The Supply of Transaction Assets, Nominal Income, and Monetary Policy Transmission

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This Draft: September 2013

Abstract

Over the last few years, the Federal Reserve has conducted a series of large scale asset purchases. Given the Federal Reserve's dual mandate, the objective of this policy has been to generate an increase in real economic activity while maintaining a low, stable rate of inflation. In addition, some such as Sumner (2011, 2012) and Woodford (2012) have advocated making such large scale asset purchases conditional upon a particular target for nominal income. Whether this type of policy can be successful is dependent upon the monetary transmission mechanism. This paper proposes a mechanism in which monetary policy works through current and expected growth in the supply of transaction assets and nominal income expectations. Empirical results focusing on the role of nominal income expectations provide support for the theoretical framework.

Keywords monetary policy, nominal income expectations, quantitative easing
JEL Classification E52, E58

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1 Introduction

Over the last few years, the Federal Reserve has conducted a series of large scale asset purchases. Given the Federal Reserve's dual mandate, the objective of this policy has been to generate an increase in real economic activity while maintaining a low, stable rate of inflation. In addition, some such as Sumner (2011, 2012) and Woodford (2012) have advocated making such large scale asset purchases conditional upon a particular target for nominal income. The effectiveness of large scale asset purchases and the ability of the central bank to achieve a particular target for nominal income has been subject to debate. Of primary importance to this debate is that the ability of the Federal Reserve to achieve these objectives through large scale asset purchases would seem to hinge on the monetary transmission mechanism.

A standard New Keynesian-type of analysis, such as that outlined by Krugman (1998), Svensson (1999) and elsewhere, suggests that monetary policy is transmitted through changes in the real interest rate. During normal times, given the existence of price stickiness, the Federal Reserve can adjust the real interest rate through corresponding changes in the nominal interest rate. However, when the nominal interest rate is at the zero lower bound, the extent to which policy can be effective is dependent on the ability of the central bank to influence inflation expectations.[1] Indeed, Sumner (2011, 2012) and Woodford (2012) have advocated a policy with an explicit nominal income level target, at least in part, on the grounds that the prospect of "catch-up" growth in nominal income will increase short run expectations of nominal growth and inflation while leaving long run expectations anchored.

Others, however, have expressed skepticism about whether the zero lower bound on nominal interest rates is binding. Ireland (2012), for example, argues that the zero lower bound is a self-imposed constraint and that large scale asset purchases are actually consistent with the way that the Federal Reserve normally conducts policy through open market operations. In addition, Bernanke (2010) has argued that policy can remain effective at the zero lower bound because policy conducted through open market purchases induce portfolio re-balancing effects that ultimately influence real economic activity.[2]

As this debate illustrates, the monetary transmission mechanism is of primary importance for understanding the effects of both the recent large scale asset purchases and of monetary policy more generally. The purpose of this paper is to propose a monetary transmission mechanism, one that is operative

[1]For a thorough discussion of monetary policy at the zero lower bound in this context see Eggertson and Woodford (2003).

[2]This idea is one that has a long tradition in the literature. For earlier explanations of portfolio re-balancing effects resulting from changes in monetary policy see Tobin (1969) and Friedman and Schwartz (1963, 1982).

whether or not the nominal interest is at the zero lower bound, and to present empirical support for this mechanism. In particular, this paper suggests that monetary policy is transmitted through changes in the growth rate of transaction assets through both a direct and indirect effect. First, an increase in the growth rate of the monetary base, whether through lump sum transfers or open market operations, generates a real balance effect that increases real economic activity. Second, the indirect effect is through bank lending. Since bank loans are often a function of nominal income, expansionary monetary policy increases bank lending. Since economics agents are forward-looking and the the effects of monetary policy are persistent, monetary policy is transmitted through the expected future time path of the growth of transaction assets and nominal income. This characteristic is especially important in light of the policy recommendations of Sumner (2011, 2012) and Woodford (2012), in which the central bank attaches an explicit target for the level of nominal income to large-scale asset purchases.[3]

This paper examines the validity of this transmission mechanism in two ways. First, the mechanism is formalized through an extension of the monetary search framework of Lagos and Wright (2005). The monetary search framework is modified in three important ways. For example, the types of financial assets are expand to include not only fiat currency, but also riskless government bonds and deposits. In addition, whereas economic agents move sequentially through different markets in the standard monetary search framework, the present model follows Williamson (2006) in assuming that economic agents enter one of two markets each period, that these markets operate simultaneously, and that agents move probabilistically across markets over time. Monetary injections take place in one market. This implies that only a subset of economic agents receive the monetary injection. As a result, this increases demand in this market, but the price level will not fully adjust to the monetary injection even though prices are flexible. Monetary policy therefore has an effect on real economic activity. This setup therefore draws on the institutional fact that monetary policy is conducted through financial markets via open market operations. In this sense, the setup bears resemblance to the limited participation framework of Lucas (1990) and Fuerst (1992). In contrast with those frameworks, however, the effects of monetary policy in the present context are persistent.

Finally, the framework is extended to include financial intermediaries. The motivation for intermediation is derived from the fact that some agents experience idiosyncratic productivity shocks. Economic agents that wish to smooth consumption will therefore prefer to borrow before the productivity shock is

[3] More on this point below.

realized. As outlined below, this assumption implies that agents that experience an adverse productivity shock might have an incentive to default on their loan. Banks therefore impose a borrowing constraint that is a function of the nominal asset holdings and expected nominal income of the economic agent. In the event of default, the bank pays a monitoring cost to seize the assets and output of the borrower.[4] If coupled with the limited participation assumption outlined above, it can be shown that the collateral constraint is always binding. This is important because when this constraint is binding monetary policy affects banking lending through changes in expected nominal income.

Whether or not the proposed mechanism is operative requires empirical analysis. The validity of this transmission mechanism is tested using a vector autoregressive (VAR) model. Given the recent advocacy of nominal income targets, the empirical analysis focuses on the role of nominal income expectations in the transmission of monetary policy. In particular, the model predicts that with a binding borrowing constraint higher expected nominal income leads to more lending, an increase in the supply of private transaction assets, higher nominal income, and an increase in real economic activity. Impulse response functions are used to determine whether the dynamics observed in the data are consistent with the predictions of the theoretical model. The estimated IRFs provide support for this prediction.

In addition to the innovation accounting described above, the VAR is also used to construct counterfactual forecasts given different paths of nominal income expectations. Given the evidence of the influence of nominal income expectations from innovation accounting, it would be useful to evaluate the predictions of the model if the large scale asset purchases were tied to an explicit target for nominal income. The forecasts provide an indication of the path of transaction assets, nominal income, and real economic activity when monetary policy is successful at influencing nominal income expectations. This provides an additional mechanism through which to evaluate the theoretical model as well as a way in which to evaluate the claims made by Sumner (2011, 2012) and Woodford (2012) regarding the adoption of an explicit nominal income target. The forecasts are shown to be consistent with the predictions of the theoretical model.

[4] This assumption is similar to that of Carlstrom and Fuerst (1997).

2 The Model

Time is discrete and continues forever. There is a continuum of infinitely-lived agents with unit mass. Each period consists of two subperiods. In the first subperiod, agents can make a deposit with or take out a loan from a financial intermediary. In second subperiod, agents interact in one of two markets that operate simultaneously. The first market is a centralized, or Walrasian market, henceforth referred to as the CM. The second market is a decentralized market (DM) in which agents are matched pairwise to trade. Each period a fraction of agents, $\pi/(1+\pi)$, are in the decentralized market. The remaining agents are in the centralized market. Agents in the CM enter the DM in the next period with probability π such that the fraction of agents in the DM is constant across time. Upon entering the DM, agents receive an idiosyncratic preference shock. Specifically, with probability σ agents are buyers who are matched pairwise with a seller. Symmetrically, with probability σ agents are sellers who are matched pairwise with a buyer. Finally, with probability $1-2\sigma$, agents are not matched. Once matched, buyers and sellers negotiate the terms of trade. In the DM, agents do not have access to the trading histories of previous agents and there is no record-keeping technology. As such, a medium of exchange is essential.[5] There are three assets that can serve as medium of exchange. The first is a fiat currency, which is intrinsically useless. The second asset is a riskless government bond. Bonds and money differ in the sense that bonds pay interest, but some fraction of bonds are illiquid due to the fact that bonds are book entry assets and are therefore not able to be used in all transactions. Finally, claims to deposits with the financial intermediary represent the third asset capable of serving as medium of exchange. More will be said on deposit claims below.

Agents can produce and consume in the CM. The production technology for the CM good is linear, $y_t(i) = z_t(i)h_t(i)$, where y denotes the output of the CM good, h denotes labor, and $z(i)$ is an idiosyncratic productivity shock for agent $i \in (0, \frac{1}{1+\pi})$. An agent's ability to consume in the CM is dependent on income from production and the level of asset balances. As a result of the idiosyncratic productivity shock, agents entering the CM in each period have an incentive to borrow from the financial intermediary to finance a particular level of consumption. However, agents that experience an adverse productivity shock have an incentive to default on their loan. The financial intermediary responds to this incentive by imposing a borrowing constraint and monitoring borrower. If the borrower defaults, the intermediary

[5] A medium of exchange is essential in the sense described in Kocherlakota (1998) in that a medium of exchange enlarges the set of feasible allocations.

seizes the assets of the agent and transfers them to depositors.

Agents entering the DM do not have an incentive to borrow from the financial intermediary for two reasons. First, agents do not know in advance whether they are buyers or sellers. Second, even if agents knew their “type" before entering the DM, sellers would not have an incentive to borrow because they produce and do not consume. Symmetrically, buyers do not produce in the DM. As a result, a loan would actually reduce the set of feasible allocations relative to using money, bonds, or deposits given the interest payment associated with the loan. Agents entering the DM, however, do have an incentive to deposit currency with the financial intermediary since, in the event that the agent is unmatched in the DM, deposits earn interest and currency does not. In addition, as noted above, deposits circulate as a medium of exchange in the DM. However, it is assumed that claims to deposits are imperfectly recognizable and therefore there is a threat of counterfeiting. It can be shown that while no counterfeiting will actually occur in equilibrium, the threat of counterfeiting is sufficient to explain why agents are indifferent between holding currency and deposits.

Formally, the preferences of agents in the model are given as

$$E_0 \sum_{t=0}^{\infty} \beta^t [u(q_t) - c(q_t) + x_t - v(h_t)]$$

where $u(q_t)$ denotes the utility associated with consuming a quantity, q_t, of the good in the DM, $c(q_t)$ is the cost of producing a quantity q_t of the DM good, x_t is the quantity of the CM good consumed and $v(h_t)$ measures the disutility of labor, h_t. In addition, it is assumed that $u(0) = 0$, $u', -u'', c' > 0$, $c'' \geq 0$, $u'(0) = \infty$, and $u'(\infty) = 0$.

Finally, there is a government that has a consolidated budget constraint and a central bank that controls the money supply. The central bank is assumed to control the money supply through lump sum transfers to agents in the centralized market.[6] The fiscal authority then adjusts the supply of bonds to satisfy the consolidated budget constraint.

To summarize, the timing of events is as follows:

1. The period begins. A fraction of agents who were in the CM will enter the DM in the second subperiod. The remaining fraction of agents from the CM and the agents who were in the DM last

[6] Lump sum transfers are used for simplicity. It would be straightforward to show that given the liquidity differences between money and bonds, an open market purchase would have the same effect.

period will enter the CM in the second sub period.

2. Agents can deposit with or borrow from the financial intermediary in the first subperiod.

3. The first subperiod ends. A fraction of agents, $\pi/(1+\pi)$, enter the DM and a fraction of agents, $1/(1+\pi)$ enter the CM.

4. Agents entering the DM receive a preference shock such that they are buyers matched with a seller, sellers matched with a buyer, or unmatched. Agents entering the CM realize an idiosyncratic productivity shock.

5. Matched buyers and sellers in the DM negotiate the terms of trade. The central bank makes transfers to agents in the CM. Agents in the CM produce, consume and pay back their loan to the financial intermediary.

6. The period ends.

The analysis begins in the second subperiod and works backward.

2.1 The Centralized Market

Let ϕ_t denote the price of money in terms of the CM good. The budget constraint for agents entering the CM is given as

$$\phi_t(m_{t+1} + b_{t+1} + d_{t+1}) = \phi_t(m_t + t_t) + \frac{\phi_t}{1+r_t}b_t + (1+i_{d,t})\phi_t d_t + (1-i_{\ell,t})\phi_t \ell_t - x_t + z_t h_t \quad (1)$$

where m_t is money balances, t_t is the lump sum transfer from the central bank, b_t are bond balances, r_t is the interest rate paid on bonds, h_t is the quantity of labor, and $z_t \in \{z_l, z_h\}$ is an idiosyncratic measure of productivity. Specifically, z_t is given as

$$z_t = \begin{cases} z_h & \text{with probability} \quad p \\ z_l & \text{with probability} \quad 1-p \end{cases}$$

The value function for those entering the centralized market satisfies

$$W_t(m_t, b_t, d_t, \ell_t) = \max_{x_t, h_t, \ell_{t+1}, d_{t+1}, b_{t+1}, m_{t+1}} \Big[x_t - v(h_t) + \pi\beta V_{t+1}(m_{t+1}, b_{t+1}, d_{t+1})$$

$$+(1-\pi)\beta W_{t+1}(m_{t+1}, b_{t+1}, d_{t+1}, \ell_{t+1})\Big]$$

Assuming an interior solution, one can solve equation (1) for x_t and substitute this into the CM value function such that

$$W_t(m_t, b_t, d_t, \ell_t) = \max_{h_t, \ell_{t+1}, d_{t+1}, b_{t+1}, m_{t+1}} \Big[\phi_t(m_t+t_t)+\frac{\phi_t}{1+r_t}b_t+(1-i_{\ell,t})\phi_t\ell_t+z_t(i)h_t-\phi_t(m_{t+1}+b_{t+1}+d_{t+1})$$

$$-v(h_t)+\pi\beta V_{t+1}(m_{t+1}, b_{t+1}, d_{t+1})+(1-\pi)\beta W_{t+1}(m_{t+1}, b_{t+1}, d_{t+1}, \ell_{t+1})\Big] \qquad (2)$$

In addition, since agents in the CM have an incentive to default in the event of an adverse productivity shock, the intermediary imposes a constraint such that the value of the loan cannot be greater than the sum of the nominal value of the agent's assets and expected nominal income. Formally, this constraint is given as:

$$m_t + b_t + d_t + E_{t-1}(y_t/\phi_t) \geq \ell_t \qquad (3)$$

2.2 The Decentralized Market

When agents enter the DM they receive a preference shock such that with probability σ the agent is a buyer that is matched with a seller, with probability σ the agent is a seller matched with a buyer, and with probability $1-2\sigma$ the agent is unmatched. The value function for agents entering the DM is therefore given by

$$V_t(m_t, b_t, d_t) = \sigma[u(q_t)+\beta E_t W_{t+1}(m_t-a_{m,t}, b_t-a_{b,t}, d_t-a_{d,t}, 0)]+\sigma[c(q_t)+\beta E_t W_{t+1}(m_t+a_{m,t}, b_t+a_{b,t}, d_t+a_{d,t}, 0)]$$

$$+(1-2\sigma)\beta E_t W_{t+1}(m_t, b_t, d_t, 0) \qquad (4)$$

where $0 < a_{m,t} \leq m_t$, $0 < a_{b,t} \leq b_t$, and $0 < a_{d,t} \leq d_t$ denote the quantities of money, bonds, and deposits offered in exchange for the DM good.

Once buyers and sellers are matched, they negotiate the terms of trade. Since trade is anonymous in the DM, buyers offer a medium of exchange, or some combination of media of exchange, for the DM good. For simplicity, it is assumed that buyers make take-it-or-leave-it offers to sellers. This offer must satisfy:

$$\phi_t(a_{m,t} + a_{b,t} + a_{d,t}) \geq c(q_t)$$

Since the buyer makes a take-it-or-leave-it offer and has an incentive to maximize the surplus, this condition will always be binding in equilibrium. It is assumed below that the supply of currency grows at a rate higher than minus the rate of time preference. This implies that money is costly to hold and therefore $a_{m,t} = m_t$. In addition, it is assumed that the quantity of bonds used in transactions is some fixed fraction of bond holding resulting from the physical characteristics of bonds such that $a_{b,t} = \nu b_t$, where $0 < \nu < 1$. Agents can offer claims to deposits as well. However, deposit claims are not perfectly recognizable and therefore there is a threat of counterfeiting. The cost of counterfeiting is assumed to be fixed and equal to κ and is known by all agents. It follows that no agent will accept a deposit claim unless the value of the claim is less than or equal to the cost of counterfeiting. Thus, the take-it-or-leave-it offer satisfies

$$\phi_t(m_t + \nu b_t + a_{d,t}) \geq c(q_t) \tag{5}$$

$$\kappa \geq \phi_t a_{d,t} \tag{6}$$

$$0 < a_{d,t} \leq d_t \tag{7}$$

Given that κ is assumed to be known by all agents, (6) ensures that no counterfeiting takes place in equilibrium.

Using equation (5) and the linearity of W, (4) can be re-written

$$V_t(m_t, b_t, d_t) = \sigma[u(q_t) - \phi_t(m_t + \nu b_t + a_{d,t})] + \beta E_t W_{t+1}(m_t, b_t, d_t, 0)$$

Iterating the DM value function forward and substituting into (2), the all agents seek to maximize equation (2) subject to (6), (7), and (3) at the beginning of each period. Formally, the maximization problem can be written

$$\max_{h_t,\ell_{t+1},m_{t+1},b_{t+1},a_{d,t+1}} \Big[z_t(i)h_t - v(h_t) - \phi_t(m_{t+1} + b_{t+1} + d_{t+1}) + \pi\sigma\beta E_t[u(q_{t+1}) - \phi_{t+1}(m_{t+1} + \nu b_{t+1} + a_{d,t+1})]$$

$$+\pi\beta^2 E_t[\phi_{t+2} m_{t+1} + \frac{\phi_{t+2}}{1 + r_{t+2}} b_{t+1} + \phi_{t+2} d_{t+1}] + (1-\pi)\beta[\phi_{t+1} m_{t+1} + \frac{\phi_{t+1}}{1 + r_{t+1}} b_{t+1} + (1 + i_{d,t+1})\phi_{t+1} d_{t+1}$$

$$+(1-i_{\ell,t+1})\phi_{t+1}\ell_{t+1}]+\lambda_t\left(\frac{\kappa}{\phi_{t+1}}-a_{d,t+1}\right)+\Lambda_t(d_{t+1}-a_{d,t+1})+\Theta_t[m_{t+1}+b_{t+1}+d_t+E_t(y_{t+1}/\phi_{t+1})-\ell_{t+1}]\Bigg]$$

where λ_t, Λ_t, Θ are Lagrangian multipliers.

Assuming for simplicity that all assets are held in equilibrium and that the constraints are binding, the equilibrium conditions are given as

$$z_t = v'(h_t) \tag{8}$$

$$\phi_t = \sigma\pi\beta E_t\phi_{t+1}\left[\frac{u'(q_{t+1})}{c'(q_{t+1})}-1\right]+\pi\beta^2 E_t\phi_{t+2}+(1-\pi)\beta E_t\phi_{t+1}+\Theta_t \tag{9}$$

$$\Theta_t = (1-\pi)\beta(1-i_{\ell,t})\phi_{t+1} \tag{10}$$

$$\phi_t = \pi\beta^2 E_t\phi_{t+2}+(1-\pi)\beta(1+i_{d,t+1})E_t\phi_{t+1}+\Lambda_t+\Theta_t \tag{11}$$

$$\phi_t = \pi\sigma\beta\nu E_t\phi_{t+1}\left[\frac{u'(q_{t+1})}{c'(q_{t+1})}-1\right]+\pi\beta^2 E_t\frac{\phi_{t+2}}{1+r_{t+2}}+(1-\pi)\beta E_t\frac{\phi_{t+1}}{1+r_{t+1}}+\Theta \tag{12}$$

$$\pi\sigma\beta E_t\phi_{t+1}\left[\frac{u'(q_{t+1})}{c'(q_{t+1})}-1\right]=\lambda_t+\Lambda_t \tag{13}$$

$$m_t+b_t+d_t+[pz_h h_t+(1-p)z_l h_t]E_{t-1}(1/\phi_t)=\ell_t \tag{14}$$

$$a_{d,t}=d_t \tag{15}$$

$$\kappa=\phi_t a_{d,t} \tag{16}$$

2.3 The Financial Intermediary

As noted above, borrowers in the CM potentially have an incentive to default if they experience an adverse productivity shock. If an agent defaults, the financial intermediary pays a monitoring cost proportional to the size of the loan, $\theta\ell_t$, and seizes the assets and output of the agent and transfers them to depositors. Thus, an agent experiencing an adverse productivity shock will have an incentive to default if

$$m_t+b_t+d_t+z_l h_t \leq \ell_t$$

Assuming that (3) is binding, an agent will default any time they experience an adverse productivity shock.

The financial intermediary's objective is to maximize profit, which is given as

$$\Pi = p\phi_t(1+i_{\ell,t})L_t + (1-p)\phi_t(\hat{m}_t + \hat{b}_t + \hat{d}_t + z_l h_t) - \phi_t(1+i_{d,t})D_t - (1-p)\phi_t\theta L_t$$

where Π denotes profit, L_t is the total quantity of loans, D_t is the total quantity of deposits, θ is the monitoring cost, which is assumed to be constant over time, and $i_{\ell,t}$ and $i_{d,t}$ are the interest rates on loans and deposits, respectively. Given that participants in the DM are depositors, it is not possible for these agents to make a withdraw until the subsequent period. As such, the intermediary will not hold reserves, which implies that $D_t = L_t$. The intermediary chooses L_t to maximize profit. The profit maximizing condition for the intermediary is given as:

$$p(1+i_{\ell,t}) = (1+i_{d,t}) + (1-p)\theta \tag{17}$$

The spread between interest rates is therefore increase in the probability of default.

2.4 Government

The government consists of a central bank and a fiscal authority. The central bank controls the money supply through lump sum transfers to agents in the decentralized market. Given the supply of money determined by the central bank, the fiscal authority adjusts the quantity of bonds to satisfy the consolidated government budget constraint:

$$\phi_t(M_t + B_t) = \phi_t[M_{t-1} + (1+r_{t-1})B_{t-1}] + g_0 \tag{18}$$

where M_t is the aggregate supply of money, B_t is the aggregate supply of bonds, and g_0 is some initial level of real government spending.

2.5 Equilibrium

The equilibrium in the market for the CM good is given as

$$z_t h_t = Z_t H_t = x_t = X_t$$

where Z_t, H_t, and X_t are aggregate productivity, the aggregate quantity of labor, and the aggregate quantity of the CM good, respectively.

Given the condition above and the fact that $M_t = M_{t-1} + T_t$, the aggregate resource constraint in the CM is given as

$$\phi_t \left\{ \frac{1}{1+\pi}[B_{t+1} + D_{t+1}] \right\} = \frac{1}{1+\pi}\left[\frac{\phi_t}{1+r_{t+1}} B_t + (1+i_{d,t})\phi_t D_t \right] + (1-i_{\ell,t})\phi_t L_t \tag{19}$$

Aggregating (14) yields

$$\frac{1}{1+\pi}(M_t + B_t + d_t) + Z_t H_t E_{t-1}(1/\phi_t) = L_t \tag{20}$$

From (5) and (15),

$$\phi_t \frac{\pi}{1+\pi}[M_t + \nu B_t + d_t] = c(q_t) \tag{21}$$

From the financial intermediary, it is true in equilibrium that

$$D_t = L_t \tag{22}$$

Finally, it is assumed that the supply of currency grows at a constant rate such that

$$M_t = \Omega M_{t-1} \tag{23}$$

where $\Omega > \beta$.

Given p, z_l, z_h, equations (8) - (13) and (17) - (23) are sufficient to solve for h_t, ϕ_t, q_t, Θ_t, $i_{\ell,t}$, $i_{d,t}$, Λ_t, r_t, λ_t, L_t, D_t, B_t, M_t.

2.6 Monetary Transmission

As alluded to above, the model implies that monetary policy is transmitted through the effects of changes in the supply of transaction assets and expectations of nominal income. Intuitively, this is the result of the limited participation assumption. Specifically, the simultaneous operation of the CM and DM coupled with the fact that lump sum transfers from the central bank are conducted solely in the CM implies that the price level does not fully adjust to the change in money balances. As a result, agents in the

CM experience a real balance effect. In addition, to the extent that monetary policy increases the price level, this reduces the price of money thereby increasing nominal income. Consistent with the borrowing constraint, this implies a greater provision of private credit and thereby a larger supply of transaction assets. In addition, and in contrast to earlier limited participation frameworks, the effects of monetary policy are persistent given the way in which agents move from one market to another over time.

To illustrate the mechanism, assume that $u(q_t) = q_t^{1-\gamma}/(1-\gamma)$ and $c(q_t) = q_t$. Again, given that (3) is binding, equation (9) can now be expressed in terms of log-deviations from the steady state as[7]

$$q_t = \lambda_1 q_{t-1} - \frac{1}{\lambda_2} E_t \sum_{i=1}^{\infty} \Bigg\{ \mu \Big[\omega_1 \Delta M_{t+i-1} + \omega_2 \Delta B_{t+i-1} + \omega_3 \Delta Y_{t+i-1} \Big]$$

$$+ \delta \Big[\omega_1 \Delta M_{t+i} + \omega_2 \Delta B_{t+i} + \omega_3 \Delta Y_{t+i} \Big] + \Gamma i_{\ell,t+i-2} \Bigg\} \tag{24}$$

where, $\lambda_1 < 1$, $\lambda_2 < -1$, ω_i and δ are functions of the parameters and steady state values of the model, μ is the steady state gross rate of growth of transaction assets, ΔM_t is growth in the supply of base money, ΔB_t is the growth in the supply of bonds, and with some abuse of notation ΔY_t is the growth rate of nominal income. Thus, the equilibrium quantity of the DM good depends positively on current and expected future growth of transaction assets and nominal income.

2.7 Discussion

The monetary transmission mechanism outlined above is particularly interesting in light of recent debates regarding monetary policy. For example, a number of economists have endorsed tying the actions taken by the Federal Reserve, whether it be forward guidance or large scale asset purchases, to an explicit target. Sumner (2011, 2012) and Woodford (2012), in particular, have advocated an explicit target for nominal income. Nonetheless, the transmission of monetary policy is often left implicit in these arguments.

The monetary transmission mechanism in the present paper is capable of providing a theoretical basis for attaching a target for nominal income to large scale asset purchases. As shown in equation (24), it is the expected future path of the growth of the supply of transaction assets and the expected future path of nominal income growth that are important for monetary policy to have an effect on real economic activity. This is especially important in light of the Sumner-Woodford policy recommendations

[7]It is important to note that any of the dynamic equilibrium conditions from the agents' problem yield a forward solution of the same general form.

in which the central bank would target a particular level of nominal income. In the model presented above large scale asset purchases in and of themselves increase the supply of transaction assets. For the policy to be effective, however, the purchases would need to be permanent.[8] In addition, the model implies that large-scale asset purchases would increase nominal income expectations. An explicit target for anchor expectations of nominal income growth. In addition, the targeting of a level of nominal income is especially important in the context of this model because it would ensure that faster nominal income growth in the short-term would not be offset by lower nominal income growth in the future and therefore would increase the expected future path of nominal income growth.

3 Empirical Approach

A key implication of the model developed in Section 2 is that a rise in income expectations should lead to an increase in the supply of transaction assets and, in turn, a rise in real economy activity. As noted above, this implication is consistent with the claims of Sumner (2011, 2012) and Woodford (2012) who argue that tying the Fed's large scale asset purchases to a nominal GDP level target should spur a faster recovery by allowing the Fed to credibly raise expectations of future nominal income growth. In this section we shed some light on this claim by empirically testing the model's implications. Specifically, we use impulse response functions from an estimated vector autoregression (VAR) to examine whether shocks to expected nominal income growth have had the dynamic effect on transaction assets and real economic activity implied by the theoretical model. We also use the estimated model to forecast what various sequences of shocks to expected nominal income growth would do to these variables between 2013:Q1 and 2018:Q4.

Formally, this approach starts with an autoregressive structural model of the form

$$A_0 x_t = A_1 x_{t-1} + \ldots + A_p x_{t-p} + u_t$$

where x_t is a vector of endogenous variables, $A_0, \ldots, A_p$ are n x n structural parameter matrices and u_t is a n x 1 vector of uncorrelated structural shocks that are assumed to be multivariate normal with mean

[8] This is similar to the finding of Weil (1991).

zero and unit variance.[9] The vector of endogenous variables for the VAR is defined as follows:

$$x_t = (\Delta py_t^e, py_t, y_t, t_t, i_t, r_t)'$$

where Δpy_t^e is expected nominal income growth, py_t is actual nominal income, y_t is real income, t_t is the stock of transaction assets, i_t is an interest rate, and r_t is a risk premium measure. The first five of these variables are chosen to be consistent with equation (24) above. The risk premium measure is included to control for exogenous changes to risk premium that may influence the level of financial intermediation. Note that the price level, p_t, can be extracted from the system since both nominal and real income are in it (i.e. the price level is the difference between the two series). We use this fact later to extract price level response to the expected nominal shock without having to explicitly estimate it. We estimate the model over the full sample period 1968:Q4 - 2013:Q1 and well as sub-sample of 1968:Q4 - 2007:Q4. The latter period is estimated as a robustness check since the severity and length of the Great Recession might imply a different regime with different model parameters. However, as shown below, excluding the Great Recession does not meaningfully change the dynamics and size of the IRFs.

Once the model is estimated, we do innovation accounting in the form of impulse response functions (IRFs). This allows us to determine the dynamic response of the system's variables to a standard deviation shock to expected nominal income growth. The IRFs allow us to see how these variables typically responded over the sample period to such shocks. To allow the data to speak for itself, we specifically use the generalized impulse response functions proposed by Peasaran and Shin (1998). This approach minimizes the structure forced on the data by using the average impulse response function (IRFs) from multiple Choleski decompositions with every variable in turn ordered first. Effectively, this is like looking at the dynamic effects of a shock to the non-orthogonalized residual in each equation.[10]

In addition to the innovation accounting, we also use the estimated VAR to create forecasts of the system's variables for the period 2013:Q1 - 2018:Q4 given four different paths of shocks to expected nominal income growth. We specifically create a sequence of shocks over a 1-year, 2-year, 3-year, and 4-year paths that cause nominal income to return to its full-employment level over these horizons. This

[9]For convenience of exposition, deterministic components are ignored in this discussion. Their inclusion does not change the general conclusions found here.

[10]We also estimated the VAR using long-run restriction such that expected nominal income shock had no permanent effect on the real variables in the system. This minimalist approach which only imposes structure on the long-run dynamics created very similar IRFs.

exercise allows us to see what would happen to the stock of transaction assets and the real economy if the Federal Reserve were to push nominal income to some level target by raising expected nominal income growth as suggested by Sumner (2011, 2012) and Woodford (2012). As in all counterfactual-type exercises, we view our results with some caution given the Lucas critique. We, therefore, see this exercise only as providing suggestive evidence that in combination with the IRFs can shed light on the implications of theoretical model.

To implement our VAR, we make use of two novel data series. The first one is the Gorton et al. (2012) measure of the safe assets. This is a broad measure of transaction assets that goes beyond the standard measures of money that focus on retail money assets. The M2 money supply, for example, is limited to checking and saving accounts, small-denomination time deposits, and retail money market funds. The Gorton et al. measure reflects these retail transaction assets as well as institutional money assets like treasury bills, commercial paper, and GSEs that facilitate exchange for institutional investors. Accounting for both retail and institutional money assets provide a more accurate portrayal of the growth of transaction assets as shown by Wilmot et al. (2009) and Singh and Stella (2012). Gorton et al. (2012) construct their measure using flow of funds data on the liabilities of financial intermediaries and the government that are information-insensitive, that is, the securities whose value is immune to adverse selection in exchange. With such safe assets there is little incentive for traders of these securities to verify their creditworthiness. This measure of transaction assets provides a good approximation to our definition of transaction assets in this paper. Figure 1 shows the Gorton et al. (2012) measure broken down into government supplied or public transaction assets and private label transaction assets.[11]

The second novel measure is the expected nominal GDP growth rate found in the Philadelphia Federal Reserve's Survey of Professional Forecasters. We specifically use the median forecast of the nominal GDP growth rate over the next year as our measure of expected nominal income growth. Empirically, nominal GDP and nominal GDI closely track each other and from an accounting perspective should be equivalent. Therefore, it is reasonable to use expected nominal GDP growth as a proxy for expected nominal income growth, for which there are no forecast survey taken. This quarterly series, however, only begins in 1968:Q4 and therefore limits our sample for the VAR to the 1968:Q4 - 2013:Q1 period. Figure 2 shows this series over this time.

[11]Beckworth and Hendrickson (2012) use this measure to show that the Great Recession can be viewed as the result of sharp contraction in the supply of transaction assets.

To be consistent with our expected nominal income measure, we use nominal GDP as our measure of nominal income and real GDP as our measure of real income. We use the 10-year nominal yield on U.S. treasuries as our interest rate and the spread between Moody's AAA corporate yield and the 10-Year nominal treasury yield as our risk premium measure. All of these data come from the St. Louis Federal Reserve database FRED and are in seasonally adjusted form.

All variables not already in rate form are transformed into log levels. Though standard unit root tests indicate non-stationarity in the levels of these variables, we follow the common practice of estimating the VAR in log levels since it has been shown that doing so does not asymptotically bias the coefficient estimates of the VAR parameters (Sims et al. (1990)). Moreover, estimating in levels allows for cointegration while not imposing it. The data are all at a quarterly frequency and 6 lags are chosen for the VARs since this amount is enough to eliminate serial correlation and is consistent with the results of the likelihood ratio test and Akaike information criteria.

4 Results

4.1 Impulse Response Functions

Figure 3 shows the impulse response functions (IRFs) generated from a 1 standard deviation shock to the expected nominal GDP growth for both the 1968:Q4 - 2013:Q1 and 1968:Q4 - 2007:Q4 samples. The solid line in the figure shows the IRF point estimate while the dotted lines show simulated 90 percent error bands. Both sample periods produce similar IRFs indicating the VAR parameters did not meaningfully change during the Great Recession period. Consequently, we focus on analysis below on the full period sample of 1968:Q4 - 2013:Q1.

The first graph in Figure 3 shows that a typical shock to the expected nominal GDP growth rate causes it to rise 0.63 percent upon impact. This increase in the expected nominal GDP growth sharply declines and is insignificant by 5 quarters after the shock. Consistent with the theoretical model's prediction, this shock causes the level of transaction assets to permanently increase as seen in the next graph. Transaction assets reach a high of 1.00 percent 11 quarters after the shock and about 0.93 percent after 20 quarters.

The rise in transaction assets is accompanied by a rise in nominal GDP. The third graph shows that the expected nominal GDP growth rate shock causes the level of nominal GDP to rise 0.35 percent upon impact and reaches a high of 0.80 percent 3 quarters out. Thereafter, it slowly declines so that by 20 quarters the level of nominal GDP is still 0.47 percent higher than before the shock. The price level also responds to the shock, but only slowly as seen in the fourth graph. Upon impact, the shock causes the price level to rise 0.04% and gradually increase until 20 quarters later it is 0.45 percent higher. The nominal GDP and price level responses, therefore, imply real GDP also rises upon impact. This is evident in the fifth graph, which shows that the level of real GDP rises to about 0.31% upon impact.

This surge in economic activity caused by the shock to expected nominal GDP growth rate also cause the corporate risk premium to fall and treasury interest rate to rise, as seen in the last two graphs. The fall in the risk premium is consistent with the improved economic outlook while the rise in the treasury yield is consistent with the procyclical nature of interest rates. Although these IRFs are what one would expect, their size is much more modest than the other variables' IRFs. The expected nominal GDP growth shock of 0.69 percent only leads to a 0.08 percent decline in the risk premium and a 0.14% increase in the interest rate upon impact. These modest effects disappear after 4 quarters.

Collectively, these results indicate that a positive change in expected path of nominal income, as measured by expected nominal GDP, will have an immediate impact on transaction assets, aggregate spending, and real economic activity. Not only is this consistent with the theoretical model, but it also lends to support to Sumner (2011, 2012) who argues that through expectations management, monetary policy works with long and variable leads, not lags.

One question not answered by the IRFs in Figure 3 is what happens to the private label and public-created components of the transaction assets. That is, when the positive shock to expected nominal GDP growth rate hits, does the growth in overall transactions assets stem from a rise in private label transaction assets, government transaction assets, or both? The theoretical model presented above suggests that the increase should be observed in private transaction assets. Figure 4 shows a new set of IRFs that answers this question. Here the VAR is estimated with the transaction assets broken down into their private label and public categories. Everything else is the same as before.

This new set of IRFs shows almost identical results for every series. What is new is we now observe that the shock to expected nominal GDP growth causes the level of privately produced transaction assets to increase and the level of publicly-created assets to decline. This is consistent with the theoretical model presented above. More broadly, this finding is also consistent with Bansal et al. (2010) and Gorton et al. (2012) who find that find that private and public transaction assets tend to act as substitutes in providing liquidity services over the business cycle. That is, during economic expansions risk premiums fall reflecting the increased demand for private label assets to function as money. Also, during expansions the supply of government securities decreases as the cyclical budget deficit declines and sometimes turns into a surplus. During a recession the opposite happens. The results from Figure 4 corroborate this story and show the potential for monetary policy to increase the supply of private label transactions assets through better management of nominal GDP expectations. The figure also implies that such expectation management would reduce the growth of public debt.

4.2 Counterfactual Forecast Results

As shown above, the IRFs support the theoretical model's prediction that a rise in income expectations will lead to an increase in the supply of transaction assets. Given these results, a natural extension we do in this section is to use the estimated VAR to produce a set of counterfactual forecasts for the period 2013:Q1 to 2018:Q4. This exercise allows us to see what would happen to the stock of transaction assets and the real economy if the Federal Reserve were to push nominal income to some level target through a series of positive shocks to expected nominal income growth. This exercise, therefore, can shed some light on what might happen if the Federal Reserve adopted a nominal GDP level target as advocated Sumner (2011, 2012) and Woodford (2012).

We specifically create a sequence of shocks over a 1-year, 2-year, 3-year, and 4-year paths that cause nominal income to return to its full-employment level over these horizons. Here we use the Congressional Budget Office (CBO) full-employment or "potential" nominal GDP as our measure. We prefer this measure since it provides a more conservative estimate of amount of nominal GDP needed to close the output gap. The CBO calculates it based on its estimate of potential real GDP and 2 percent inflation. An alternative approach would simply be to extract a pre-crisis trend of nominal GDP. This latter approach, however, creates a far larger nominal GDP gap for policymakers to fill than the CBO estimate which has been revised down since 2007. Consequently, we use the CBO's full employment estimate of nominal GDP. As in all counterfactual-type exercises, we view our forecasts with some caution given the Lucas critique. We, therefore, see this exercise only as providing suggestive evidence that in combination with the IRFs can help shed light on the implications of the Fed adopting a nominal income level target.[12]

[12]Our counterfactual forecast is similar to Sims (1998) who takes the estimated VAR model parameters of the Greenspan Fed and the actual estimated shocks of the Great Depression to see if the Greenspan Fed could have done a better job. Like Sims, we are using estimated VAR model with a different set of shocks to see what would happen. For more discussion on the Lucas

Figures 5 and 6 show the results of this counterfactual forecast. The top left graph in figure 5 shows the four various paths of expected nominal GDP growth shocks needed to restore nominal GDP to its full employment level. The 1-year path would require expected nominal GDP growth to accelerate for the first few quarters, peaking out at about 7.5 percent expected growth and then sharply declining. The other three shock paths require 5 to 6 percent expected nominal GDP growth initially, but they only gradually decline to about 4.5 percent. The bottom left graph shows what happens to the actual level of nominal GDP under these four shock paths. At the outset, the nominal GDP is about $15.8 trillion while its full-employment level is about $16.8 trillion. This $1 trillion gap is closed over the next four years based on the different paths of shocks and leaves nominal GDP at about $21.5 trillion by 2018:Q4.

The forecasted effect of these shocks paths on transaction assets is striking. Private label transaction shocks start in 2013:Q1 at about $39 trillion and by 2018:Q4 reach roughly $62 trillion. Public transaction assets fall from about $12 trillion in 2013:Q1 to the low-to-mid $8 trillion range in 2018:Q4. This counterfactual forecast indicates, then, that raising expected nominal GDP growth would go a long ways in both shoring up the supply of private-label transaction assets while reducing the stock of public debt.

The top left graph of Figure 6 shows the private label and public transaction assets combined. This graph also shows, as a benchmark, an optimal amount of transaction assets. This measure is constructed following Belongia and Ireland (2013) which use the equation of exchange to solve for an optimal stock of money given full employment nominal GDP and trend velocity.[13] We apply their technique to construct our optimal amount of transaction assets.[14] This graph shows that actual transaction assets in 2013:Q1were about $51 trillion while the optimal amount was close to $55 trillion. This $4 trillion shortfall is eventually closed so that by 2018:Q4 the total transaction assets reaches almost $71 trillion.

The bottom left graph of Figure 6 shows what happens to the output gap. We construct the output gap as the percent difference between the counterfactual real GDP forecasted and the CBO's potential real GDP. The output gap stands at about 5.8 percent in 2013:Q1 and depending on the path of shocks, it returns to zero between 2014 and 2015. The 10-year treasuries yield also slow increases and the corporate risk premium declines some as seen in the last two graphs. However, in these cases, the magnitude of the response is modest. This is consistent with the smaller IRFs for these two variables seen above.

Critique implication of these type counterfactuals, Sims discussion on page 152-156.

[13]That is, they solve for $M_t^* = \frac{PY_t^*}{V_t^*}$, where PY_t^* is full employment nominal GDP and V_t^* is trend velocity.

[14]We use the HP-filter to calculate trend velocity of transaction assets and use the CBO's full employment or potential nominal GDP measure.

Overall, these results in conjunction with the IRFs indicate that an increase in the expected path of nominal GDP should immediately raise transaction assets, the level of nominal spending, and real economic activity. These findings are consistent with both the implications of the theoretical model and the related policy prescriptions of Sumner (2011, 2012) and Woodford (2012).

5 Conclusion

Large scale asset purchases have been carried out by the Federal Reserve in an effort to boost economic activity while maintaining a low, stable rate of inflation. Some have argued that these purchases should be tied to an explicit target for nominal income. Whether this type of policy can be successful is dependent upon the monetary transmission mechanism. This paper proposes a mechanism in which monetary policy works through current and expected growth in the supply of transaction assets and nominal income expectations. Empirical results focusing on the role of nominal income expectations provide support for the theoretical framework. The paper therefore provides some support for conducting quantitative easing with an explicit nominal income target.

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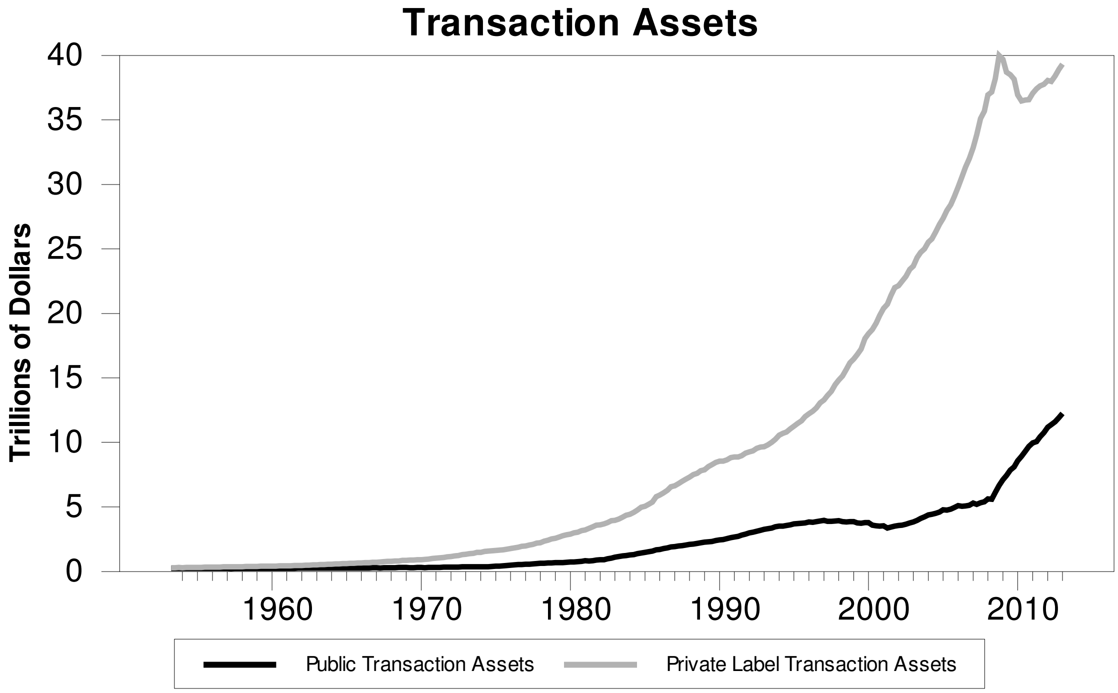
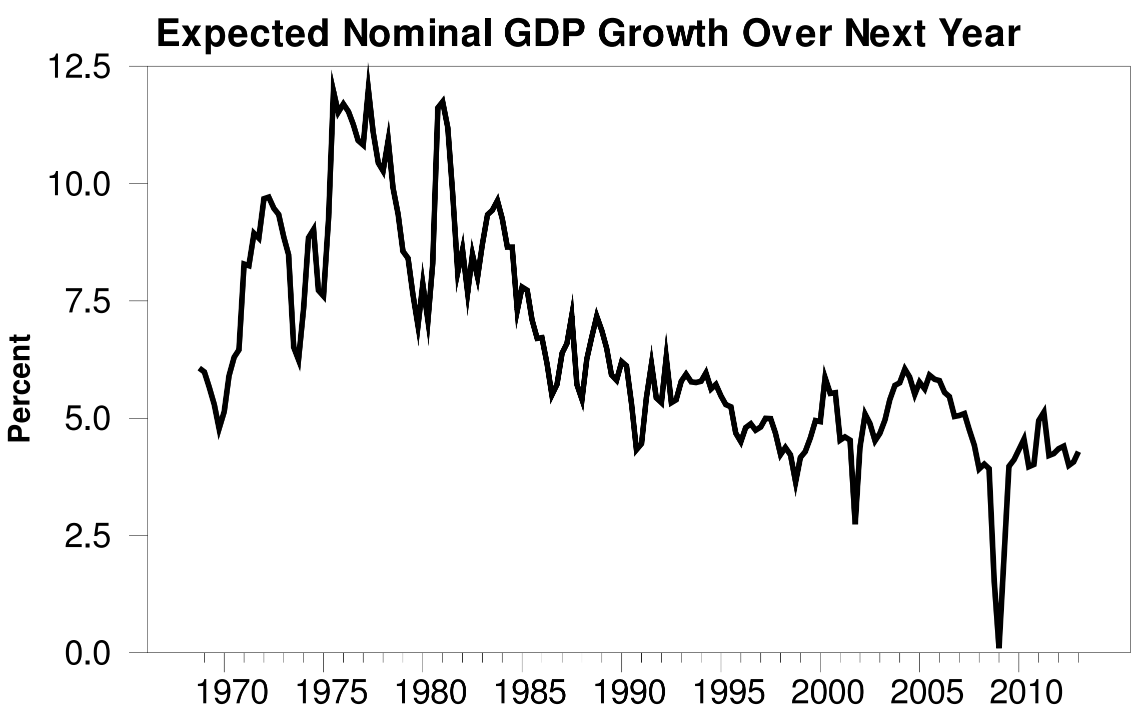
Figure 1



Source: Gary Gorton et al (2012)

Figure 2

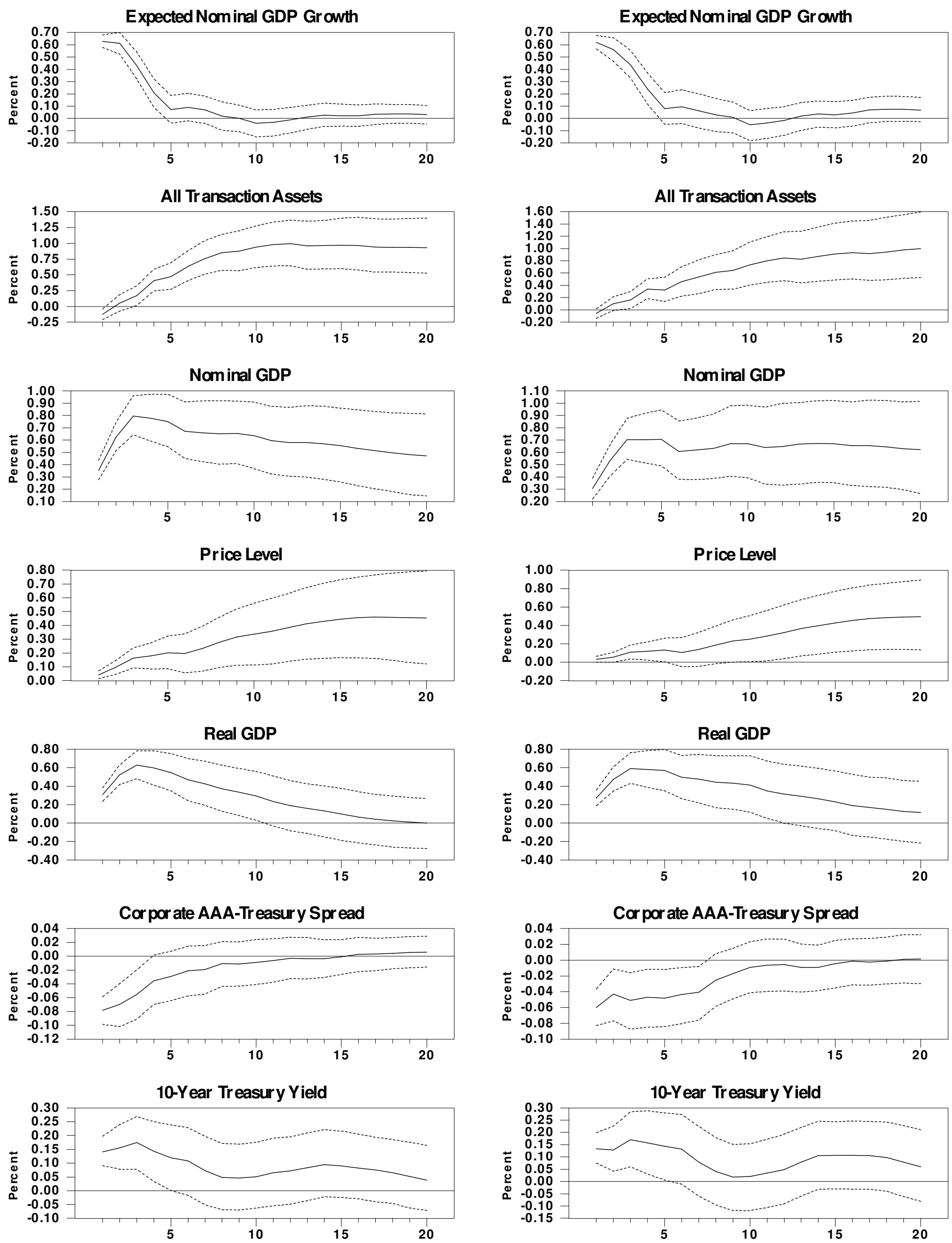


Source: Philadelphia Federal Reserve's Survey of Professional Forecasters

Figure 3

IRF from Standard Deviation Shock to Expected Nominal GDP Growth

1968:4 – 2013:1 | **1968:4 – 2007:4**



Quarters after shock | **Quarters after shock**

Figure 4

IRF from Standard Deviation Shock to Expected Nominal GDP Growth

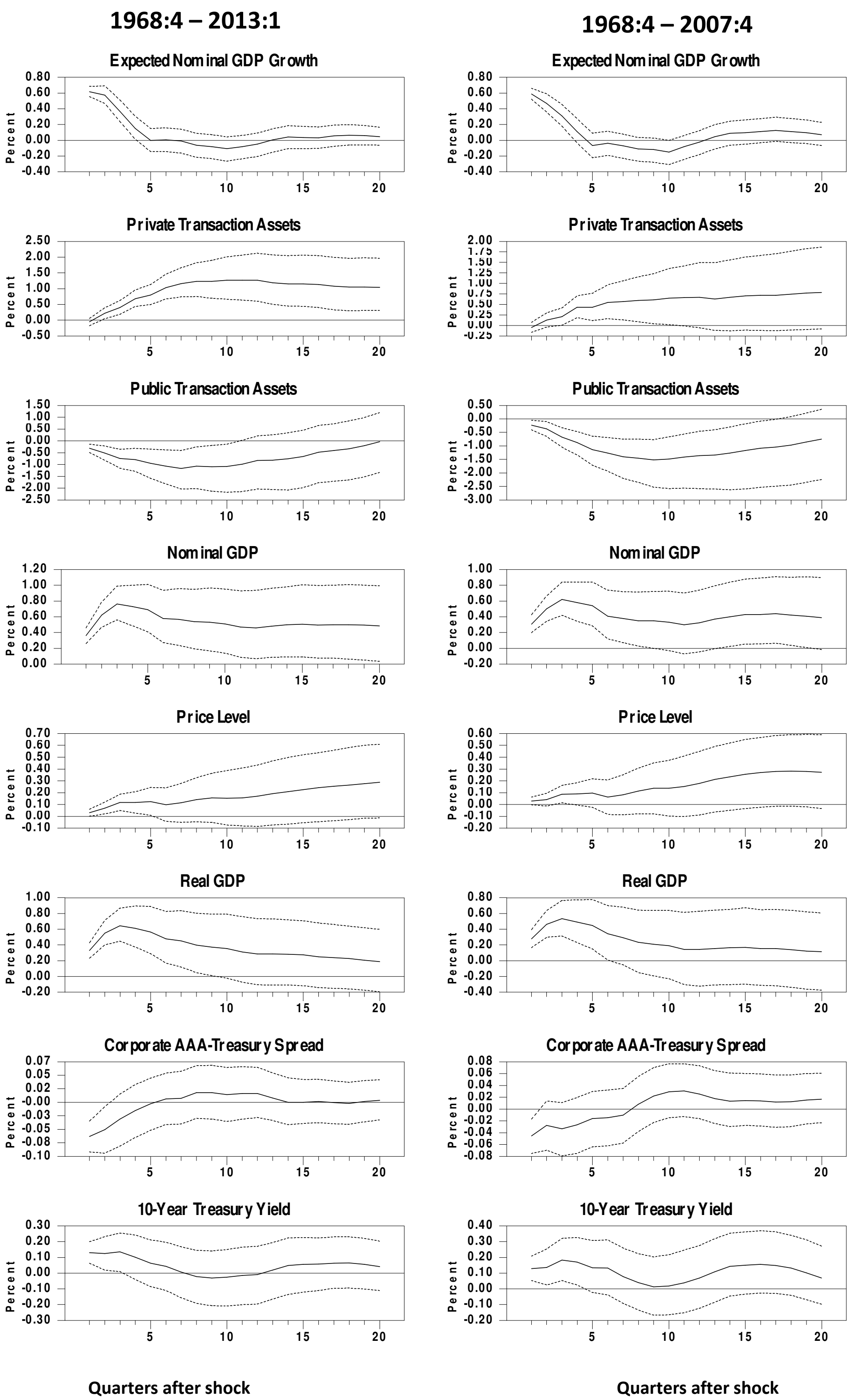
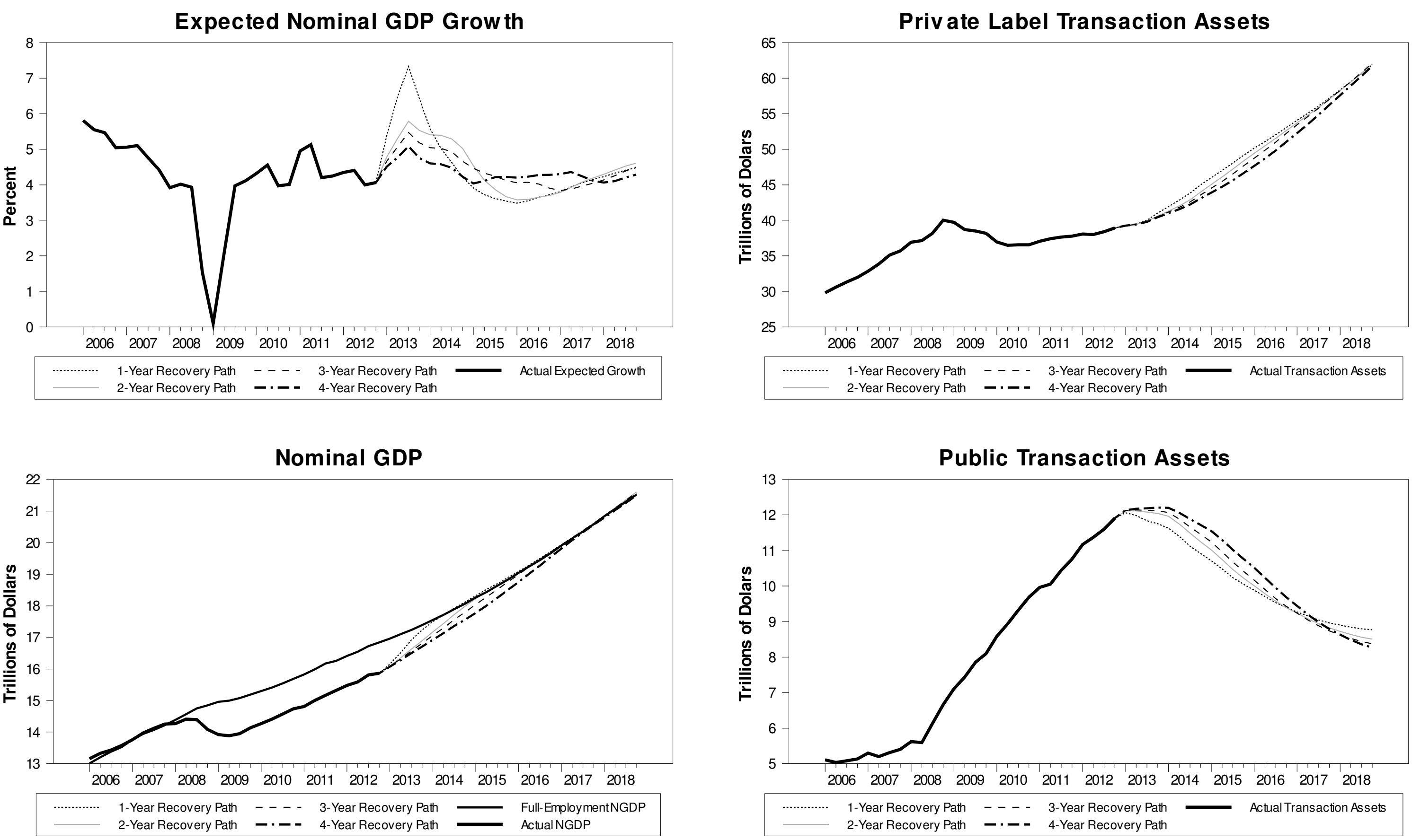
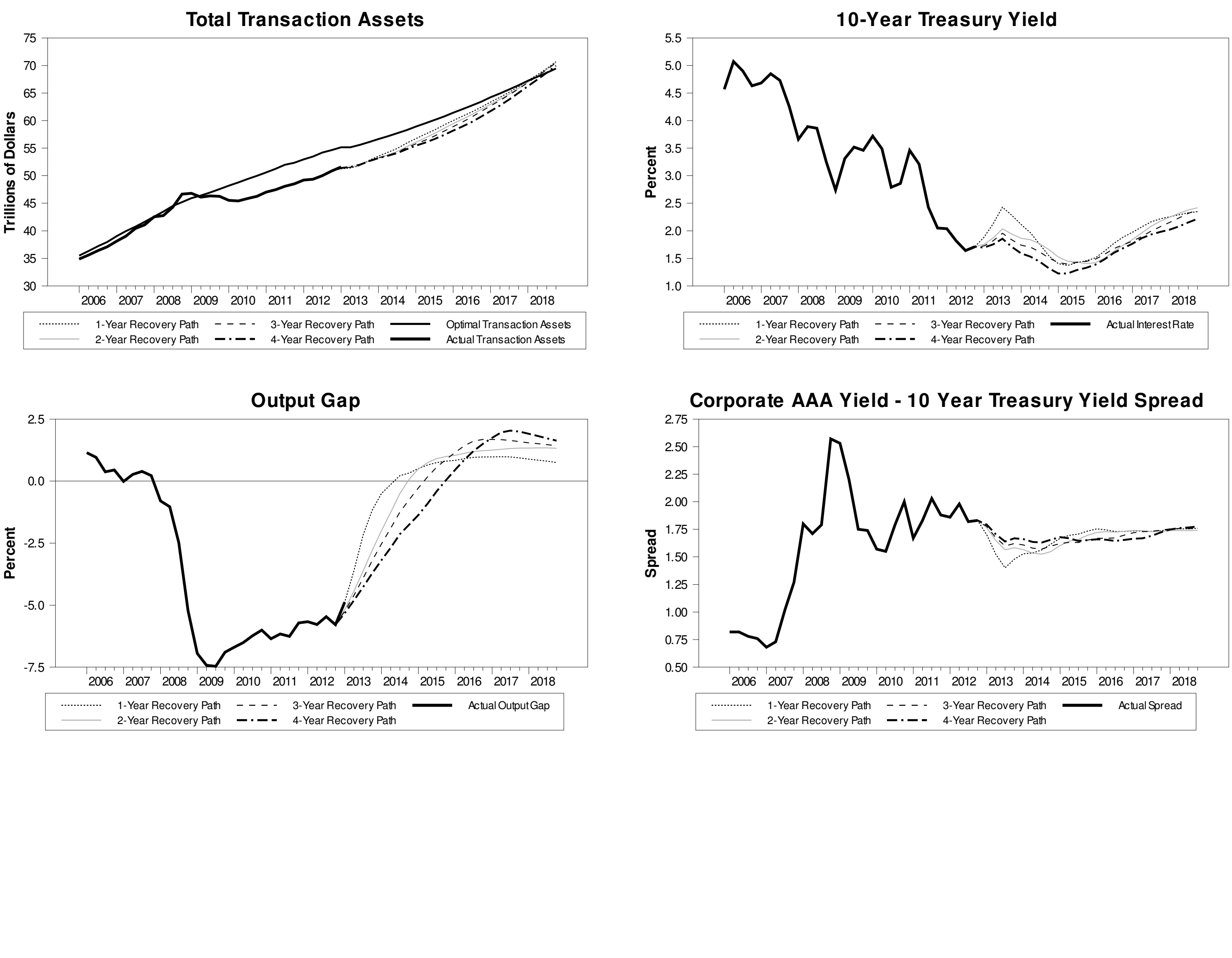


Figure 5



Expected Nominal GDP Growth
Percent
1-Year Recovery Path
2-Year Recovery Path
3-Year Recovery Path
4-Year Recovery Path
Actual Expected Growth
Private Label Transaction Assets
Trillions of Dolars
1-Year Recovery Path
2-Year Recovery Path
3-Year Recovery Path
4-Year Recovery Path
Actual Transaction Assets
Nominal GDP
Trillions of Dollars
1-Year Recovery Path
2-Year Recovery Path
3-Year Recovery Path
4-Year Recovery Path
Full-Employment NGDP
Actual NGDP
Public Transaction Assets
Trillions of Dolars
1-Year Recovery Path
2-Year Recovery Path
3-Year Recovery Path
4-Year Recovery Path
Actual Transaction Assets

Figure 6



Total Transaction Assets
Trillions of Dollars
1-Year Recovery Path
2-Year Recovery Path
3-Year Recovery Path
4-Year Recovery Path
Optimal Transaction Assets
Actual Transaction Assets
10-Year Treasury Yield
Percent
Actual Interest Rate
Output Gap
Percent
Actual Output Gap
Corporate AAA Yield - 10 Year Treasury Yield Spread
Spread
Actual Spread