herrenbrueck (2019). We set the separation rate δ to 1.3%, its average monthly value from the Current Population Survey (CPS) data for 1982 - 2018 (Goensch, Gulyas, and Kospentaris, 2021). Regarding the annual nominal rate, we cannot use any observed interest rate since no traded asset is perfectly illiquid. Instead, we use an estimate of 7%, based on time preference, expected real growth, and expected inflation, following Herrenbrueck (2019).[9] Finally, we normalize the match output in the LM, $y = 1$, and set the value of unemployment b to 0.99.[10]

Next, we specify the functional forms used in the calibrated model. As in much of the New Monetarist literature, e.g. Berentsen et al. (2011) or Bethune et al. (2020), we work with the CRRA form for the household's utility of the GM good: $u(q) = Bq^{1-\gamma}/(1-\gamma)$. Our model features three frictional markets for which we need to specify matching functions. Labor market matching functions are extensively studied. We follow Den Haan, Ramey, and Watson (2000) and Petrosky-Nadeau and Wasmer (2013) and work with a

[9] As a comparison, Berentsen et al. (2011) use an annual rate of 7.4% (the average rate on AAA corporate bonds), while the average in Lucas and Nicolini (2015) data is 6.28%.

[10] The value $b = 0.99$ comes from Lahcen et al. (2022) and works well with our calibration strategy. The total output of a successful match is R (see equation (5)), which is greater than $y = 1$. Hence, the ratio b/R is close to 0.96, the value used by Hagedorn and Manovskii (2008) and widely adopted by the literature.

Parameter	Description	Value
η_L	Worker's Bargaining Power in the LM	0.66
η_G	Seller's Bargaining Power in the GM	0.94
κ_R	Firms' Recruiting Cost	0.01
κ_O	Firms' Operational Cost	0.01
B	Household's Utility Coefficient	1.03
γ	Household's Utility Elasticity	0.11
ϵ	Matching Function Elasticity in the LM	0.29

Table 2: Internally Calibrated Parameters

Target	Data	Model
Job-finding Rate	23.8%	23.8%
Unemployment Rate	5%	5.2%
Product Market Markup	1.39	1.39
Liquidity Premium of Corporate Bonds	0.3%	0.29%
Average Money Holdings over GDP	23.2%	23.7%
Elasticity of Money Holdings wrt AAA rate	-0.51	-0.52

Table 3: Targets and Model Performance

CES matching function in the labor market (which guarantees bounded matching probabilities between 0 and 1): $f_L = \alpha_L s_L b_L/(s_L^\epsilon + b_L^\epsilon)^{\frac{1}{\epsilon}}$. Matching functions in product and financial markets are relatively understudied. As a result, and due to the absence of relevant data, we parameterize them with the telephone-line matching form, which does not require using extra parameters: $f_j = \alpha_j s_j b_j/(s_j + b_j)$, where $j \in \{A, G\}$.

In total, this leaves us with seven parameters to be calibrated through the lens of the model: the bargaining shares in the labor and product market, η_L and η_G; the firms' recruiting and operation costs, κ_R and κ_O; the households' utility function parameters, B and γ; and, finally, the elasticity of the labor market matching function, ϵ. For the main calibration, the matching function coefficients α_j, with $j \in \{L, A, G\}$, are set to unity but we vary their values for our numerical exercises in Section 5.

To pin down these parameters, we employ various labor, monetary, and financial moments. First, to pin down ϵ, we target the average monthly job-finding rate from CPS (Goensch et al., 2021). Given that, the firm's recruiting cost κ_R adjusts to match the long-run average of the unemployment rate in the US economy, which is another targeted moment. Second, to pin down η_G, we target an average markup of 1.39 in the product market, following Bethune et al. (2020). Third, the firm's operation cost κ_O is informed by the available measurements of the liquidity premium of corporate bonds, since it is the main determinant of corporate bond supply in the model. d'Avernas (2018) estimates that 30% of the corporate bond spread can be attributed to liquidity considerations, while Friewald, Jankowitsch, and Subrahmanyam (2012) estimate the spread of investment grade bonds to be around 1%[11]. Together, these two estimates pin down the liquidity premium of investment grade corporate bonds. Next, regarding the utility function parameters, we follow the standard practice of the New Monetarist literature. We target the average money holdings as a fraction of GDP to pin down B (Bethune et al., 2020), and the elasticity of money holdings with respect to the return on AAA bonds (Berentsen et al., 2011) using the data shared by Lucas and Nicolini (2015). Finally, we apply the Hosios condition (Hosios, 1990) and target the elasticity of the matching function with respect to the measure of unemployed workers (evaluated at the equilibrium tightness) for η_L.[12]

As can be seen in Table 3, the model matches the data targets very well. We use the calibrated model as a laboratory for various quantitative exercises in the following section.

5 Quantitative Analysis

In this section, we present the implications of the model for the relationship between monetary, financial, and real economic variables. To do so, we analyze how much unemployment and output change in response to shocks in: i) the AM matching coefficient α_A ("financial shocks"), and ii) the nominal interest rate i ("inflation shocks"). Following Berentsen et al. (2011), we focus on comparisons between steady states, a common practice in search theory (see, e.g., Hornstein, Krusell, and Violante (2005), Petrosky-Nadeau (2013), and Ljungqvist and Sargent (2017), among others).[13]

Before discussing the results, let us briefly explain our choices of comparative statics exercises and their economic interpretation. First, changes in the efficiency of the secondary asset market influence how easy it is for consumers to find liquidity when it

[11] We focus on investment grade bonds since there is no default in the model and this bond category is considered practically default-free.

[12] In Appendix A.1, we present the mathematical notation for the targets used in the calibration.

[13] In Appendix A.2, we present the results for productivity shocks, that is, steady state changes of the labor market output y. Moreover, in Appendix B we show the impulse response functions for one-time ("MIT") financial, inflation, and productivity shocks.

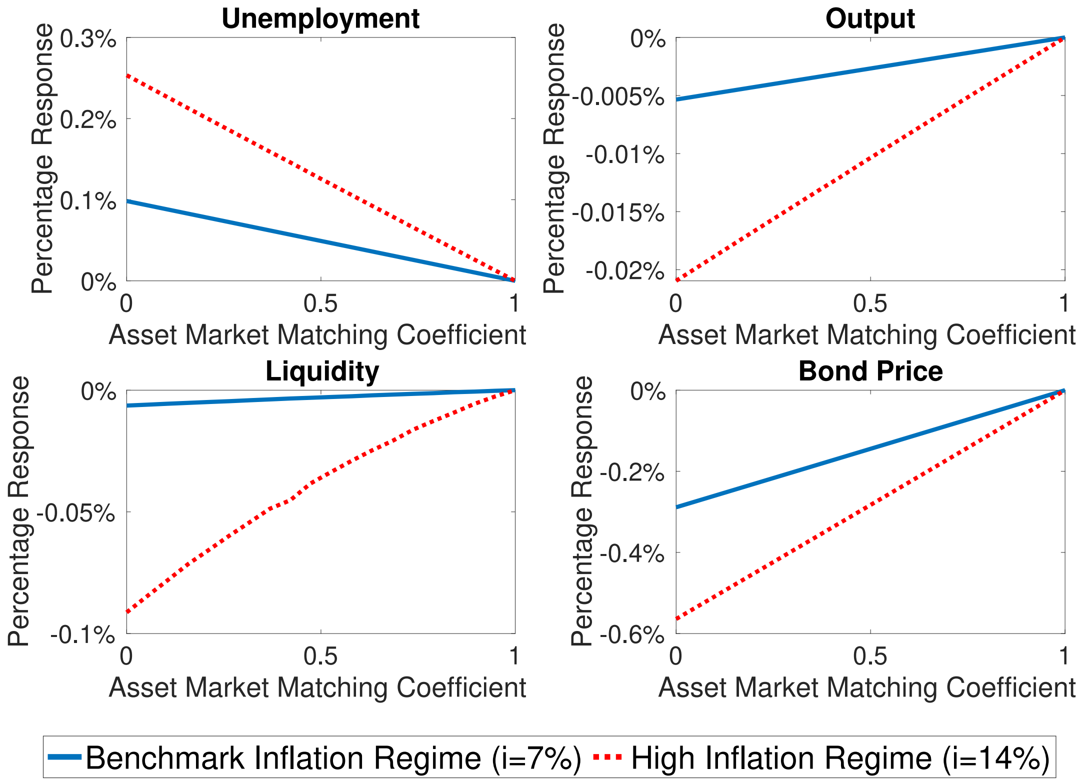

Figure 2: Financial Shocks
Steady state responses to changes in the matching efficiency of the bond market

is needed for consumption purposes, as well as how costly is for firms to issue debt. Changes in α_A amount to shocks in bond prices and the liquidity provided by the financial sector in the model, and their effects on the real side of the economy is the main focus of this paper. Second, varying inflation (through different levels of the nominal interest rate) implies changing the cost of holding money, which is of central interest in monetary models. In sum, the experiments with financial and inflation shocks allow us to clearly lay out the model's real-financial linkages and study how financial shocks interact with inflation levels.

5.1 Financial Shocks

We begin with the analysis of the direct impact of asset market frictions on the real economy. That is, we consider the effects of changes in the AM matching efficiency, α_A, on the unemployment rate, u, and aggregate output, $(1-u)R$. We vary α_A from 0 to 1 (its steady state value) and present the results as percentage deviations from the model's steady state levels. Effectively, the case of $\alpha_A = 0$ corresponds to an "asset market freeze", a case in which the asset market seizes to operate (Gu et al., 2021). To understand how the existence of money affects the liquidity provided by the corporate bond market, we perform an experiment with the benchmark level of inflation, $i = 7\%$, and one with high inflation, $i = 14\%$.

As can be seen in Figure 2 (top left and right panels), a lower level of asset market efficiency lowers aggregate output and raises unemployment. A better-functioning secondary market allows consumers to find liquidity faster, which increases firm revenue in the GM, and incentivizes firm entry. Importantly, the economy with benchmark inflation is less responsive to changes in asset market frictions than the high inflation economy. An asset market freeze lowers output and raises unemployment by 0.02% and 0.3% respectively in the high inflation economy, while the changes in the benchmark inflation economy are even smaller. Asset markets are more important for liquidity provision under higher inflation. To understand why this is the case, we need to dissect the mechanisms connecting the financial and monetary variables with the real side of the economy in the model.

There are two channels through which the efficiency of matching in the asset market affects real economic variables. The first one is the *liquidity channel*: α_A influences how easy it is for consumers to trade bonds for money, but also affects the incentives of consumers to hold their wealth in real balances. Changes in α_A affect consumers' *direct* (through the portfolio choice) and *indirect* (through the asset market) liquidity. The total effect on consumers' *effective* liquidity $(f_A/s_A\sigma(q^+) + (1 - f_A/s_A)\sigma(q))$ depends on these two forces. A lower α_A decreases consumers' indirect liquidity from the AM but incentivizes consumers to work more in the CM and bring directly more money in the GM.

It is important to note that the magnitude of this liquidity substitution depends on inflation: the lower i is, the lower the cost for consumers to hold money and cope with the low levels of α_A. This explains the behavior of effective liquidity, pictured in the bottom left panel of Figure 2: consumers need the liquidity from the asset market more under high inflation because it is more costly to carry money in the GM. As a result, their liquidity level responds more strongly to the efficiency of the AM when inflation is higher. In other words, the importance of secondary asset markets for liquidity provision depends on the level of inflation. If it is relatively cheap for consumers to hold money, then financial disruptions in secondary markets would not affect consumers' liquidity and consumption much. If inflation is high, then severe frictions in asset markets may have larger effects on consumers' liquidity and consumption.

The second channel connecting nominal with real variables is the *asset price channel*: a lower α_A decreases the liquidity premium and the price of corporate bonds (equation 3), which increases the firms' borrowing cost and, in turn, lowers firm entry and aggregate output, and increases unemployment. This channel can be seen in the bottom right panel of Figure 2 where the bond price, ψ, is positively correlated with the level of asset market efficiency, α_A. The bond price is more responsive to asset market shocks under higher inflation, due to the fact that liquidity is more scarce and the liquidity premium moves more in this case. To summarize, both the liquidity and asset price channel are stronger under high than benchmark inflation, which explains why unemployment and output change more in that case.

Apart from its qualitative implications, a striking feature of Figure 2 is the modest magnitude of the effects of financial disruptions on output and unemployment. The driver behind this result is the small response of effective consumer liquidity, which drops less than 0.1% when the bond market freezes. This happens because it is very easy for consumers to substitute the liquidity provided by the secondary market with carrying more money. As a result, the significance of financial frictions for output and unemployment is limited. To be clear, there is a substantial difference in the *levels* of the endogenous variables for different inflation levels (analyzed with detail in Section 5.2). The point here is that the bond market does not matter much for the *slope* of the responses: for a given inflation level, the frictions in secondary markets do not matter much for effective consumer liquidity and, consequently, output and unemployment.[14]

5.2 Inflation Shocks

Figure 3 presents the effects of changes in the inflation level of the economy. We vary i from an annual level of 0% to 14% (as a reminder, we use 7% for the model's calibration) and present the results as percentage deviations from the model's steady state values.[15] To understand the implications of frictions in the secondary asset market, we consider an experiment with the benchmark level of AM matching coefficient, $\alpha_A = 1$, as well as one with severe frictions freezing the secondary market, $\alpha_A = 0$.

To begin with, the economy's unemployment rate and aggregate output strongly move with changes in the inflation rate. The main force at work here is the direct part of our liquidity channel: as the interest rate increases consumers hold less money, which

[14] As can be seen on the bottom right panel of Figure 2, the drop of the bond price as a result of the asset market freeze is 0.6%, larger than the responses of all other variables. This number may not look sizeable, but one needs to keep in mind that the liquidity premium (which, by definition, becomes zero when the market freezes) is only a small fraction of the total bond price.

[15] Given that we use a real rate of 3%, this experiment varies the annual inflation rate from -3% (the Friedman rule) to 11%.

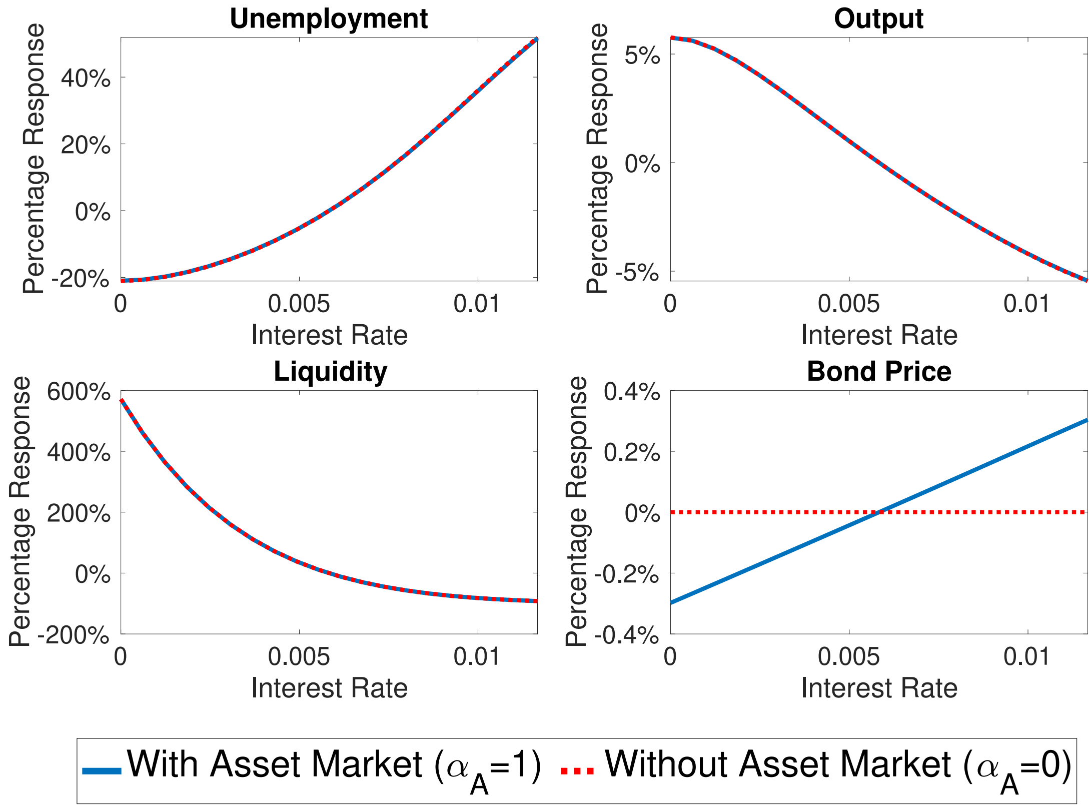

Figure 3: Inflation Shocks
Steady state responses to changes in the interest rate

lowers firms' revenue in the GM, and, in turn, lowers firm entry. This can be directly seen in the bottom left panel of Figure 3, in which consumers' liquidity is strongly decreasing in interest rate increases. As a result, unemployment goes up and match output goes down, implying a positively sloped long-run Phillips curve. This is precisely the mechanism that Berentsen et al. (2011) focus on connecting real variables with the cost of holding real balances in a New Monetarist model. That is, the direct liquidity channel in our model and the mechanism of Berentsen et al. (2011) behave in the same way and have a similar quantitative magnitude (also found in Lahcen et al. (2022)).

Our framework, however, contains two more elements not present in Berentsen et al. (2011). First, there is indirect liquidity coming from the asset market. Indirect liquidity explains why effective liquidity in the economy with an asset market ($\alpha_A = 1$) is less responsive than in the economy without an asset market ($\alpha_A = 0$): it is easier for consumers to find liquidity from the asset market when the cost of real balances increases. In turn, this channel explains why unemployment increases more and output decreases more in the economy with severe asset market frictions when inflation is high. This is another way to see the interaction between financial markets and inflation: financial markets mitigate the adverse effects of high inflation on real variables by allowing agents to acquire additional liquidity when it is needed. What is again striking, though, is how small the differences between $\alpha_A = 1$ and $\alpha_A = 0$ cases are: they are of the order of 0.2%, making them barely visible compared to the effects of changes in the interest rate.

Another channel that is new in our framework compared to Berentsen et al. (2011) is the asset price channel, pictured in the bottom right panel of Figure 3. As i increases and direct liquidity becomes scarce, the liquidity premium and the corporate bond price increase in the economy with an asset market.[16] This lowers firms' cost of borrowing, increases entry and output, and lowers unemployment. That is, the asset price channel has the opposite effect than the liquidity channel on real variables, pushing for a lower unemployment rate as inflation increases. This is reminiscent of the "interest rate channel of monetary policy transmission" (see, e.g., Rupert and Šustek 2019) in New Keynesian models, which creates a negative relationship between inflation and unemployment due to nominal rigidities. Here this happens for a very different reason: as rates increase and corporate bonds become more attractive, this lowers the firms' borrowing costs and incentivizes entry. Hence, the bottom right panel of Figure 3 provides another interesting lesson: in times of high financial trade ($\alpha_A = 1$), asset prices may be more susceptible to inflation or monetary policy shocks than they are during times of low trade frequency. However, the magnitude of this channel is significantly smaller than the magnitude of the liquidity channel and, as a result, real variables follow effective liquidity closely.

Finally, Figure 4 depicts the money "replacement" ratio: the additional money holdings agents carry when they know the asset market has shut down ($\alpha_A = 0$) relative to the liquidity agents expect to raise by selling bonds in the OTC market when that market operates properly ($\alpha_A = 1$). This ratio captures how good of a substitute is money for the liquidity provided from the financial market computed for different levels of inflation. When the interest rate is low, money is an almost perfect substitute for the liquidity agents enjoy from the secondary market. As the cost of holding money increases due to higher inflation, it becomes more costly for agents to fully replace the liquidity provided by the bond market. Put differently, the importance of financial markets for liquidity provision is disciplined by the inflation level. Even for high interest rates, however, this ratio never falls below 96%, showing that agents can easily adjust money holdings to achieve their desired liquidity levels.

[16] In the economy without an asset market, this channel is of course absent since the value of corporate bonds is always equal to the bond's fundamental value.

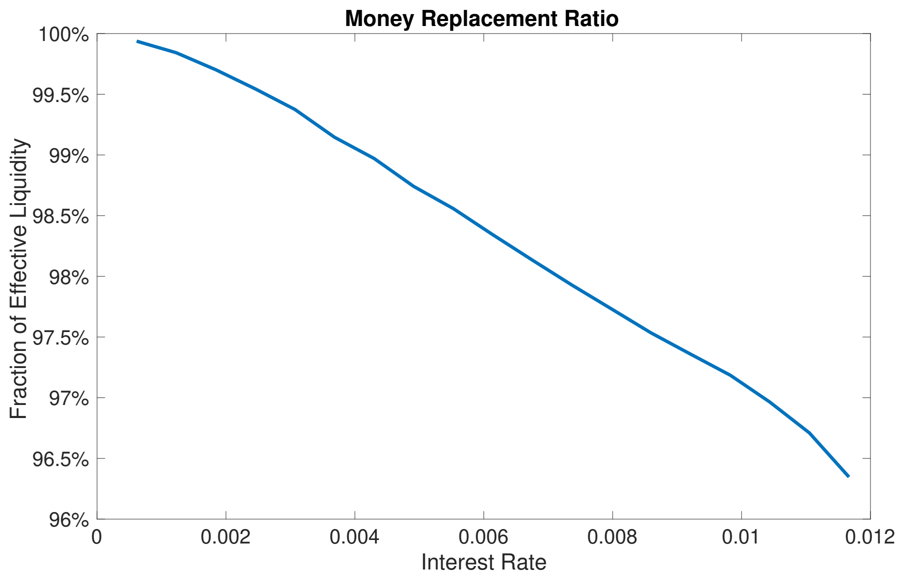

Figure 4: Money Replacement Ratio
Steady state response to changes in the interest rate

6 Conclusion

An extensive literature in macroeconomics argues that disruptions in financial markets have large negative effects on output and (un)employment. Although the papers under consideration come from different strands of the (macroeconomics) literature, they all share a common feature: they employ frameworks where money is not explicitly modeled. The goal of this paper is to study the real effects of financial market disruptions, but, importantly, do so within an economy where money plays an essential role. We argue that the absence of money may limit a model's ability to accurately evaluate the real effects of financial disruptions, since it deprives agents of a payment instrument that they *could* have used to cope with the resulting liquidity disruption.

To study the question at hand, we build on the work of Berentsen et al. (2011), which contains two of the essential ingredients our analysis should incorporate: a frictional labor market that gives rise to equilibrium unemployment, and a frictional product market that gives money an essential role as a liquid asset. We extend this framework by assuming that firms face recruiting and operational costs, which they must cover by issuing corporate bonds. In our model, only money can serve as a medium of exchange, but corporate bonds are also liquid, as agents can sell them for cash in a secondary OTC market. This *indirect* bond liquidity is crucial, as it determines the ultimate rate at which firms can borrow funds and the consumers' effective liquidity (i.e., the amount of money with which they will eventually enter the product market). Thus, our model captures *all* the salient features of the question we are after: equilibrium unemployment, an essential role for money, but also a financial market that is crucial to the firms' ability to cover recruiting and operational costs and, thus, create jobs.

In this environment, one would expect a shock that impedes agents' ability to liquidate bonds in the secondary market to have sizable effects on firm entry, unemployment, and output. This expectation, however, is not supported by a careful quantitative analysis of the model. We find that output and unemployment respond very modestly to changes in the efficiency of matching in the secondary corporate bond market. The intuition behind this result is that, in our *monetary* model, agents are able to increase their money holdings and *substitute* the foregone liquidity due to the financial market disruption. Thus, we argue, working with a moneyless model does not come without loss of generality. We also find that the size of the transmission mechanism between the financial market shock and the real economy is disciplined by the inflation level, which can be viewed as an additional argument in favor of a framework where money is explicitly modeled. Our model can also be used to derive a number of interesting comparative statics results; in particular, it suggests that there is a strong positive relationship between inflation and unemployment, i.e., a positively-sloped Phillips curve.

Appendix

A Steady State

A.1 Calibration Targets

For calibration, we target seven moments, which include the job-finding rate:

$$\frac{f_L}{s_L},$$

the unemployment rate:

$$s_L,$$

the average markup in the product market:

$$\frac{f_A}{s_A}\frac{\sigma(q^+)}{q^+} + \left(1 - \frac{f_A}{s_A}\right)\frac{\sigma(q)}{q},$$

the liquidity premium of corporate bonds:

$$\frac{f_G}{b_G}\,\frac{f_A}{s_A}\left[\frac{u'(q^+)}{\sigma'(q^+)} - 1\right],$$

the Hosios condition:

$$\frac{\partial f_L}{\partial s_L}\frac{s_L}{f_L} = \eta_L,$$

the average level of money holdings as a fraction of GDP:

$$\frac{\sigma(q)}{(1 - s_L)R},$$

and its elasticity with respect to i.

A.2 Productivity Shocks

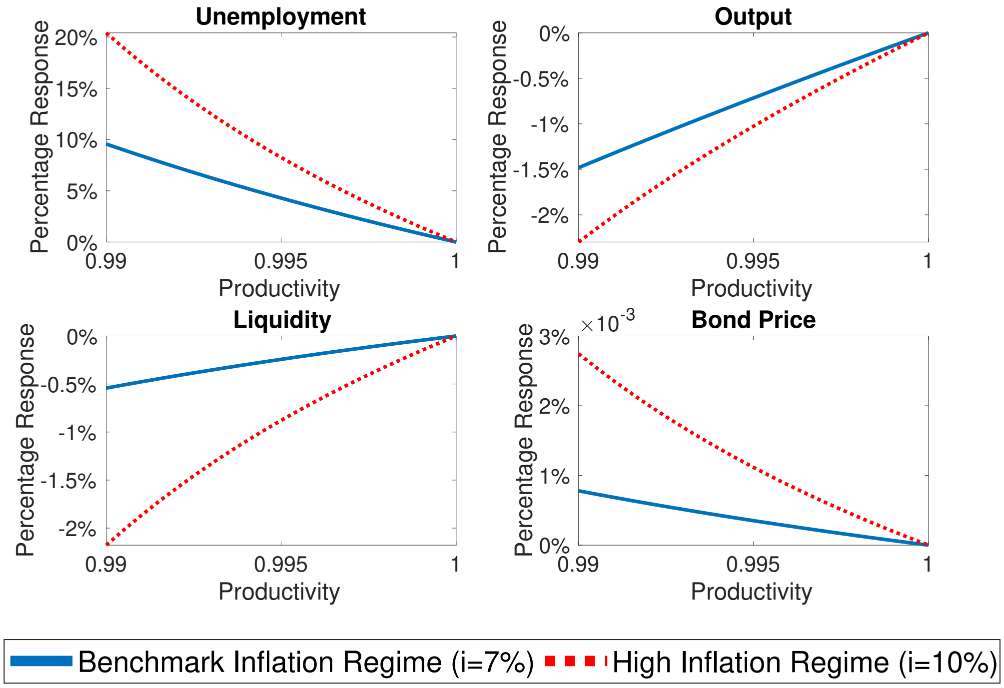

Figure 5: Productivity Shocks for $\alpha_A = 1$
Steady state responses to changes in labor market output

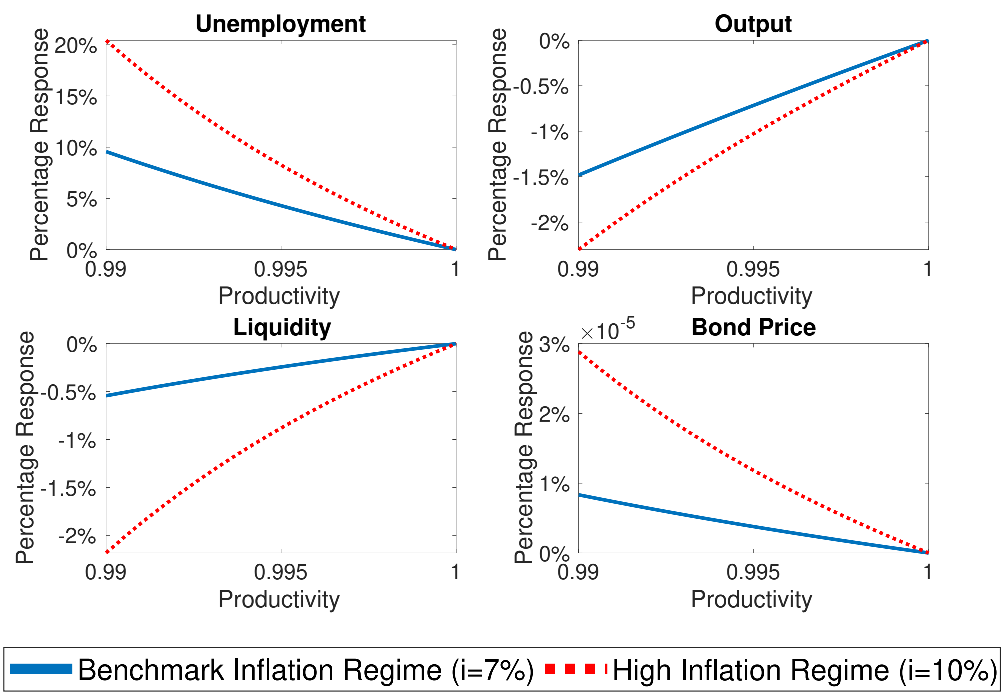

Figure 6: Productivity Shocks for $\alpha_A = 0.01$
Steady state responses to changes in labor market output

B Out of Steady State

B.1 Equilibrium

Money and bond market equilibrium The households' money demand equation is derived following the same steps as in Section 3.4:

$$i_t = \frac{f_{Gt+1}}{b_{Gt+1}}\left(1 - \frac{f_{At+1}}{s_{At+1}}\right)\left[\frac{u'(q_{t+1})}{\sigma'(q_{t+1})} - 1\right] + \frac{f_{Gt+1}}{b_{Gt+1}}\frac{f_{At+1}}{s_{At+1}}\left[\frac{u'(q^+_{t+1})}{\sigma'(q^+_{t+1})} - 1\right], \tag{B.1}$$

where the trading protocol in the AM implies

$$q^+_t = \min\{q^*_t,\, \sigma^{-1}(\sigma(q_t) + a_t)\}. \tag{B.2}$$

The households' bond demand implies the equilibrium bond price, and it is also derived following the same steps as in Section 3.4:

$$\psi_t = \beta\left(1 + \frac{f_{Gt+1}}{b_{Gt+1}}\frac{f_{At+1}}{s_{At+1}}\left[\frac{u'(q^+_{t+1})}{\sigma'(q^+_{t+1})} - 1\right]\right), \tag{B.3}$$

and the bonds are supplied according to the following schedule:

$$A_t = \frac{\kappa_R}{\psi_t} b_{Lt} + \frac{\kappa_O}{\psi_t}(b_{Lt} + (1 - s_{Lt})(1 - \delta)) \tag{B.4}$$

The money market clearing condition is

$$\varphi_t M_t = \sigma(q_t),$$

and the bond market clearing condition is

$$a_{t+1} = A_t.$$

Labor market equilibrium The free entry condition implies the job creation curve:

$$0 = \frac{f_{Lt+1}}{b_{Lt}} V^f_{1t+1}\left(\frac{\kappa_R + \kappa_O}{\psi_t}\right) - \left(1 - \frac{f_{Lt+1}}{b_{Lt}}\right)\frac{\kappa_R + \kappa_O}{\psi_t}. \tag{B.5}$$

Observe, following the same steps as in Section 3.4, that

$$V^f_{1t}(d_t) = R_t - d_t - w_t + \beta(1 - \delta)V^f_{1t+1}\left(\frac{\kappa_O}{\psi_t}\right),$$

where we define

$$R_t \equiv y + \frac{f_{Gt}}{s_{Gt}} \left[\frac{f_{At}}{s_{At}} \eta_G(u(q_t^+) - q_t^+) + \left(1 - \frac{f_{At}}{s_{At}}\right) \eta_G(u(q_t) - q_t) \right]. \tag{B.6}$$

Therefore, we have

$$V_{1t}^f\left(\frac{\kappa_R + \kappa_O}{\psi_{t-1}}\right) = R_t - \frac{\kappa_R + \kappa_O}{\psi_{t-1}} - w_t + \beta(1-\delta) V_{1t+1}^f\left(\frac{\kappa_O}{\psi_t}\right), \tag{B.7}$$

$$V_{1t}^f\left(\frac{\kappa_O}{\psi_{t-1}}\right) = R_t - \frac{\kappa_O}{\psi_{t-1}} - w_t + \beta(1-\delta) V_{1t+1}^f\left(\frac{\kappa_O}{\psi_t}\right). \tag{B.8}$$

The wage bargaining implies

$$\eta_L \left[V_{1t}^f\left(\frac{\kappa_R + \kappa_O}{\psi_{t-1}}\right) + \frac{\kappa_R + \kappa_O}{\psi_{t-1}} \right] = (1 - \eta_L) \left[U_{1t}^h(m_t, a_t) - U_{0t}^h(m_t, a_t) \right],$$

which is equivalent to

$$\begin{aligned} &\eta_L \left[R_t - w_t + \beta(1-\delta) V_{1t+1}^f\left(\frac{\kappa_O}{\psi_t}\right) \right] \\ &= (1-\eta_L) \left[w_t - b + \beta\left(1 - \delta - \frac{f_{Lt+1}}{s_{Lt}}\right) \left(U_{1t+1}^h(m_{t+1}, a_{t+1}) - U_{0t+1}^h(m_{t+1}, a_{t+1}) \right) \right]. \end{aligned}$$

Solving this for w_t, utilizing the bargaining solution and the free entry condition, yields the wage curve:

$$w_t = (1-\eta_L) b + \eta_L R_t - \eta_L \beta (1-\delta) \frac{\kappa_O}{\psi_t} + \eta_L \beta \frac{b_{Lt}}{s_{Lt}} \frac{\kappa_R + \kappa_O}{\psi_t}. \tag{B.9}$$

The measure of the unemployed evolves according to the following equation:

$$s_{Lt} = \left(1 - \frac{f_{Lt}}{s_{Lt-1}}\right) s_{Lt-1} + \delta(1 - s_{Lt-1}). \tag{B.10}$$

Measures of sellers and buyers The measures of successful matches in the LM, AM, and GM are determined, respectively, by the matching technologies $f_{Lt} = f_L(b_{Lt-1}, s_{Lt-1})$, $f_{At} = f_A(b_{At}, s_{At})$, and $f_{Gt} = f_G(b_{Gt}, s_{Gt})$, where $b_{At} = 1 - f_{Gt}$, $s_{At} = f_{Gt}$, $b_{Gt} = 1$, and $s_{Gt} = 1 - s_{Lt}$. The measures of buyers and sellers in the LM, b_{Lt} and s_{Lt}, are determined in equilibrium.

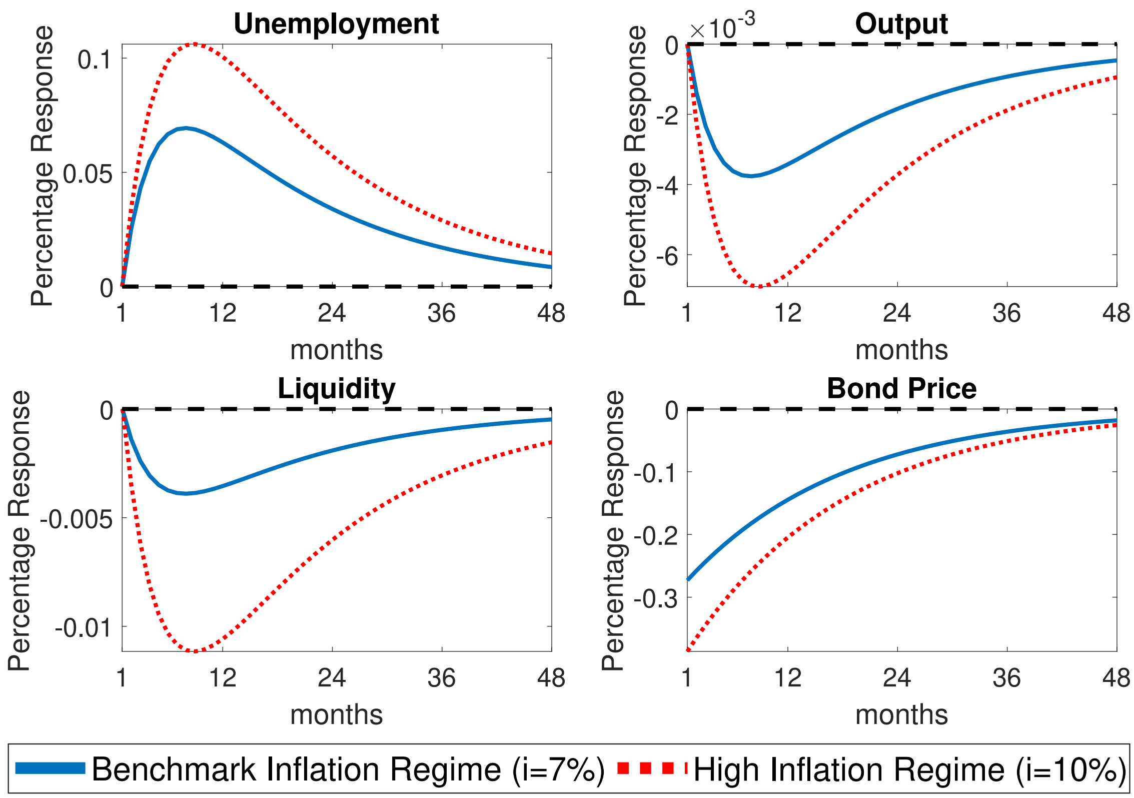

Figure 7: Short-Run Financial Shocks
Short-run responses to a one time shock in the matching efficiency of the bond market

B.2 Short-Run Dynamics

In this section, we look into the transition dynamics of unemployment and output as well as consumers' effective liquidity and the bond price, in response to one time financial, inflation, and productivity shocks. Figure 7 considers a financial shock to α_A from 1 (its steady state value) to 0 and presents the results as percentage deviations from the model's steady state levels. To understand how the cost of holding money alters the effect of the financial shock, we experiment with the benchmark level of inflation, $i = 7\%$, and high inflation, $i = 10\%$. Figure 8 considers an inflation shock to i from 7% (its steady state value) to 14%. To understand the implications of financial frictions, we experiment with the benchmark level of AM matching coefficient, $\alpha_A = 1$, and severe frictions, $\alpha_A = 0.01$. Figures 9 and 10 consider a productivity shock to y from 1 (its steady state value) to 0.99. We experiment with the benchmark level of inflation, $i = 7\%$, and high inflation, $i = 10\%$, and with the benchmark level of AM matching coefficient, $\alpha_A = 1$, and severe financial frictions, $\alpha_A = 0.01$. The frequency is monthly, and, for all shocks, we consider a half-life of 12 months. All results in the steady state analysis go through in the short-run dynamics.

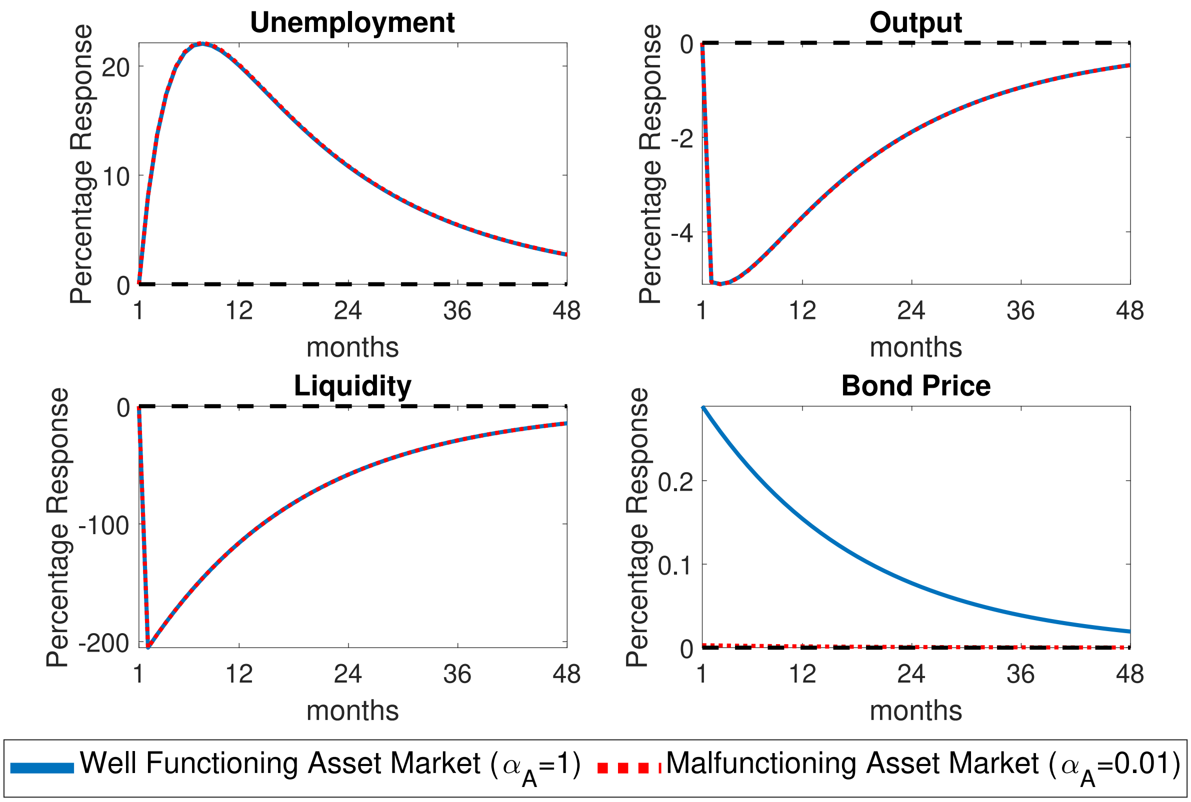

Figure 8: Short-Run Inflation Shocks
Short-run responses to a one time shock in the interest rate

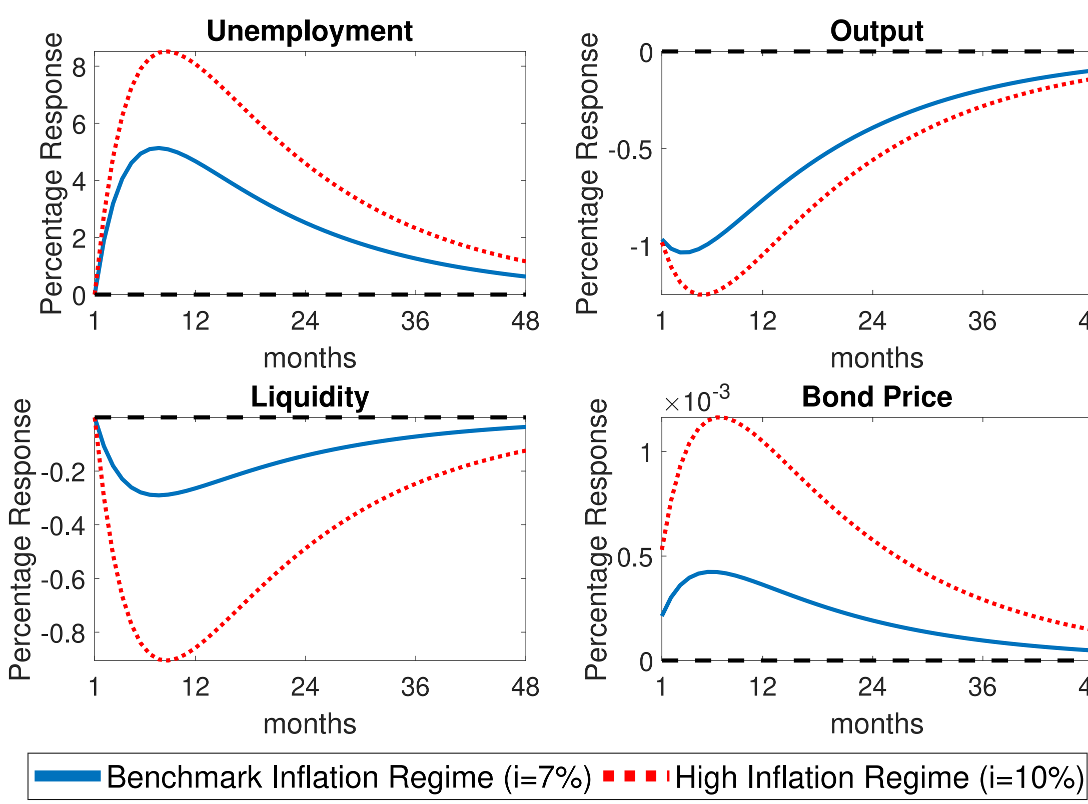

Figure 9: Short-Run Productivity Shocks for $\alpha_A = 1$
Short-run responses to a one time shock in labor market output

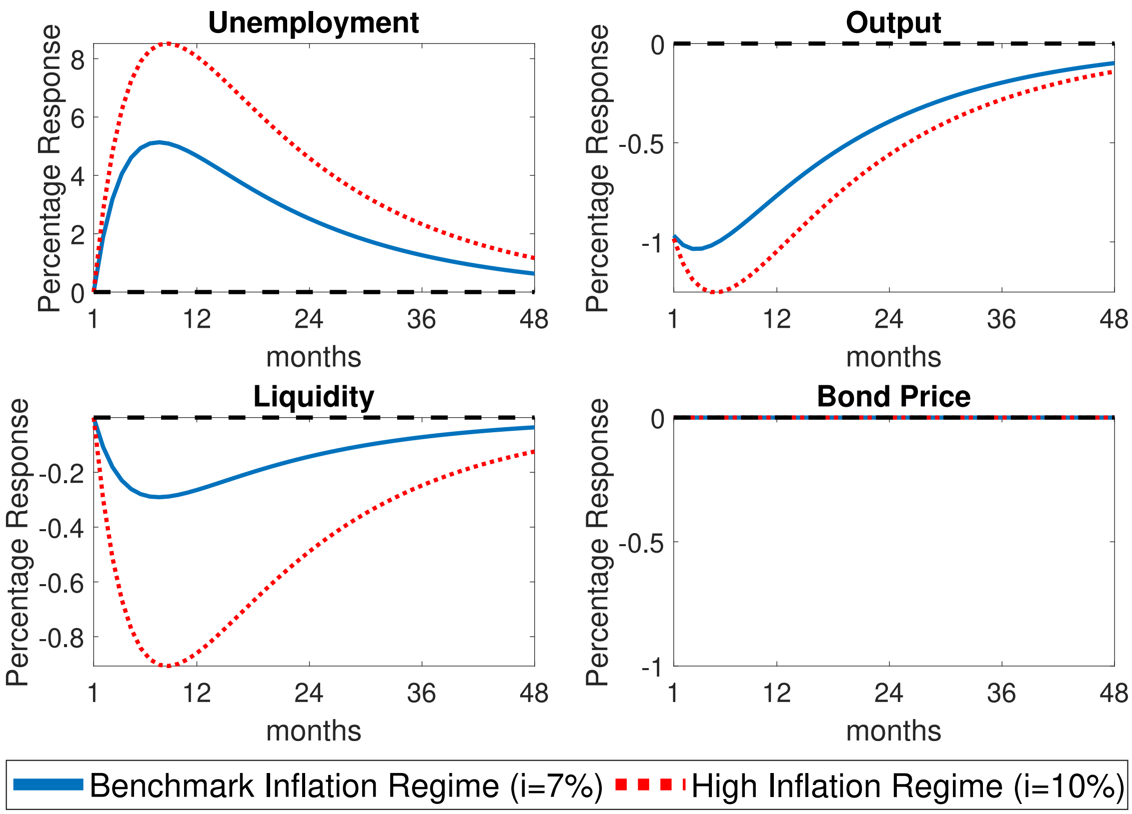

Figure 10: Short-Run Productivity Shocks for $\alpha_A = 0.01$
Short-run responses to a one time shock in labor market output

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