Increased Strength of Monetary Policy

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Abstract
Firms cash holdings distribution changed substantially from 1980 to 2013. We study the effects of this change in the formulation of monetary policy using a model with financial segmentation. We find that the interest rate channel of the transmission mechanism of monetary policy has become more powerful, as the impact of monetary policy over the real interest rate increased. Now, with the increase in firm cash holdings, the real interest rate takes 3.4 months more to return to its initial value after a shock to the nominal interest rate. (JEL: E40, E50, G12, G31)

Keywords: firm cash holdings, interest rates, financial frictions, market segmentation, liquidity effect, monetary policy.

Introduction

The U.S. corporate cash holdings changed dramatically in the last 35 years. Bates *et al.* (2009) and Bover and Watson (2005), among others, have noticed the increase in corporate cash holdings since 1980, both in real terms and as a percentage of total cash. Corporate cash holdings corrected for inflation was in 2010 about five times its value in 1980. Figure 1 shows the mean and median of cash-sales ratio for the period 1980-2013. The median cash-sales ratio increased from 3% in 1980 to 12% in 2010. The mean cash-sales ratio increased from 6% to 23% during the same period. [1]

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The opinions expressed in this article are those of the authors and do not necessarily coincide with those of Banco de Portugal or the Eurosystem. Any errors and omissions are the sole responsibility of the authors.

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1. Throughout this paper, cash corresponds to the Compustat definition of cash and equivalents. Here we restrict our sample to firms with positive cash, positive assets, assets greater than cash, and sales greater than 10 million (CPI adjusted with base 1982-1984). We also truncated the firms at the 1 and 99 percentiles of the cash-sales ratio. With the less stringent constraint of sales greater than zero, the increase in the median cash-sales ratio is from 3.5%

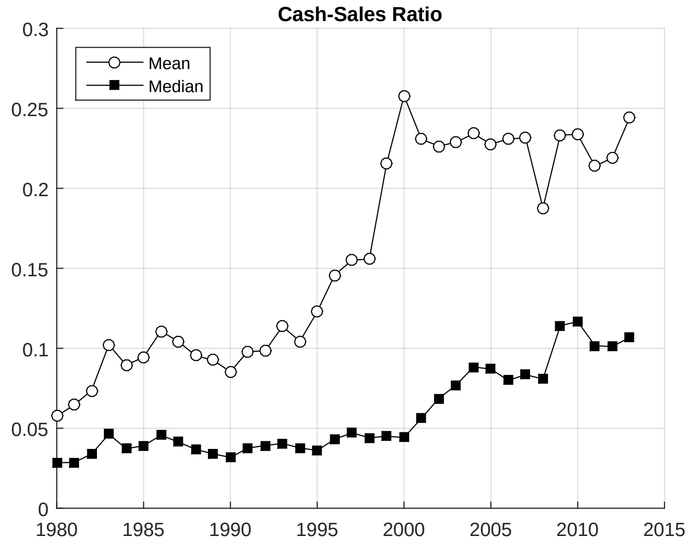

FIGURE 1: Mean and median of the cash-sales ratio across firms for each year. The cash-sales ratio state how much firms maintain of their sales in cash. A cash-sales ratio of 0.1, for example, means that firms maintain 10 percent of their yearly sales, or 1.2 months of sales, in cash.

Source: Authors' calculations with Compustat data. See note 6 for details.

In addition to the increase in the cash-sales ratio, firms cash holdings correspond to a large fraction of the monetary aggregates and this fraction has increased substantially. From 1980 to 2010, the ratio between corporate cash holdings, measured as cash and equivalents of the U.S. nonfinancial firms listed in Compustat, and M1, according with the FED of St. Louis data increased from 0.27 to 0.83. This fraction decreased to 0.65 percent in 2013, still more than two times the ratio in 1980.[2] For the same year, the cash component of the item cash and equivalents, which includes mainly currency and demand

to 13.4%, i.e. a 3.8 times increase. There are different measures of cash holdings such as the cash-assets and the cash-net assets ratio. We use the cash-sales ratio because it has a better data counterpart to the variables in the model.

2. M1 is defined as currency plus traveler checks plus checkable deposits. In January 2014, currency corresponds to 43.6% of M1 and checkable deposits to 56.3%. The definition of cash and equivalents in Compustat includes the components of M1 and "securities readily transferable to cash," which includes short term commercial paper, short term government securities, and money market funds. In our sample, 1980-2013, the Compustat cash portion of cash and equivalents, which includes mainly currency and demand deposits, corresponds on average to 70% of the cash and equivalents item.

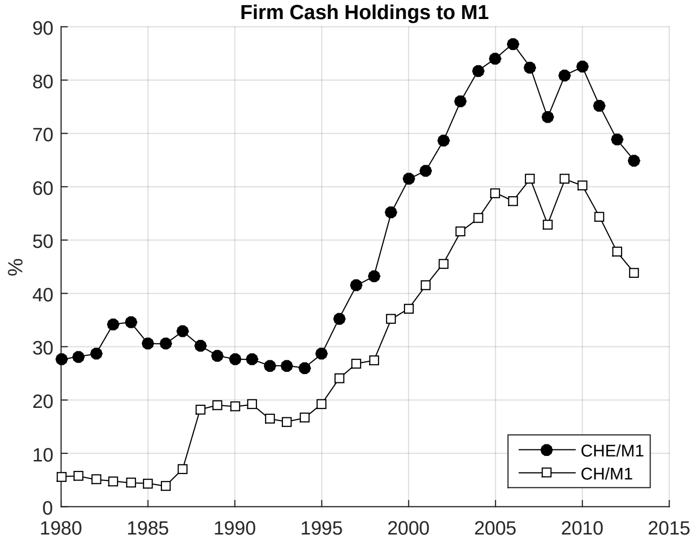

FIGURE 2: M1 is the ratio between cash and equivalents and M1, and CH/M1 is the ratio between the cash portion of cash and equivalents and M1. Both series increase during the period considered.

Source: Compustat and Federal Reserve Bank of St. Louis.

deposits, was 60% of M1. Figure 2 shows the evolution of these two series for the period 1980-2013. [3]

The distribution of cash across firms is not uniform and it has changed during the period 1980-2013. Figure 3 shows the median of the cash-sales ratio over the same period for firms grouped in percentiles of sales. We see that the cash ratio increased for all groups. Moreover, while the cash ratio increased 3 times for all firms as a whole, it increased 5 times for firms in the smaller percentiles. Bates *et al.* (2009) show a similar evolution for the cash-assets ratio.

There is a large literature on the determinants of firm cash holdings. Among the explanations for firm cash holdings, a partial list includes the transactions role of cash (Baumol (1952) and Tobin (1956)), financial constraints (Almeida *et al.* (2004)), tax purposes (Foley *et al.* (2007)), and corporate governance (Jensen (1986), and Blanchard *et al.* (1994)). Empirically, the different determinants of firm cash holdings are analyzed by, among others, Opler *et al.* (1999), and Ozkan and Ozkan (2004).

3. Firms in Portugal, for the period 2005-2013, mantained substantially smaller cash balances. The ratio between the total of currency and bank deposits for nonfinancial firms, according to the data base "Informação Empresarial Simplificada", and M1, according with Banco de Portugal, from 2005 until 2013 was above 0.28 and below 0.36.

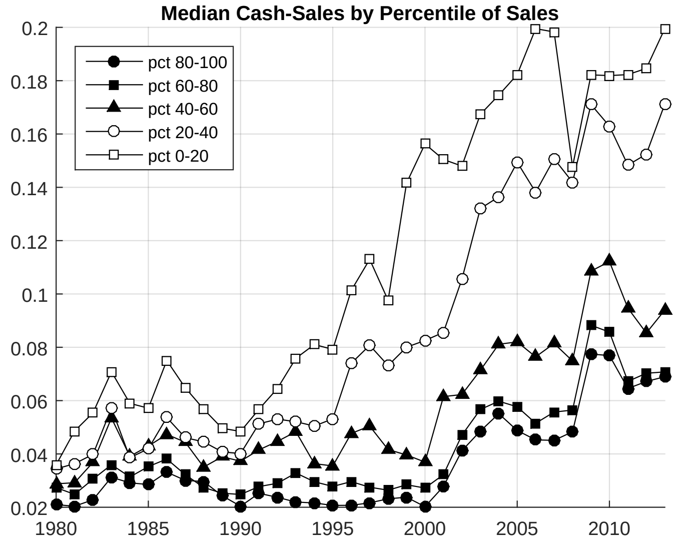

FIGURE 3: Median of the cash-sales ratio for different percentiles of sales. Source: Compustat; see note 6 for details.

Source: Authors' calculations with Compustat data. See note 6 for details.

The increase in cash holdings is surprising, as the evolution of the technology of financial transactions allows firms to sell, frequently and at a low cost, illiquid assets for cash and to maintain their operations with little cash. It is also surprising to find that firms hold more than half of M1. It would be expected that households would have more difficulty than firms to manage cash, as households face higher transactions costs and have more difficulty in using credit. We do not aim at explaining the cash holdings or their secular trend.[4] Our objective is to analyze the implications of the secular increase in corporate cash holdings on the effects of monetary policy. As firms hold a large portion of the monetary aggregates, it is important to study the effects of the increase in cash holdings on macroeconomic variables. To the best of our knowledge, we are the first to study the consequences of corporate cash management decisions for monetary policy.

As we are interested in the effects of the distribution of money holdings, we use a model in which the distribution of money holdings plays an active role. For instance, in the first generation cash-in-advance models, such as Lucas Jr. and Stokey (1987), the distribution of money holdings is degenerate. All participants in the economy behave as a representative agent and they

4. Bates *et al.* (2009) identify four causes for the increase: an increase in R&D expenditures, a fall in inventories, a fall in capital expenditures, and an increase in cash flow risk.

have the same demand for money. It is not possible to evaluate the impact of the distribution of money with these models because they do not allow any role for the distribution of money.

More recently, the real effects of monetary policy have been studied in new Keynesian models (for example, Clarida *et al.* (2000) and Michael Woodford (2003)). These models contain frictions usually in the form of price rigidities. There is a distribution of prices across firms, but the distribution of money is again degenerate. A representative agent uses all money carried from the last period to buy products in the current period. As in the first generation cash-in-advance models, the distribution of money holdings in these models does not affect monetary policy.

Here, to take into account the effects of changes in the distribution of cash holdings in monetary policy, we use a model with market segmentation.[5] The friction is the separation of markets for liquid and illiquid assets. Liquid assets are used for transactions while illiquid assets receive higher interest yields and are kept mainly as a reserve of value. These markets are separated in the sense that firms cannot exchange illiquid assets for cash with a high frequency. The higher the level of cash holdings relatively to the transactions conducted by the firm, the lower is the frequency with which the firm makes transactions in the assets market.

In this model a nominal interest rate shock has real effects because firms behavior with respect to the use of cash depends on their cash holdings at the time of the shock. Firms with little cash adapt faster to the shock, as they trade in the assets market soon after the shock, while firms with large cash holdings take longer to adapt, as they trade in the assets market relatively late after the shock. If the market segmentation friction is removed, the real interest rate does not move after the shock and the real effects vanish. As we want to isolate the effects of the change in cash holdings, we eliminate other mechanisms besides market segmentation that could generate additional real effects. In particular, there are no sticky prices, output is constant, and the only change in the economy during the period is in the distribution of cash holdings.

For each year from 1980 to 2013 the cross-sectional distribution of cash in the data is used to calibrate the size of the type and the frequency with which each type of firm in the model trades in the financial market. Once the model is calibrated, it can deliver closed-form solutions for all macro variables of interest. In particular, the response of the real interest rate to a nominal interest rate shock. The shock follows the interest rate dynamics in Christiano

5. The model is described in detail in Adão and Silva (2015). Is a modified version of the models in Alvarez *et al.* (2004) and Silva (2012), which only allow for one type of economic agent. The modified model, by allowing many types of firms, each type exchanging illiquid assets at a different frequency, permits a better correspondence between the cross-sectional distribution of cash in the data and the model.

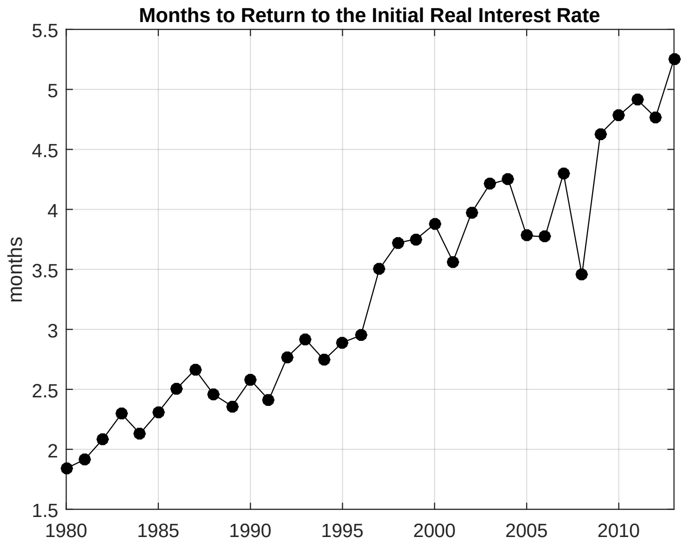

FIGURE 4: Simulations for a given a nominal interest rate shock. The simulations take into account the distribution of cash-sales ratio for each year.

Source: Authors' calculations.

et al. (1999) and Uhlig (2005). For each year, we recalibrate the model to the distribution of cash holdings of that year. As the distribution of cash holdings changes, the response of the real interest rate changes too.

Figure 4 shows, for the period 1980-2013, how long the real interest rate would take to return to its initial value after a monetary shock, according to the model. We find that the real interest rate takes 3.4 more months in 2013 than in 1980 to revert to its initial value after a nominal interest rate shock. For the 1980 distribution of money holdings the real interest rate took 1.84 months to revert to its initial value, while with the 2013 distribution of money holdings, the real interest rate took 5.25 months to revert to its initial value.

Due to the substantial increase in the cash holdings by firms, monetary policy has become more powerful, as the effects of monetary policy over the real interest rate are now more persistent than in 1980. Consistent with this idea, Clarida *et al.* (2000) state that monetary policy has been more effective after 1980.

The Distribution of Cash Holdings over Time

Figure 1 shows the median and the mean of the cash-sales ratio from 1980 to 2013. In the literature different measures of cash have been used to analyze firms cash holdings, such as the cash-net assets ratio (used, for example, by Opler *et al.* (1999)) and the cash-assets ratio (by Bates *et al.* (2009)). The cash-sales ratio has been used, among others, by Harford (1999) and Bover and Watson (2005). Both, the cash-assets ratio and the cash-sales ratio, have increased substantially over time. The cash-assets ratio indicates the relative weight of cash in the firm's portfolio. The cash-sales ratio indicates how much cash a firm holds with respect to the flow of resources obtained with its operations. It has a more direct relation with the use of cash for transactions. We use the cash-sales ratio because its interpretation—cash relative to the flow of resources obtained—allows a better connection between the model parameters and the data. The conclusions of this paper are robust if instead the cash-assets ratio is used.[6]

As cash is measured in dollars and sales are measured in dollars per unit of time, the cash-sales ratio is a variable given in units of time. For example a median cash-sales ratio of 0.12 in year 2010, means that firms maintained about 1.4 months of their sales in the form of cash. In 1980, this same ratio was only 0.03, or 11 days. The mean cash-sales ratio in the same period increased from 0.06 in 1980 to 0.23 in 2010. The distribution of the cash-sales ratio across firms is highly asymmetric as it can be inferred by the difference between its mean and median. The mean was more than two times the median during the whole period and it reached 5.8 times the median in 2000.

If there was no benefit of maintaining cash, firms would choose a cash-sales ratio approximately equal to zero, as holding cash implies an opportunity cost in interest foregone. As the cash-sales ratio is sizeable in economic terms, the data indicate the existence of costs in the management of money. These costs may be in the form of transaction costs or in the form of management costs. A portfolio manager, for example, may schedule sales of long term bonds to coincide with cash needs, but this and other more elaborate schedules of payments are costly. For our purposes it does not matter the nature of the costs of managing cash holdings. What is important is that firm cash holdings are positive and considerable.

Usually, firms maintain cash-sales ratios smaller than one. The 95th percentile of the distribution of the cash-sales ratio reached a maximum of 1.3 in 2000 and it was about 1 during 2002-2007. If a firm maintains a cash-sales ratio above one, it means that the firm keeps more than one year of sales

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6. Our measure of cash is cash and equivalents from Compustat, "cash and short-term investments," CHE, U.S. nonfinancial firms. CHE is not available for utilities, so the dataset removes this sector. To avoid anomalies, we remove observations with cash or assets equal to zero, and observations with cash greater than assets. To avoid extreme cash-sales ratios, we remove observations with sales smaller than 10 million and observations with cash/sales below the 1st and above the 99th percentiles of cash/sales. We later report results without this truncation, which barely changes results. We correct for inflation with the CPI from the FED St. Louis, CPIAUCSL, base 1982-84. For sales, we use SALE in Compustat. Our procedure implies 140,435 firm-years or about 4,130 firms per year.

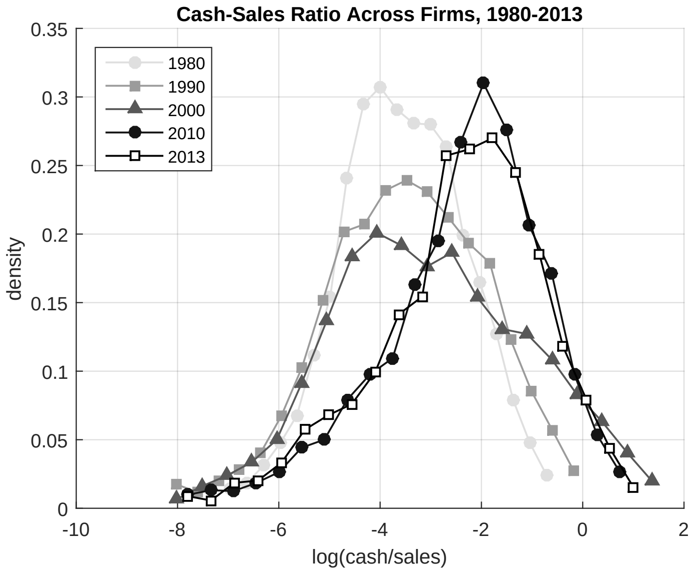

FIGURE 5: Distribution of the cash-sale ratio across firms from 1980 to 2013 for selected years. Each curve has the distribution for one year (density histograms with 20 groups). The curves are approximately symmetric because it shows the logs of the cash-sales ratio; the actual distribution is highly asymmetric. Over the years, the support and the median of the cash-sales ratio increased.

Source: Authors' calculations with Compustat data. See note 6 for details.

in the form of cash. Firms that maintain high cash-sales ratios tend to be small firms in terms of sales; the same is true for the cash-assets ratio.

Figure (5) shows the distribution of the cash-sales ratio for each year. The distributions look symmetric because the figure shows the logs of the cash-sales ratio. The support and the median of the distribution of the cash-sales ratio increased over time. The support of the distribution increased first and later the median increased. In 1980, the maximum cash-sales ratio was equal to 7 months, i.e., below one year. The maximum cash-sales ratio was above 1 after 1983. In 2000, the maximum cash-sales ratio was 5 years (the 95th percentile was 1.3). Figure 1 shows that the increase in the median of the cash-sales ratio accelerated after 2000 and figure 5 shows that the distribution of cash holdings changed substantially after this date. The two figures complement each other as they show that firm cash holdings changed especially after 2000.

It is important that the model can take into account that the distribution of cash holdings across firms is not uniform and that it has changed over time. Changes in the heterogeneity of the cash holdings change the speed and the size of the adjustment to the shock. This property is not unique to our model, the new Keynesian Phillips curve model shares this property.

Carvalho and Nechio (2011) shows that when the heterogeneity in the firms price setting behavior is taken explicitly into account the aggregate dynamics are substantially different from the case when all firms have the same price setting behavior.

The Model

The economy is composed by firms with different amounts of liquid assets, that we call money, and illiquid assets, that we call bonds. There is market segmentation in the financial market, in the sense that firms only trade occasionally in the assets market. Firms trade bonds for money, in the assets market and goods for money in the goods market. Because bonds pay interest while money does not, firms accumulate bonds and periodically trade them for cash to do transactions in the goods market. As firms do not do this at the same time there will be a non degenerate distribution of cash and bonds across firms in the economy.

The groups of firms are indexed by $i = 1, ..., I$ and the fraction of firms in each group by v_i, where $\sum_{i=1}^{I} v_i = 1$. Each firm has a bank account and a brokerage account. A firm in group i, s_i, is identified by its pair of initial values of cash and bond holdings, (M_{0i}, B_{0i}). The bank account is used to hold cash for transactions in the good and inputs market. The brokerage account is used to trade bonds in the asset market. The time interval between transfers of money from the asset market to the good market, the holding period, is the same for all firms that belong to the same group and is denoted by N_i. Different holding periods express different forms of portfolio management by the firms in the economy, which we do not address in the paper.

Time is continuous, $t \geq 0$. Firms produce goods at time t, which they sell instantaneously. The proceeds of sales are deposited directly to the brokerage account and converted into bonds. The portfolio choice across different bonds in the brokerage account is not important for our results. For this reason, we simplify the model by having just one positive and deterministic nominal rate of return $r(t)$. This rate of return on assets in the brokerage account is the opportunity cost of money, and the firms manage cash over the holding period according with the path of $r(t)$.

Let $T_{ji}(s_i)$, $j = 1, 2, ...$, denote the times of the transfers of firm s_i, $i = 1, ..., I$. At $T_{ji}(s_i)$, firm s_i sells bonds for money and transfers the proceeds to the good market. The holding period of firm s_i is $[T_{j,i}(s_i), T_{j+1,i}(s_i))$, for $i = 1, ..., I$. We have $T_{j+1,i}(s_i) - T_{j,i}(s_i) = N_i$ for $j = 1, 2, ...$ for all s_i firms. Cash holdings are denoted by $M_i(t, s_i)$. Cash holdings in the brokerage account are zero, as cash does not receive interest and it is not possible to do transactions with the cash in the brokerage account. The optimal policy is to keep the resources in bonds in the brokerage account and make periodical transfers to the bank account to do transactions.

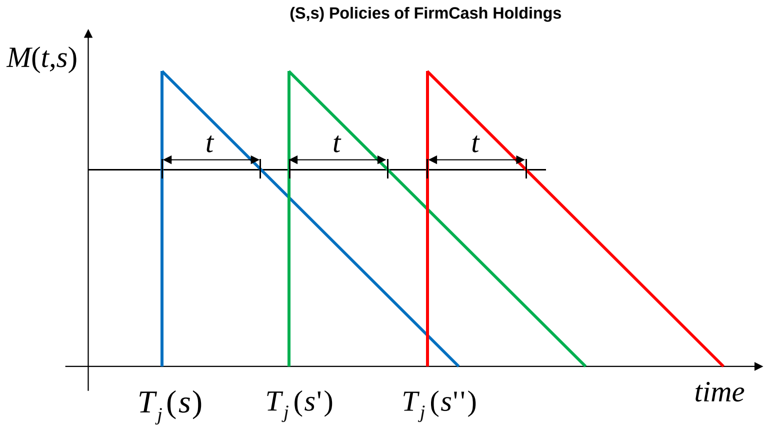

FIGURE 6: Along the holding periods the pattern of the cash stock evolution is similar across the firms in the same group. The firms cash money balances follow a sawtooth pattern. However, at any point in time different firms in the same group will have different levels of cash.

Source: Authors' calculations.

The government executes monetary policy through open market operations, that is, by exchanging bonds for money with the firms in the assets market.

The Distribution of Cash Holdings in the Steady State

The firms engage in (S, s) policies for cash. The opportunity cost of holding cash implies that it is optimal to start a holding period with more cash than in the rest of the holding period and spend this cash gradually until the next transfer, which initiates a new holding period. As the times of the transfers $T_{ji}(s_i)$, $j = 1, 2, ...$, are not the same across firms, at any point in time some firms will have little cash while others will have a lot of cash.

In a steady state with constant inflation rate, π, and nominal interest rate, r, the (S, s) policies concerning the cash of the different firms in each group i, $M_i(t, s_i)$ for $i = 1, ..., I$, have the same pattern. This is highlighted in figures 5 and 6. The paths for cash and bonds have the same pattern across firms in the same group.

The aggregate cash holdings at time t, $M(t)$, are obtained by the aggregation of the cash holdings of each firm at t. At t most firms will have different levels of cash, but the aggregate money demand will grow at the steady state inflation rate.

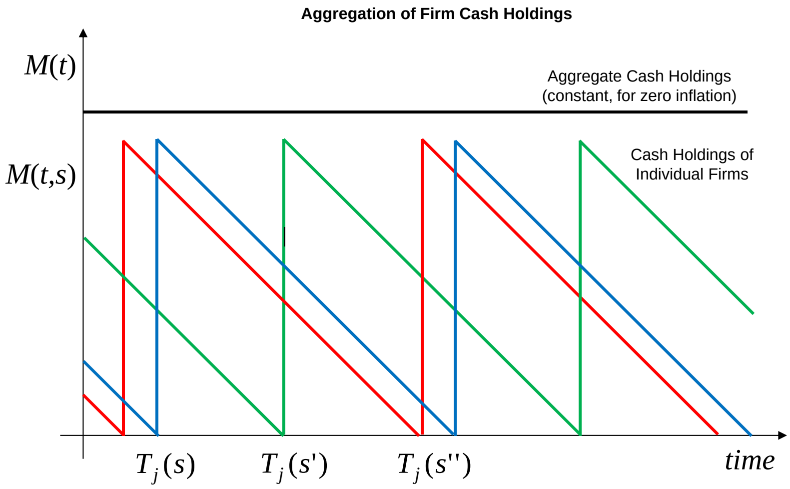

FIGURE 7: Inside each group and at each moment different firms have different cash balances but the aggregate cash holdings is constant if inflation is zero.

Source: Authors' calculations.

A relevant variable for a firm is its position in the holding period. Let $n_i \in [0, N_i)$ denote how long ago a firm of the group i made a transfer. It can be shown that the optimal transactions during the holding periods of firms in group i are a decreasing function of time the last transfer occurred and of the nominal interest rate. Given the transactions of each firm s_i in group i it is possible to compute the value of cash holdings of each firm s_i, as well as the cash holdings of group i and the aggregate cash holdings.

Instead of working with cash we focused on the variable cash-sales ratio of the firms. The cash-sales ratio gives how much of their sales firms maintain in cash, it is the inverse of the money velocity. For instance, according to the Compustat data, the median cash-sales ratio in 2012 was equal to 10%. Therefore, the median firm in 2012 held $0.1 \times 360 = 36$ days of sales in cash.

From the cash holdings of the firms and the sales of firms we get the density $f_i(m_i)$ of firms cash-sale ratios, m_i. The group i firms cash-sale ratios are distributed along $[0, m_{H_i})$, where $m_{H_i} = \lim_{n_i \to N_i} m(n_i)$. For the aggregate firms in the economy, the density function is $f(m) = \sum_i v_i f_i(m)$, where v_i is the fraction of firms distributed along $[0, N_i)$, which ensures that $\int f(m)\, dm = 1$.

For each year the nominal interest rate, r, is the commercial paper interest rate, and the values of m_{H_i} and v_i are set so that the model distribution of the cash-sales ratio approximates the actual distribution of the cash-sales ratios, available in the Compustat data. Figure (8) shows an example with $I = 4$.

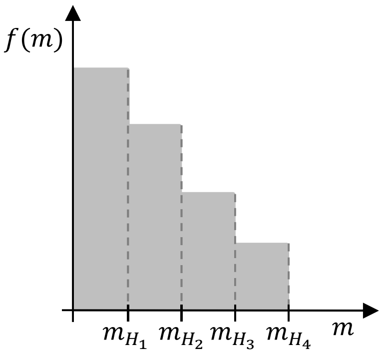

FIGURE 8: The parameterization is made by finding the values of m_{H_i} and v_i, $i = 1, ..., I$, so that the model distribution of cash-sales ratios approximates the distribution in the data. In the simulations $I = 50$.

Source: Authors' calculations.

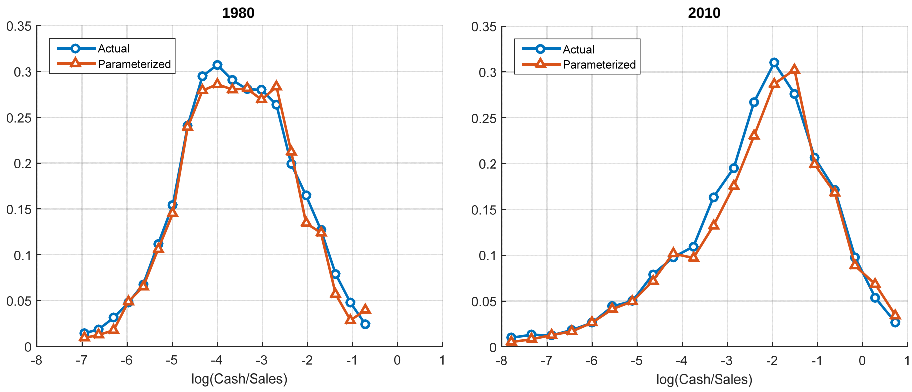

FIGURE 9: Actual and parameterized distributions of the cash-sales ratio for 1980 and for 2010.

Source: Authors' calculations.

The actual distributions of the cash-sales ratio are shown in figure (5). Figure (9) shows the actual distribution and the parameterized distributions for the years 1980 and 2010. As the distributions are highly asymmetric toward small values of the cash-sales ratio, figures (5) and (9) show the distributions of the logs of the cash-sales ratio.

Firm Cash Holdings and Monetary Policy Shocks

In the model monetary policy is summarized by a nominal interest rate path $r(t)$, $t \geq 0$. The central bank sets the interest rate path, and then changes the money supply accordingly. A change in the interest rate path $r(t)$ affects firms' cash holdings but the central bank adjusts the supply of cash, $M(t)$, to satisfy the money market clearing condition. It is equivalent to set $M(t)$ and obtain the equilibrium $r(t)$ or to set $r(t)$ and obtain the equilibrium $M(t)$. However, it is computationally simpler to set $r(t)$ and obtain the other equilibrium variables. Moreover, the evidence suggests that the practice of central banks is to set monetary policy in terms of interest rates. By focusing on $r(t)$ as the target for the monetary policy, we follow the literature, for example, Michael Woodford (2003).

When an unexpected increase in the interest rate hits the economy, firms have different cash holdings $M_{0i}(n)$. Firms with little cash are about to make a transfer. These firms adapt faster to the shock because they will make a transfer soon after the shock. With the bond trade and subsequent transfer, they adjust cash holdings taking into account the new interest rate path. Firms with large cash holdings take longer to make their first transfer and thus adjust more gradually. Until they make a transfer, they can only adjust transactions.

The different adjustments of transactions and assets affect the real interest rate. If the holding periods N_i's are small, firms adjust quicker and the real interest rate changes little. In the limit, if $N_i \to 0$, we are back to the standard cash-in-advance model with a representative firm and the real interest rate doesn't move. Conversely, if the values of N_i are large, there is a large degree of heterogeneity across firms and a large portion of the firms adjust slowly to the shock. The gradual adjustment to the shock implies larger and more persistent changes in the real interest rate.

Longer holding periods imply different and longer adjustments in transactions that bring about slower and smaller changes in the price level after an increase in the nominal interest rate. As the real interest rate is equal to the difference between the nominal interest rate and the rate of inflation, the real interest rate increases together with the nominal interest rate after the shock. Market segmentation, therefore, explains the real effects of monetary policy through the different cash holdings of the firms at the time of the shock and the subsequent diverse reactions of the firms.[7]

The price level changes less after a shock in the economy if the holding periods are larger. In this sense increasing the dimension of the holding periods in this segmentation model is similar to decreasing the probability that the firm can reset its price in the Calvo price setting mechanism. The

7. A slow response of prices and an increase in the real interest rate after an increase in the nominal interest rate is found in many empirical studies.

price stickiness property arises endogenously in this segmentation model and the degree of the price stickiness increases with the increase in the holding periods. Thus, longer holding periods imply larger and more persistent effects in the real variables after a shock.

According to the Fisher relation the real interest rate changes after a nominal interest rate shock only if inflation moves slowly after the shock. In a standard cash-in-advance model, inflation changes instantaneously after a shock to nominal interest rate and the real interest rate remains constant. Here, inflation remains constant just after the shock because of the market segmentation. Therefore, the real interest rate increases with the nominal interest rate shock.

Consider now a monetary policy shock as the one described in Uhlig (2005). Figure (10) reproduces figure 2, plot 6, in Uhlig (2005), which shows the possible range of impulse response functions for the federal funds rate to a monetary policy shock. On average, on impact the interest rate increases 0.3 percentage points and gradually decreases towards its initial value in about 2 years, and stays below its initial value, for some time, until it returns to zero. We approximate this shock with the process for the interest rate given by $r(t) = r_1 + (r_2 - r_1 + Bt)\, e^{-\eta t}$, also depicted in figure 10, where $r_2 - r_1 = 0.3$ percentage points per year. We set B and η so that $r(t)$ approximates the average impulse response of the federal funds rate in Uhlig (2005). [8]

From 1980 to 2013, we parameterize the economy by determing the values of v_{Y_i} and N_i so that the distribution of the cash-sales ratio from the model replicates as close as possible the actual distribution of the cash-sales ratio from the Compustat data. In each year, given the parameterizations, we hit the economy with the shock to $r(t)$ and obtain the real interest rate path.

Figure 11 shows equilibrium real interest rate paths for five years in the period between 1980 and 2013. We show the difference in percentage points from the initial value of the real interest rate. For a standard cash-in-advance model, we would have a straight line at zero after the shock, as a standard cash-in-advance model implies an instantaneous reaction of prices and no change in real interest rates. However, with market segmentation, the real interest rate increases after the nominal interest rate shock and returns gradually to its initial value. The real interest rate undershoots before returning to its initial value.

We measure the effect of monetary policy by how long it takes for the real interest rate to reach its initial value. In figure (11), we have, for example, that given the cash distribution of 1980 the real interest rate reaches its initial

8. The expression of $r(t)$ is a result of the differential equation $m\ddot{r}(t) + c\dot{r}(t) + kr(t) = 0$, $\eta = c/(2m)$, which describes a dampened shock. We set $r_1 = 3\%$ p.a. and $r_2 = 3.3\%$ p.a. Figure (10) expresses the results as the difference from initial values of the nominal and real interest rates. In our simulations, t denotes one day and we divide the year in 360 days. We set $B = -0.15\%$ and $\eta = 0.30$, for $r(t)$ given in percentage per year.

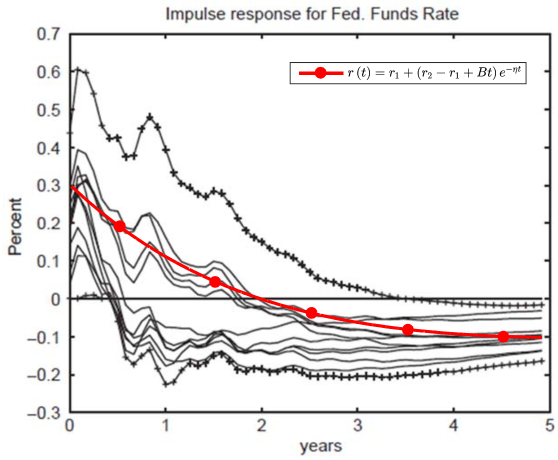

FIGURE 10: The red line corresponds to the nominal interest rate path $r(t) = r_1 + (r_2 - r_1 + Bt)\, e^{-\eta t}$, with the parameters B and η used in the simulations.

Source: Figure 2, plot 6, in Uhlig (2005).

value in 1.84 months. Given the cash distribution of 2013, the real interest rate reaches its initial value in 5.25 months. The values for all years from 1980 to 2013 are in figure (4). As the distribution of cash-sales ratio changed from 1980 to 2013, the effect on the real interest rate implied by the model has changed too. The recent distribution of cash-sales implies that the real interest rate takes longer to return to its initial value. The monetary authority, therefore, is able to affect the real interest for a longer period.

These results are qualitative robust to different calibration methods, different interest rate shocks, and different cash aggregates. For instance if the model was calibrated to the cash portion of cash and equivalents item from the Compustat data the qualitative results would be similar. Figure 12 reports the results when instead cash is used. Also in this case the time it takes for the real interest rate to return to the initial value increases substantially.

Conclusions

We show that the recent increase in cash holdings by firms has strong macroeconomic consequences, since it affects substantially the response of the real interest rate to nominal interest rate shocks. According to our predictions, the changes in the distribution of cash holdings from 1980 to 2013 imply that the real interest rates takes 3.4 months more in 2013 than in 1980 to return to its initial value after a shock.

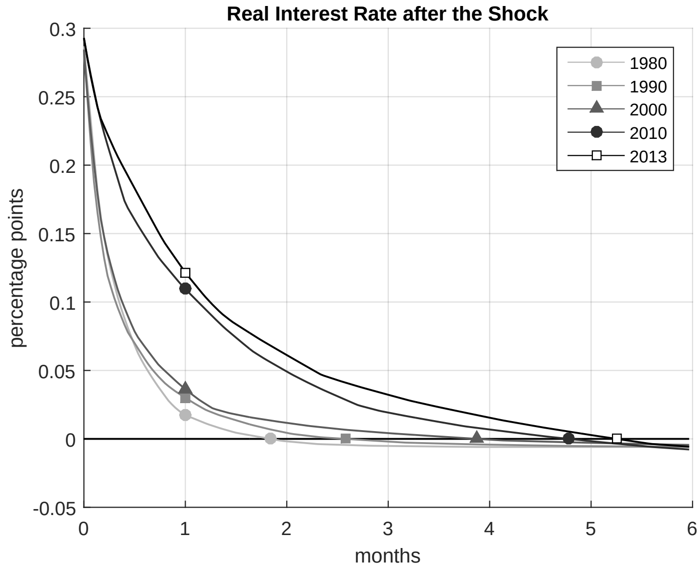

FIGURE 11: Response of the real interest rate for selected years given the nominal interest rate shock of figure (10). Results from simulations. The distribution of cash holdings is determined through the data for each year. The markers in the horizontal axis show the time for the real interest rate to return to its initial value. The values are 1.84, 2.58, 3.88, 4.78, and 5.25 months for the selected years. The values for all years are in figure (4).

Source: Authors' calculations.

It is a broad conviction that when the nominal interest rates are low monetary policy is less efective. The implication of our results is just the opposite. Given the high current values of the cash-sales distribution as compared to past values, changes in nominal interest rates will have stronger effects in the economy. A small change in the nominal interest rate today as the same real effect as a large change in the nominal interest rate some decades ago.

Our argument is not as general as we would like because it takes as given the firms' cash holdings. In future work we would like to investigate what are the determinants of corporate cash holdings and why have corporate cash holdings increased so much. Only after this work is done can we allow for firms' cash holdings to be an endogenous variable in the model.

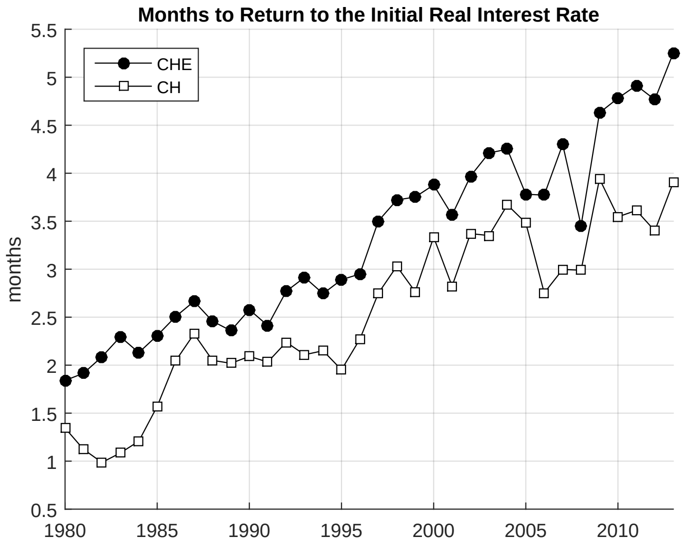

FIGURE 12: CHE: simulations as in figure (4), with cash and equivalents. CH: simulations with the cash portion of cash and equivalents. In both cases, the time to return to the initial value of the real interest rate increases substantially.

Source: Authors' calculations.

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