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by José Dorich

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Abstract

I present a structural econometric analysis supporting the hypothesis that money is still relevant for shaping inflation and output dynamics in the United States. In particular, I find that real money balance effects are quantitatively important, although smaller than they used to be in the early postwar period. Moreover, I show three additional implications of the econometric estimates for monetary policy analysis. First, by including real money balance effects into the standard sticky price model, two stylized facts can be explained: the modestly procyclical real wage response to a monetary policy shock and the supply side effects of monetary policy. Second, the existence of real money balance effects causes higher volatility of output and lower volatility of interest rates under the optimal monetary policy. Third, the reduction in the size of real money balance effects can account for a significant decline in macroeconomic volatility.

JEL classification: E31, E32, E52
Bank classification: Business fluctuations and cycles; Monetary aggregates; Transmission of monetary policy

Résumé

L'auteur présente une analyse économétrique structurelle qui valide l'hypothèse selon laquelle la monnaie joue toujours un rôle pertinent dans l'évolution de l'inflation et de la production aux États-Unis. Il conclut en particulier à l'importance quantitative des effets d'encaisses réelles, bien que ceux-ci soient désormais moindres qu'au sortir de la guerre. Sur le plan de l'analyse de la politique monétaire, trois autres implications se dégagent des estimations économétriques obtenues. D'abord, l'intégration d'effets d'encaisses réelles dans un modèle type à prix rigides permet d'éclaircir deux faits stylisés : la réaction procyclique modérée des salaires à un choc de politique monétaire et les effets de la politique monétaire sur l'offre. Ensuite, l'existence d'effets d'encaisses réelles accentue la volatilité de la production, mais réduit celle des taux d'intérêt en contexte de politique monétaire optimale. Enfin, la diminution de l'ampleur des effets d'encaisses réelles est un facteur explicatif potentiel de la forte baisse de la volatilité à l'échelle macroéconomique.

Classification JEL : E31, E32, E52
Classification de la Banque : Cycles et fluctuations économiques; Agrégats monétaires; Transmission de la politique monétaire

1 Introduction

The standard New Keynesian (NK) model, commonly used in discussions about monetary policy analysis, assigns no role to money in the monetary transmission mechanism. In fact, the standard model is cashless. The widespread use of this type of model is justified by Woodford (2003) and Ireland (2004). Woodford argues that money does not play an important role in determining the equilibrium values of other economic variables because the central bank controls interest rates (without responding to money) and real money balance effects are not quantitatively important.[1] Woodford assesses the size of these effects to be very low after calibrating a money in utility function (MIU) model for the U.S. economy.[2] In addition, Ireland provides Maximum Likelihood (ML) estimates of a larger structural model that support Woodford's position regarding the negligible size of real money balance effects.

The previous conclusions stand in contrast to recent structural VAR evidence provided by Favara and Giordani (2009). They identify shocks to monetary aggregates by using restrictions suggested by the standard NK model. They find, contrary to predictions of the NK model, that money demand shocks have substantial and persistent effects on output and prices.

In this paper, I revisit the importance of real money balance effects by using a structural estimation approach that is different from those proposed by Woodford and Ireland. In particular, by employing the Generalized Method of Moments (GMM), I jointly estimate the Euler equation for consumption (IS curve) and the money demand (LM curve) derived from a MIU model that allows, but does not require, non-separable utility in consumption and real money. These equations reflect the optimizing behavior of households in the same manner as their counterparts in the models used by Woodford and Ireland.

[1] Real money balance effects exist when consumption (or aggregate demand) is directly influenced by the level of real money balances held by the private sector, for reasons that are independent of movements in interest rates that ordinarily accompany a change in real money supply. In a money in utility function framework, real money balance effects take place when utility is non-separable in consumption and real money.

[2] McCallum (2000) performs a different calibration exercise that leads to the same conclusion.

There are two important differences with respect to Woodford's approach. First, I jointly use the dynamics and the cross-equation restrictions that are present in the IS and LM curves in order to estimate the size of real money balance effects implied by the parameters of the model. This is in contrast to Woodford, who only uses the cross-equation restrictions and assigns values for the parameters in order to infer the quantitative importance of real money balance effects. Second, I use a broad measure of money (M2 instead of the monetary base). M2 includes all assets that provide liquidity services, and therefore better captures the value of money as a means of payment.[3]

With respect to Ireland's approach, the difference is that he estimates a larger system of equations, derived with more assumptions and involving more restrictions on the parameter space. For instance, besides the IS and LM curves that I estimate, his system of equations includes, among others, an aggregate supply (AS) curve. To introduce this equation, Ireland assumes a production function that is linear in labor, Rotemberg's (1982) price adjustment costs, flexible wages, constant marginal disutility of work, and no investment in the economy. With these additional assumptions, the specification of the AS curve implies cross-equation restrictions between the AS and IS curves. My econometric method does not involve these restrictions, and is therefore immune to potential misspecification in the AS curve.

The structural econometric analysis presented in this study shows that real money balance effects are still quantitatively important in United States, but smaller than they were in the early postwar period. Therefore, real money balances enter directly in aggregate demand, which implies that the specification of money demand is still relevant in determining inflation and output dynamics. Moreover, I use a standard sticky price model matching my econometric estimates to obtain three further implications for monetary policy analysis.[4] First, the modestly procyclical real wage response to a monetary policy shock and the supply side effects of monetary policy can be explained by the

[3]In Section 3.2, I explain the method for determining whether an asset furnishes liquidity services.

[4]The parameters of the IS and LM curves are set according to my econometric estimates. The rest of the model is calibrated according to standard values in the literature.

existence of quantitatively important real money balance effects.[5] Second, the optimal monetary policy implies higher volatility of output and lower volatility of the interest rate when there are real money balance effects. Third, the decline in the size of real money balance effects, which occurred in the beginning of the 1980´s, can explain a significant reduction in the volatility of output and inflation. By using the functional equivalence between the transaction cost model developed by Schmitt-Grohe and Uribe (2004) and the MIU model, I show that this last implication supports the hypothesis that financial innovation explains part of the Great Moderation in the United States.

The remainder of the paper is organized as follows. Section 2 presents the MIU model and describes the equilibrium conditions that determine the IS and LM curves that are estimated. It is shown that the size of real money balance effects is given by the elasticity of marginal utility of consumption with respect to real money divided by the coefficient of risk aversion. Section 3 presents the methodology and the econometric specification used in order to estimate the parameters that measure the magnitude of real money balance effects. The estimates, robustness exercises and a comparison between my estimation procedure and those of Woodford and Ireland are also presented in this section. Section 4 shows how the three additional implications of my econometric estimates are obtained. Section 5 concludes.

2 Money in Utility Function Model

In this section, I present briefly a slightly modified version of the model developed by Woodford (2003). The main goal is to show the log-linearized representation of the Euler equation (IS curve or aggregate demand) and money demand (LM curve) that are going to be used in the empirical part.

The representative household seeks to maximize the following expected discounted utility:

[5] There exist other explanations for these stylized facts. The most common explanation for the modestly procyclical real wage response after a monetary policy shock is the existence of sticky prices and sticky wages. The supply side effects of monetary policy are commonly explained with the cost channel of monetary transmission.

$$E_0 \left\{ \sum_{t=0}^{\infty} \beta^t \left[U(C_t, M_t/P_t; \xi_t) - V(H_t) \right] \right\} \quad (1)$$

where $0 < \beta < 1$ is a discount factor, C_t is the level of consumption of the economy's single good, M_t is the household's end-of-period money balances, P_t is the price of the single good in terms of money in period t, ξ_t is a disturbance in the liquidity services provided by money and H_t is the quantity of labor supplied (measured in hours). The period indirect utility is given by the sum of two functions: U and V. The function U is concave and strictly increasing in each of the arguments (consumption and real money balances). All these assumptions are consistent with the microfounded transaction cost model and shopping time model. Moreover, utility is allowed to be nonseparable in consumption and real money balances. However, the sign of the cross derivative U_{cm} is not assumed because the previous microfounded models do not provide it. If $U_{cm} = 0$, then utility is separable in consumption and money, and consequently there are no real money balance effects. It is also assumed that disturbances in liquidity services affect both the marginal utility of consumption and of money ($U_{c\xi} \neq 0$, $U_{m\xi} \neq 0$). Finally, the function V is an increasing and convex function that represents the disutility of labor.

Notice that it is assumed that the indirect utility function is separable with respect to labor.[6] This means that marginal utility of consumption and real money balances do not depend on labor. Therefore, as is shown later, labor affects neither the Euler equation nor the money demand equation directly.

The maximization of the expected utility is subject to an intertemporal budget constraint of the form:

$$\sum_{t=0}^{\infty} E_0 Q_{0,t} \left[P_t C_t + \Delta_t M_t \right] \leq A_0 + \sum_{t=0}^{\infty} E_0 Q_{0,t} \left[W_t H_t - T_t \right] \quad (2)$$

[6] This assumption is consistent with a microfounded transactions costs model, but not with a shopping time model.

where $\Delta_t = \frac{i_t - i_t^m}{1+i_t}$, i_t is the nominal interest rate paid on a riskless one period bond, i_t^m is the nominal interest rate paid on money balances held at the end of period t, A_0 is the initial level of wealth, W_t is the nominal wage per hour worked, and T_t represents net (nominal) tax collections by the government. Moreover, $Q_{0,t}$ is a stochastic discount factor that satisfies $Q_{0,0} = 1$ and $E_0 Q_{0,t} = \prod_{s=0}^{t-1} \frac{1}{1+i_s}$. It is also worth noting that the price of a riskless one period bond is given by:

$$\frac{1}{1+i_t} = E_t \left[Q_{t,t+1} \right] \tag{3}$$

The household's optimization problem is to choose processes C_t, M_t, $H_t \geq 0$ for all dates $t \geq 0$, satisfying (2) given its initial wealth A_0 and the good price, the nominal wage and the stochastic discount factors that it expects to face, so as to maximize (1).

The first order conditions associated with the household's problem are:

$$\frac{U_c(C_t, M_t/P_t; \xi_t)}{U_c(C_{t+1}, M_{t+1}/P_{t+1}; \xi_{t+1})} = \frac{\beta}{Q_{t,t+1}} \frac{P_t}{P_{t+1}} \tag{4}$$

$$\frac{U_m(C_t, M_t/P_t; \xi_t)}{U_c(C_t, M_t/P_t; \xi_t)} = \Delta_t \tag{5}$$

$$\frac{V_H(H_t)}{U_c(C_t, M_t/P_t; \xi_t)} = \frac{W_t}{P_t} \tag{6}$$

Equation (4) is a standard intertemporal optimality condition (Euler equation) whereas equations (5) and (6) are the optimality conditions for money demand and labor supply respectively. Using (3) and (4), I can rewrite the Euler equation as:

$$1 + i_t = \beta^{-1} \left\{ E_t \left[\frac{U_c(C_{t+1}, M_{t+1}/P_{t+1}; \xi_{t+1})}{U_c(C_t, M_t/P_t; \xi_t)} \frac{P_t}{P_{t+1}} \right] \right\}^{-1} \tag{7}$$

In order to conduct the empirical part of the paper, I just need to approximate conditions (7) and (5).[7] A log linear approximation to condition (7) is then given by:

$$E_t(\widehat{C}_{t+1} - \widehat{C}_t) = \frac{\chi}{\sigma_c^{-1}} E_t(\widehat{m}_{t+1} - \widehat{m}_t) + \frac{(\widehat{i}_t - E_t \widehat{\pi}_{t+1})}{\sigma_c^{-1}} + \frac{U_{c\xi}}{U_c \sigma_c^{-1}} E_t(\xi_{t+1} - \xi_t) \tag{8}$$

where $\widehat{C}_t = \log(\frac{C_t}{\overline{C}})$, $\widehat{m}_t = \log(\frac{m_t}{\overline{m}})$, $\widehat{i}_t = \log(\frac{1+i_t}{1+\overline{i}})$, $\widehat{\pi}_t = \log(\frac{P_t}{\overline{\pi} P_{t-1}})$, $\sigma_c = -\frac{U_c}{\overline{C} U_{cc}}$, $\chi = \frac{\overline{m} U_{mc}}{U_c}$ and $\overline{i}, \overline{C}, \overline{m}, \overline{\pi}$ are the steady state values of the nominal interest rate, consumption, real money balances and gross inflation respectively. Hats over variables indicate log deviations from trend or steady state.

Equation (8) represents the basis for building the aggregate demand block in most of the macroeconomic models that are used for monetary policy analysis. In fact, equation (8) combined with a market clearing condition that will be seen later completely defines the aggregate demand in a closed economy without capital. The parameter σ_c^{-1} is the coefficient of relative risk aversion. According to the assumptions I made on the utility function, it is strictly positive. The parameter χ is the elasticity of marginal utility of consumption with respect to real money. The importance of real money balance effects is given by the ratio $\frac{\chi}{\sigma_c^{-1}}$, which measures the effect of a one percent deviation of money from its steady state on the percentage deviation of consumption from its steady state. If this ratio is significantly different from zero, then real money directly affects aggregate demand, and consequently influences the equilibrium evolution of all the macroeconomic variables.

A corresponding log linear approximation to condition (5) is given by:

$$\widehat{m}_t = \eta_c \widehat{C}_t - \eta_i (\widehat{i}_t - \widehat{i}_t^m) + \left[\frac{U_{m\xi}}{U_m} - \frac{U_{c\xi}}{U_c} \right] \frac{1}{(\sigma_m^{-1} + \chi)} \xi_t \tag{9}$$

where $\eta_c = \frac{\frac{\overline{v}\chi}{\overline{\Delta}} + \sigma_c^{-1}}{\sigma_m^{-1} + \chi}$, $\eta_i = \left(\frac{1+\overline{i}^m}{\overline{i} - \overline{i}^m} \right) \frac{1}{\sigma_m^{-1} + \chi}$, $\widehat{i}_t^m = \log(\frac{1+i_t^m}{1+\overline{i}^m})$, $\sigma_m = -\frac{U_m}{\overline{m} U_{mm}}$, $\overline{v} = \frac{\overline{C}}{\overline{m}}$ and $\overline{v}, \overline{i}^m, \overline{\Delta}$ are the

[7] Condition (6) can also be log linearized and be taken into account when estimating real money balance effects. However, given that using (6) implies imposing the assumption of flexible wages, it is omitted so as to have econometric estimates that are immune to potential misspecification in the wage setting.

steady state values of money velocity, the nominal interest rate paid on money and the opportunity cost of holding money, respectively. The parameters η_c and η_i are the consumption elasticity and the interest semielasticity of money demand correspondingly. According to the assumptions on the utility function, both of them are strictly positive. The last term represents a money demand shock (given by a linear function of the disturbance on the liquidity services provided by real money balances). Finally, it is assumed that this disturbance has mean equal to zero and follows the autoregressive process:

$$\xi_t = \rho_\xi \xi_{t-1} + \eta_t \tag{10}$$

where η_t is an innovation with mean zero and serially uncorrelated. These assumptions on this disturbance and its innovation are consistent with the structure of the money demand shock that is assumed in the literature.[8]

In equilibrium all output must be consumed, thus implying a goods market clearing condition given by $\widehat{C}_t = \widehat{Y}_t$.[9] This condition could be used to write (8) and (9) as a function of the percentage deviation of output (instead of consumption) from its steady state. I consider this alternative in the empirical section of the paper.

3 New Estimates of Real Money Balance Effects

This section contains four parts. In the first one, I describe the econometric specification used to estimate jointly the Euler equation and money demand by applying the Generalized Method of Moments (GMM). In the second one, I present the data and baseline estimates of the model in order to determine how important real money balance effects are from a quantitative point of view. Two robustness exercises on the estimation process are presented in the third subsection. Finally, I make

[8] See Ireland (2004) and Bouakez et al. (2005).

[9] Notice that this condition also holds in steady state, which means that $\overline{C} = \overline{Y}$.

a comparison of my estimation procedure with those of Woodford (2003) and Ireland (2004) in order to understand the differences among them.

3.1 Econometric Specification

In order to employ the GMM technique, two orthogonality conditions are inferred from the model developed in the previous section. One is inferred by combining equations (8), (9) and (10) in the following way: first, by using (10), we can compute the last expectation term that is present in equation (8). Then, we have:

$$E_t\left(\xi_{t+1}-\xi_t\right) = E_t\left(\rho_\xi \xi_t + \eta_{t+1} - \xi_t\right) = -(1-\rho_\xi)\xi_t \tag{11}$$

Using (11) and (9), we can rewrite (8) in the following way:

$$E_t(\widehat{C}_{t+1}-\widehat{C}_t) = \frac{\chi}{\sigma_c^{-1}} E_t(\widehat{m}_{t+1}-\widehat{m}_t) + \frac{(\widehat{i}_t - E_t\widehat{\pi}_{t+1})}{\sigma_c^{-1}} - \frac{(1-\rho_\xi)\mu(\sigma_m^{-1}+\chi)v_t}{\sigma_c^{-1}} \tag{12}$$

where

$$\mu = \frac{\frac{U_{c\xi}}{U_c}}{\frac{U_{m\xi}}{U_m} - \frac{U_{c\xi}}{U_c}} \text{ and } v_t = \widehat{m}_t - \eta_c \widehat{C}_t + \eta_i(\widehat{i}_t - \widehat{i}_t^m)$$

The first orthogonality condition comes from equation (12), and follows from the fact that, under rational expectations, the forecast errors in consumption, real money and inflation one period ahead should be uncorrelated with the information set dated at period t and earlier. Then, this orthogonality condition is given by:

$$E_t\left\{\left[(\widehat{C}_{t+1}-\widehat{C}_t) - \frac{\chi}{\sigma_c^{-1}} E_t(\widehat{m}_{t+1}-\widehat{m}_t) - \frac{(\widehat{i}_t - E_t\widehat{\pi}_{t+1})}{\sigma_c^{-1}} + \frac{(1-\rho_\xi)\mu(\sigma_m^{-1}+\chi)v_t}{\sigma_c^{-1}}\right] z_t\right\} = 0 \tag{13}$$

where z_t denotes a vector of variables dated at period t and earlier.

The second orthogonality condition comes from equation (9) and (10). It follows from the properties of the innovation η_t. Under rational expectations, this innovation should be uncorrelated with earlier information. Then, the following orthogonality condition can be established:

$$E_t\left\{\left[\widehat{m}_t - \eta_c\widehat{C}_t + \eta_i(\widehat{i}_t - \widehat{i}^m_t) - \rho_\xi(\widehat{m}_{t-1} - \eta_c\widehat{C}_{t-1} + \eta_i(\widehat{i}_{t-1} - \widehat{i}^m_{t-1}))\right] z_{t-1}\right\} = 0 \qquad (14)$$

where z_{t-1} denotes a vector of variables dated at period $t-1$ and earlier.

The orthogonality conditions given by equations (13) and (14) constitute the basis for estimating the structural parameters of the model via GMM. Notice that there are eight structural parameters in the system: σ_c^{-1}, χ, $\bar{i}$, $\bar{i}^m$,$\bar{v}$, σ_m^{-1}, ρ_ξ and μ. They are not all simultaneously identifiable from the system. For this reason, three of them ($\bar{i}$, $\bar{i}^m$,$\bar{v}$) are calibrated to perform the estimation, because they are pinned down more directly from the first moments of the data.[10] I set them equal to their averages during the sample period. The rest of parameters are estimated.

Before performing the estimation, one econometric issue should be faced. In small samples, the way the orthogonality conditions are written (or normalized) affects the GMM estimates.[11] More specifically, there is no agreement about how to specify the orthogonality condition (13) in order to estimate $\sigma_c^{-1}$and χ, the set of parameters that measure the importance of real money balance effects. An alternative normalization for the moment restriction (13) is given by the following expression:[12]

$$E_t\left\{\left[\widehat{i}_t - \widehat{\pi}_{t+1} - \sigma_c^{-1}(\widehat{C}_{t+1} - \widehat{C}_t) + \chi(\widehat{m}_{t+1} - \widehat{m}_t) - (1-\rho_\xi)\mu(\sigma_m^{-1} + \chi)v_t\right] z_t\right\} = 0 \qquad (15)$$

Hansen and Singleton (1983) and Hall (1988) use normalization (13) and (15) respectively, without

[10] Given a definition of money, there is agreement about the definition of $\bar{i}$, $\bar{i}^m$,$\bar{v}$ in the model. In fact, all monetary models used for macroeconomic analysis set them equal to their averages during the sample period. This is not the case for the rest of parameters. For instance, the range of values used in calibration for σ_c^{-1} goes from 0.16 (Woodford (2003)) to 10 (the maximum level considered plausible by Mehra and Prescott (1985)).

[11] See Campbell (2003), Hamilton et al. (2005), Neely et al. (2001), and Yogo (2004).

[12] Notice that normalization (15) is obtained by multiplying the orthogonality condition (13) by σ_c^{-1}.

allowing for the existence of real money balance effects ($\chi = 0$) and the presence of money demand shocks ($\mu = 0$) in the Euler equation. Hansen and Singleton estimate the coefficient of relative risk aversion, whereas Hall estimates its reciprocal (the intertemporal elasticity of substitution). They find very different results, as surveyed in Neely et al. (2001) and confirmed by updated estimates performed by Campbell (2003).[13] In particular, the implied coefficient of relative risk aversion estimated by Hall is much higher than the one directly estimated by Hansen and Singleton. These two alternative specifications of the orthogonality conditions are thus taken into account in order to see how sensitive the results are to the normalization issue. Specification 1 considers equations (15) and (14) whereas specification 2 considers equations (13) and (14).

3.2 Data and Baseline Estimates

The data that I use is United States quarterly data and runs from the first quarter of 1959 through the fourth quarter of 2004. Consumption is measured by real personal consumption expenditures, real money balances are measured by dividing the M2 money stock by the CPI, inflation is measured by percentage changes in the CPI, the interest rate is measured by the three-month Treasury bill rate, expressed in quarterly terms and the interest rate paid on money is measured by the M2 money own rate, expressed in quarterly terms. Given this data, I set $\overline{v} = 0.29$ (M2 consumption velocity), $\overline{i} = 0.0136$ and $\overline{i}^m = 0.0091$. Consumption and real money balances are expressed in per capita terms, by dividing by the civilian noninstitutional population, aged 16 and over. Prior to estimation, the logarithm of per-capita consumption and per-capita real money balances were detrended by using a deterministic linear trend in order to get stationary series.[14]

M2 is used as a measure of money because it is the monetary aggregate that includes all the

[13] Campbell (2003) reports point estimates of 0.71 and 15 for the coefficient of relative risk aversion when he uses normalization (15) and (13), respectively. His point estimates comes from an estimation of the euler Equation only, without allowing the existence of real money balance effects.

[14] Alternative ways to detrend time series have been used in the literature. In this case, I follow the procedure presented in Ireland (2004).

assets that provide liquidity services. Given that it is clear that M1 furnishes these services, a way to show that M2 is the correct measure of money is by arguing that (M2-M1) also provides liquidity services. To test the latter, I check whether the opportunity cost of (M2-M1) is significantly different from zero. The intuition for this is as follows. $U_{m2-m1} > 0$ implies that (M2-M1) furnishes liquidity services and holds if and only if $\Delta_t = \frac{i_t - i_t^{m2-m1}}{1+i_t} > 0$. So, after computing the average own rate of return of (M2-M1) and comparing it with the average rate of return of the short term Treasury bond, I find that the average opportunity cost of holding (M2-M1) is 1 percent annually. Then, (M2-M1) provides liquidity services.[15]

INSERT TABLE 1

Table 1 presents the GMM estimation of the structural parameters σ_c^{-1}, χ, σ_m^{-1}, ρ_ξ and μ. It also shows the ratio $\frac{\chi}{\sigma_c^{-1}}$, which measures the importance of the real money balance effects, and the consumption elasticity (η_c) and interest semielasticity (η_i) of money demand implied by the estimated and calibrated parameters. The last column of the table reports the p-value for the Hansen's J statistic of overidentifying restrictions. The results are presented for the two specifications of the orthogonality conditions discussed earlier and two sets of instruments. Set 1 includes interest rate, inflation, real money balances, and consumption from $t-3$ to $t-6$. Set 2 includes the same variables but just until $t-5$. Standard errors (with a Newey West correction) for all the parameter estimates are reported in brackets.

Some interesting results arise from these estimations, which are robust to the specifications and to the set of instruments. First, real money balance effects are quantitatively important. In all the cases, the ratio is significantly different from zero and its point estimates are higher than 0.32. This result contrasts considerably with those provided by Woodford (2003) and Ireland (2004), who obtain

[15] Alternatively, Alvarez et al. (2003) decompose (M2-M1) into saving deposits, time deposits and retail money market funds. They conclude, by using the same type of analysis as above, that saving deposits and time deposits provide liquidity services whereas retail money market funds do not. So, their proposal of a monetary aggregate that provides liquidity services is M2 minus retail money market funds. However, it is difficult to argue that retail money market funds furnish no liquidity services. In fact, they are extremely liquid (most even checkable), and have essentially no default risk and no interest rate risk.

point estimates of 0.05 and 0.00 respectively for this ratio. Woodford uses a calibration procedure, whereas Ireland performs Maximum Likelihood estimation. A detailed comparison of their estimation methods with mine is presented in subsection 3.4. Second, the estimates of the coefficient of risk aversion are strictly positive and significantly different from zero in all cases. This result is consistent with the restriction I imposed theoretically on this parameter. Third, all the point estimates of the degree of risk aversion belong to the 95 percent confidence interval of this parameter provided by Campbell (2003). Without taking into account real money balance effects, he suggests values for this coefficient between -0.73 and 2.14 when instrumental variables and normalization 1 are used.

Fourth, the elasticity of marginal utility of consumption with respect to real money balances (the parameter χ) is significantly different from zero and strictly positive. This result implies that utility is not separable in consumption and money, and discards the possibility that this parameter could be negative.[16] Moreover, from the latter result and the fact that $\frac{\chi}{\sigma_c^{-1}}$ is significantly different from zero, it can be concluded that money plays an independent role in the monetary transmission mechanism. Fifth, both parameters of the money demand are also significantly different from zero. Sixth, the money demand shock is quite persistent. This result is consistent with those found by Ireland (2004, 2001) and Bouakez et al. (2005). Finally, the validity of all the regressions is confirmed by the p-value for the Hansen's J statistic of overidentifying restrictions with a significance level of 5 percent.

From Table 1, it is clear that real money balance effects are quantitatively important but the magnitude is not apparent. Under specification 1, the ratio $\frac{\chi}{\sigma_c^{-1}}$ is around 0.6, whereas under specification 2, it is around 0.3. The main reason behind this result is that the estimate of the degree of risk aversion is very sensitive to normalization in the GMM estimation. Using specification 1, the degree of risk aversion is close to 1; while in the second specification it is around 2.

Finally, there exist minor differences in the estimates of the elasticity of marginal utility of

[16] There are some microfounded models in which χ can be negative. See Wang and Yip (1992) for a detailed discussion.

consumption and in those of the interest rate semielasticity. The point estimates of χ are between 0.5 and 0.7; whereas those of η_i go from 6.0 to 9.0.[17] All the interest rate semielasticity estimates are in line with the money demand estimation performed by Reynard (2004) for the postwar period.[18]

3.3 Robustness Exercises

In this subsection, I perform two robustness exercises. First, I use the goods market clearing condition so that $\widehat{C}_t = \widehat{Y}_t$ and $\overline{C} = \overline{Y}$. Second, I check sub-sample stability.

3.3.1 Using GDP Data

Consumption is different from output in the data. However, I will assume that consumption equals output because many macroeconomic studies (e.g. Ireland (2004)) impose this condition in the estimation of macroeconomic models. Then, I specify the orthogonality conditions in the same manner as when consumption was used. Specification 1 considers equations (15) and (14) whereas specification 2 considers equations (13) and (14). Both specifications impose the requirement that consumption equals output. This also implies that some parameters change their definition in the equations as follows:

$$\sigma_c = \sigma_y = \frac{-U_y}{\overline{Y}U_{yy}},\ \chi = \frac{\overline{m}U_{my}}{U_y},\ \eta_c = \eta_y = \frac{\frac{\overline{v}\chi}{\Delta} + \sigma_y^{-1}}{\sigma_m^{-1} + \chi},\ v = \frac{\overline{Y}}{\overline{m}},\ \ \mu = \frac{\frac{U_{y\xi}}{U_y}}{\frac{U_{m\xi}}{U_m} - \frac{U_{y\xi}}{U_y}}$$

The frequency of the data and the sample period are the same as in the previous subsection. Now, output is measured by real GDP, real money balances are measured by dividing the M2 money stock by the GDP deflator, inflation is measured by changes in the GDP deflator and the interest rates are the same as before. Real GDP and real money balances are expressed in per capita terms,

[17] These point estimates for the interest semielasticity imply that the interest rate elasticity is between 0.085 and 0.121.

[18] He uses output and M2 minus instead of consumption and M2, respectively, in order to perform his money demand study.

by dividing by the civilian noninstitutional population, aged16 and over. Prior to estimation, the logarithm of per-capita real GDP and per-capita real money balances have been detrended by using a deterministic linear trend. Again, ($\bar{i}$, $\bar{i}^m$,$\overline{v}$) are calibrated and the rest of parameters are estimated. Given that I use data on output, $\overline{v} = 0.45$ in this case.

INSERT TABLE 2

Table 2 presents GMM estimates of the structural parameters σ_y^{-1}, χ, σ_m^{-1}, ρ_ξ and μ. It also shows the ratio $\frac{\chi}{\sigma_y^{-1}}$, and the income elasticity (η_y) and interest semielasticity (η_i) of money demand implied by the estimated and calibrated parameters. The results are presented for both specifications of the orthogonality conditions discussed earlier and two sets of instruments. Set 1 includes the interest rate, inflation measured by the percentage change in the GDP deflator, real money balances and output from $t-3$ to $t-6$. Set 2 includes the same variables but just until $t-5$. Standard errors (with a Newey West correction) for all the parameter estimates are reported in brackets.

Under both specifications, the estimates of the real money balance effects are statistically significant and much higher than those obtained when consumption is used. When specification 1 is used, the point estimates are between 1.2 and 1.3; while they are around 0.5 when the second normalization is used. Therefore, all this evidence implies that the result obtained in the baseline case is not driven by using consumption instead of output.

The parameter σ_y^{-1} measures the inverse of the interest sensitivity of real expenditure that is exclusively due to the interest rate channel.[19] The point estimates are strictly positive (as theory predicts) and statistically significant. When specification 1 is used, they are around 0.3. This value is small and very close to what has been found in other macroeconomic papers that estimate this parameter. Rotemberg and Woodford (1997) find that it is equal to 0.16 whereas Amato and Laubach

[19] When there are real money balance effects, a change in the interest rate affects aggregate demand through two channels: the interest rate channel and the real money balance effect channel. The former channel is the one by which interest rates impact the desired timing of private expenditures. The latter channel is the one by which a movement in the interest rates affects marginal utility of consumption through their impact on real money balances.

(2003) estimate it to be 0.26.[20] Under specification 2, the point estimates are much higher (around 1), and support the standard practice in macroeconomics of calibrating this value equal to one. It should also be noticed that the values obtained for the interest sensitivity of total output (σ_y) are higher than those found for the interest sensitivity of real consumption (σ_c).

When output is used instead of consumption, χ represents the elasticity of marginal utility of real income with respect to real money. All the point estimates for this parameter are statistically significant and very similar to those found when consumption was used. Therefore, the main conclusions related to this parameter do not change: utility is non-separable and χ is strictly positive. Moreover, it can be concluded that the increase in the estimates of real money balance effects when the goods market clearing condition is imposed are associated with the drop in σ_y^{-1}.

Both parameters of money demand are also significantly different from zero. According to three out of the four estimates, an income elasticity (η_y) of one cannot be rejected, which is consistent with several empirical studies of money demand. Furthermore, the point estimates of the interest rate semielasticity go from 3.4 to 5.4. All these values are plausible under the money demand estimation for the postwar period performed by Reynard (2004). He finds a point estimate of 10.4 for this parameter, with a standard error of 4.4.[21]

Finally, the last column of the table reports the p-value for the Hansen's J statistic of overidentifying restrictions, which confirms the validity of all the regressions with a significance level of 5 percent.

3.3.2 Sub-Sample Stability

In this subsection, I investigate whether the baseline estimates (those from Table 1) are sensitive to the sample period. In order to do this, I divide the full sample in two sub-samples: 1959:1-1979:4

[20] Both papers consider cashless sticky price models.

[21] He uses M2 minus and reports interest elasticity. The implicit interest semielasticities have been calculated by multiplying the interest elasticity by the inverse of the opportunity cost of the monetary base.

and 1980:1-2004:4. The beginning of the second sub-sample is chosen such that it coincides with the beginning of the sample used by Ireland (2001, 2004). This strategy allows a fair comparison of my estimates with his. Results are presented in Table 3 for both specifications of the orthogonality conditions and the instrument set 1.[22]

INSERT TABLE 3

The quantitative importance of real money balance effects is also confirmed by this exercise. Under both specifications, the ratio $\frac{\chi}{\sigma_c^{-1}}$ is positive and significantly different from zero across sub-samples. However, the point estimates are not constant across time. Prior to 1980, they are 0.85 and 0.74, while since 1980 they are 0.54 and 0.21. This result suggests that real money balance effects would have decreased its quantitative importance in the more recent period. However, the magnitude of the reduction in the size of real money balance effects is not apparent. Notice that the decrease with specification 2 is much higher than the one with specification 1.

Other interesting results arise from these estimations, which are robust to the specifications. First, the estimates of the coefficient of relative risk aversion and the elasticity of marginal utility of consumption are lower since 1980. Second, the reduction in the elasticity of marginal utility of consumption is the main factor driving the decrease in the size of real money balance effects. Third, the interest semielasticity has increased considerably since 1980. Fourth, the degree of persistence of the money demand shocks is higher in the recent period.

3.4 Previous Studies on Real Money Balance Effects: a comparison

The estimates of the size of real money balance effects differ dramatically from those obtained previously in the literature. To understand why this might be so, in this subsection I describe the estimation procedures performed by Woodford (2003) and Ireland (2004), and then, compare them with my procedure.

[22] Results are very similar when Set 2 is used.

Woodford, by using a calibration procedure and considering the goods market clearing condition, suggests a value of 0.05 for the size of real money balance effects. This result is obtained by setting $\sigma_y^{-1} = 0.16$ and $\chi = 0.008$. The former is calibrated using an estimate from the study performed by Rotemberg and Woodford (1997). To obtain a value for χ, he uses the following relation implied by the MIU model:

$$\frac{\eta_y}{\eta_i} = \frac{\frac{\overline{v}\chi}{\overline{\Delta}} + \sigma_y^{-1}}{\left(\frac{1+\overline{i}^m}{\overline{i}-\overline{i}^m}\right)} \tag{16}$$

He considers $\eta_y = 1$ and $\eta_i = 28$ from a long run money demand study performed by Lucas (2000). He also sets $\overline{v} = 4$ (monetary base velocity), $\overline{i}^m = 0$ and $\overline{i} = 0.01$.

There exist two important differences between Woodford's procedure and mine. First, the definition of money is different: monetary base versus M2. Second, the estimation approach is also different: calibration versus GMM. In order to illustrate how these two differences explain the discrepancy between my estimates and that given by Woodford, I perform two different calibration exercises, as shown in Table 4.

INSERT TABLE 4

Calibration 1 follows Woodford (2003) but changes only the definition of money for M2; and consequently, changes appropriately the money velocity and the interest rate semielasticity. This exercise shows how Woodford's conclusion on real money balance effects changes with the definition of money. It can be seen that the change is substantial. The magnitude of real money balance effects goes from 0.05 to 3.05. Therefore, the definition of money matters considerably. Calibration 2 just changes the degree of risk aversion used in Calibration 1 by assuming a value consistent with my econometric evidence, in order to see how GMM estimates make a difference. The size of real money balance effects again changes dramatically, going from 3.05 to 0.49 (a value that is very close to the average of all my baseline estimates). Therefore, the estimation approach also matters.

Ireland estimates a small macroeconomic model by ML, containing seven relations: an Euler equation, a M2 money demand equation, an AS curve, an interest rate rule, a process for a preference shock, a process for a money demand shock and a process for a technology shock. All these relations contain twenty parameters that he estimates by using quarterly data that run from 1980:1 through 2001:3. One of these parameters is $\frac{\chi}{\sigma_y^{-1}}$. Ireland estimates it equal to zero, with a standard error of 0.26. The point estimates of the determinants of this ratio were obtained in two different ways: σ_y^{-1} was calibrated and set equal to 1, whereas χ was estimated. Ireland argues that σ_y^{-1} was calibrated because preliminary attempts to estimate it, described in Ireland (2001), led to unreasonably high values for this parameter.

The difference with respect to Ireland´s procedure is that he estimates a larger model imposing three additional restrictions on the structure of the economy. The first constraint is that money should enter simultaneously in the AS and IS curves. To obtain this restriction, besides those assumptions that are necessary to derive the IS curve, he assumes a production function that is linear in labor, Rotemberg (1982) adjustment costs to set prices, flexible wages, constant marginal disutility of labor and no investment. The motivation to leave aside the AS curve in my estimation is based on the argument put forward by Galí and Gertler (1999) concerning the specification of the AS curve. They propose the following specification:

$$\pi_t = \frac{(1-\alpha)(1-\alpha\beta)}{\alpha}\widehat{mc}_t + \beta E_t \pi_{t+1} \tag{17}$$

with

$$\widehat{mc}_t = \widehat{w}_t - \widehat{mph}_t \tag{18}$$

where α is the probability of a firm not changing prices in a given period, mc_t is the average real marginal cost, w_t is the real wage and mph_t is the marginal product of labor. Notice that specifying the AS curve in this manner has two implications. First, money does not enter the AS curve. This is because Galí and Gertler do not replace the real wage with that derived from the labor supply with flexible wages, which is equal to the marginal disutility of labor divided by the marginal utility of consumption. Second, there are no cross equation restrictions between the AS and the IS and LM curves. Therefore, adding the AS curve to my system of equations in the way Galí and Gertler propose does not affect my GMM estimates.

The second constraint comes from the ML estimation method that Ireland uses. This procedure requires that the parameter estimates satisfy the determinacy of the equilibria. Therefore, how the monetary policy rule is specified affects the econometric estimates. In contrast, my estimates are invariant to the specification of the policy rule. The reason is that there are no cross equation restrictions between the equations I estimate and the rule.

The last constraint is imposed over the shocks of the model. Ireland assumes that they follow a normal distribution in order to obtain the likelihood function. My approach does not impose the normality assumption over the money demand shock that is present in the equations. It is assumed that this shock is orthogonal to past information (instruments) in order to derive the orthogonality conditions used to obtain the objective function that my GMM estimates minimize. Therefore, the different assumptions over the shocks determine different objective functions, and consequently, different estimates.

Unfortunately, it is not possible to quantify the differences between the approach used in this study and that used by Ireland. This is because Ireland's approach requires using all the constrains simultaneously, given that he uses a full information procedure. Therefore, the differtent results reflect that the additional constraints Ireland imposes importantly affect the econometric estimates. If these additional constraints are right, Ireland's estimates are more efficient. However, if one of these constraints is false, then Ireland's estimates are inconsistent, whereas mine remain consistent. Consequently, there is a trade off: imposing more restrictions can improve efficiency, but consistency may potentially be lost.

4 Implications of my Findings

The econometric estimates presented in the previous section suggest that real money balance effects are quantitatively important, but lower than they used to be in the beginning of the 1980´s. Given the model used to evaluate the existence of real money balance effects, the results imply that utility is non-separable in consumption and real money balances. Therefore, money plays a direct role in determining the dynamic behavior of inflation and output.

In this section, using a sticky price model that allows for non-separable utility in consumption and real money balances, I obtain and analyze three additional implications of my estimates. The derivation of this model can be found in Woodford (2003). Besides the IS and LM curves presented in section 2, the model includes an AS curve, an equation for real wages and an interest rate rule. The parameters in the IS and LM curves are calibrated according to my econometric estimates, while the rest of parameters are calibrated according to standard values in the literature.

The implications are the following. First, the existence of quantitatively important real money balance effects is a possible explanation for two stylized facts: the modestly procyclical real wage response to a monetary policy shock, and the supply side effects of monetary policy. Second, conditional on productivity and money demand shocks, much higher volatility of output and much lower volatility of the interest rate should arise under the optimal monetary policy when there exist real money balance effects of the magnitude estimated in this study. Third, the reduction in the size of real money balance effects can account for much of the decrease in the volatility of inflation and output.

4.1 The Model

In this subsection, I present all the equations necessary to obtain the implications. All equations are log-linearized around a zero inflation steady state. Moreover, the calibration of the model is presented.

4.1.1 Equations

a) IS Curve:

$$E_t(\widehat{Y}_{t+1} - \widehat{Y}_t) = \frac{\chi}{\sigma_c^{-1}} E_t(\widehat{m}_{t+1} - \widehat{m}_t) + \frac{1}{\sigma_c^{-1}}(\widehat{i}_t - E_t\pi_{t+1}) \tag{19}$$

where π_t is inflation in period t and the rest of variables and parameters are defined as in section 2.

b) Money Demand:

$$\widehat{m}_t = \eta_c \widehat{Y}_t - \eta_i \widehat{i}_t + \xi_t \tag{20}$$

where ξ_t is a money demand shock that follows an autoregressive process of the form:

$$\xi_t = \rho_\xi \xi_{t-1} + \eta_t \tag{21}$$

where η_t is an i.i.d. mean zero innovation with variance σ_η^2.

c) AS Curve:

$$\pi_t = \frac{(1-\alpha)(1-\alpha\beta)}{\alpha(1+(\omega_w+\omega_p)\theta)} \widehat{mc}_t + \beta E_t \pi_{t+1} \tag{22}$$

with

$$\widehat{mc}_t = (\omega_w + \omega_p + \sigma_c^{-1} - \eta_c\chi)x_t + \eta_i\chi\widehat{i}_t \tag{23}$$

where $\widehat{mc}_t$ is the average real marginal cost and x_t is the output gap; the latter being defined as the difference between actual output $(\widehat{Y}_t)$, and the natural level of output $(\widehat{Y}_t^n)$.[23] Moreover, α is the probability of a good price remaining unchanged, β is the discount factor, θ is the elasticity of

[23]Natural output in the presence of real money balance effects is defined as in Woodford (2003). In particular, it is the equilibrium level of output at each point in time that would prevail under flexible prices, given a monetary policy that maintains $i_t = \bar{i}$.

demand, ω_w is the elasticity of marginal disutility of work with respect to output, and ω_p is the negative of the elasticity of marginal product of labor with respect to output. Equations (22) and (23) are derived assuming monopolistic competition, sticky prices a la Calvo (1983), and flexible wages.

d) Natural Output:

$$\widehat{Y}_t^n = \frac{1 + \omega_w + \omega_p}{\omega_w + \omega_p + \sigma_c^{-1} - \eta_c \chi} \widehat{A}_t + \frac{\chi}{\omega_w + \omega_p + \sigma_c^{-1} - \eta_c \chi} \xi_t \tag{24}$$

where $\widehat{A}_t$ represents the log deviation of the technology factor from its steady state level. This factor follows an autoregressive process of the form:

$$\widehat{A}_t = \rho_a \widehat{A}_{t-1} + \varsigma_t \tag{25}$$

where ς_t is an i.i.d mean zero technology shock with variance σ_ς^2.

e) Interest Rate Policy Rule:

$$\widehat{i}_t = \bar{i}_t + \phi_\pi \pi_t + \phi_x x_t \tag{26}$$

where $\phi_\pi > 0, \phi_x > 0$ and $\bar{i}_t$ is a monetary policy disturbance with the following process:

$$\bar{i}_t = \rho_i \bar{i}_{t-1} + \varepsilon_t \tag{27}$$

where ε_t is an i.i.d mean zero shock.

f) Equation for Real Wages:[24]

$$\widehat{w}_t^r = (\omega_w + \sigma_c^{-1}) \widehat{Y}_t - \chi \widehat{m}_t - \omega_w \widehat{A}_t \tag{28}$$

[24] It is implied by the solution of the model. It is not assumed ad hoc.

where $\widehat{w}_t^r$ is the real wage.

4.1.2 Calibration

The calibrated parameters of the model are:

$$\sigma_c^{-1} = 1,\ \chi = 0.48,\ \eta_c = 1,\ \eta_i = 7,\ \beta = 0.99,\ \ \theta = 11,\ \ \omega_w = 0.09,\ \ \omega_p = 0.38,\ \alpha = 0.75,$$

$$\phi_\pi = 3.0,\ \phi_x = 0.5,\ \rho_\xi = 0.96,\ \rho_a = 0.95,\ \rho_i = 0.7,\ \sigma_\eta = 0.0104,\ \sigma_\varsigma = 0.0071,\ \sigma_\varepsilon = 0.0025$$

According to the baseline estimates, the size of the ratio $\frac{\chi}{\sigma_c^{-1}}$ can take four values: 0.33, 0.38, 0.59 and 0.61. For illustrative purposes, I explore a calibration that sets the size of the real money balance effects equal to the mean of all these possible values. The coefficient of risk aversion is set equal to 1, from which it follows that $\chi = 0.48$. The values assigned to the parameters of money demand are consistent with my econometric estimates and with other studies, as I discussed in section 3. The value for θ implies a markup of 10 percent and is taken from Galí et al. (2001). The parameter ω_p is obtained by means of the following procedure. I assume a Cobb Douglas aggregate production function of the form $F(H) = H^\lambda$. Given this production function, $\omega_p = \lambda^{-1} - 1$. Then, using the fact that λ is equal to the markup times the labor share (from the first order conditions of the firm), $\omega_p = (1.1 \times 0.66)^{-1} - 1 = 0.38$. The value for α is consistent with the macro study performed by Galí and Gertler (1999), and implies that prices are fixed for four quarters. This period length is close to the average price duration found with microeconomic evidence.[25] The coefficients of the interest rate rule are the standard ones of a Taylor rule, except for ϕ_π, which is higher than the traditional value of 1.5.[26] The parameter ω_w is picked by assuming a value of 0.47 for the elasticity of real marginal cost with respect to output, which is taken from Rotemberg and Woodford (1997).[27] The calibration of

[25] See Nakamura and Steinsson (2008).

[26] It is set equal to 3.0 in order to have a determinate equilibrium.

[27] In this model, the elasticity of real marginal cost with respect to aggregate output is equal to $\omega_w + \omega_p + \sigma_c^{-1} - \eta_c\chi$.

the persistence of the technology factor and the standard deviation of its innovation is the standard one in the Real Business Cycle literature. The degree of persistence of the money demand shock and the standard deviation of its innovation are calibrated according to my money demand estimates. The persistence of the monetary policy disturbance is calibrated by following Woodford (2003). Finally, the standard deviation of the innovation to the monetary policy disturbance is taken from Ireland (2004).

4.2 The Modestly Procyclical Real Wage Response to a Monetary Policy Shock

It is a stylized fact that there is a very modest response of real wages relative to that of output after a monetary policy shock. Studies developed by Altig et al. (2004) and Christiano et al. (2005) support this stylized fact by using an impulse response function derived from a structural VAR. The most common explanation for this is the existence of sticky prices and sticky wages.[28] In this section, I show that this stylized fact can also be explained without sticky wages and with real money balance effects.

INSERT FIGURE 1

Figure 1 displays the response of real wage and output to a contractionary monetary policy shock, given $\chi = 0.48$. The solid line represents the response of output whereas the dashed line represents the response of real wage. The real wage response is much lower than that of output, as the VAR studies show. Furthermore, the difference between these two responses is increased significantly by the addition of real money balance effects.

INSERT FIGURE 2

Figure 2 displays the responses when there are no real money balance effects, and it is clear that

[28] See Woodford (2003).

the difference between the responses is much lower in this case. In particular, when there are no such effects, the response of real wages is slightly higher than that of output. The difference between Figures 1 and 2 is explained by two facts: real wage responds more and output responds less when there are no real money balance effects. Then, I can conclude that the existence of such effects, when quantitatively significant, may offer an explanation for the very modest response of real wages relative to output after a monetary policy shock.

The intuition behind my result is as follows. After a contractionary monetary policy shock, in a model with real money balance effects, both labor demand and labor supply move in the same direction. On the one hand, the monetary contraction reduces the demand for an industry's output, which means that firms respond by lowering their output and consequently labor demand. On the other hand, it increases the opportunity cost of holding money, and hence diminishes real money holdings. Ceterib paribus, this decreases the marginal utility of consumption (given that marginal utility of consumption depends positively on real money balances), and therefore increases the real wage asked by labor suppliers.[29] The latter means that there is also a reduction in labor supply. Then, the impact of monetary policy is basically on average hours worked (and consequently on output), and not on real wages, given the calibration I propose.

4.3 The Supply Side Effects of Monetary Policy

Barth and Ramey (2001) show empirically that a monetary policy shock can affect inflation and output also through the supply side. These effects are commonly explained with the cost channel of monetary transmission, which is present when firms' marginal cost depends directly on the nominal interest rate.[30] In a general equilibrium model, this channel is usually incorporated by assuming that firms must borrow money to pay their wage bill. The need to borrow introduces an additional

[29] Notice that labor supply is given in this model by $\frac{W_t}{P_t} = \frac{V_H(H_t)}{U_c(Y_t, m_t)}$.

[30] See Barth and Ramey (2001).

component to the cost of labor. In this setting, the marginal cost of hiring labor is the real wage multiplied by the gross nominal interest rate. So, when the interest rate increases, so too does the marginal cost of hiring and, hence, inflation. Notice also that the supply side effects of monetary policy are associated with a shift in the labor demand after a monetary policy shock. In this section, I claim that these effects can be due to the existence of real money balance effects. In addition, I show that the supply side effects in this case are associated with shifts in labor supply.

The aggregate supply curve, when real money balance effects exist, is given by equations (22) and (23). By combining these, it can be shown that inflation is not only affected by the output gap but also by the interest rate through the term $\frac{(1-\alpha)(1-\alpha\beta)}{\alpha(1+(\omega_w+\omega_p)\theta)}\eta_i\chi\widehat{i}_t$. In this way, the model with real money balance effects generates supply side effects. The mechanism by which these effects arise is as follows. An increase in the interest rate raises the opportunity cost of holding money, and consequently, reduces real money holdings. This decreases the marginal utility of consumption (as it depends positively on real money balances), and consequently, increases the real wage asked by labor suppliers. This implies that real marginal cost increases, and thus also, inflation and the price index. It should be noted that the total effect on inflation after an increase in the interest rate is negative in the model I present. This means that the traditional demand side effects are more important than the supply side effects.

4.4 The Impact of Real Money Balance Effects on the Design of Optimal Monetary Policy

In this subsection, I examine the implications of real money balance effects for optimal monetary policy analysis. In particular, I show how optimal volatility of the economic variables change when real money balance effects are taken into consideration.

In order to characterize the optimal policy solution, I assume full commitment of the monetary authority and a non distorted steady state. Under these assumptions, Woodford (2003) shows that the optimal policy problem can be written as:

$$Min \sum_{t=0}^{\infty} \beta^t L_t + t.i.p$$

where $L_t = \pi_t^2 + \lambda_x x_t^2 + \lambda_i \widehat{i}_t^2$ is the quadratic period loss function with the weights (λ_x and λ_i respectively) expressed by the following formulas:[31]

$$\lambda_x = \frac{(1-\alpha)(1-\alpha\beta)(\omega_w + \omega_p + \sigma_c^{-1} - \eta_c \chi)}{\alpha\theta(1 + (\omega_w + \omega_p)\theta)}, \quad \lambda_i = \frac{(1-\alpha)(1-\alpha\beta)\eta_i}{\alpha\theta(1 + (\omega_w + \omega_p)\theta)\overline{v}}$$

Before solving this problem, it is convenient to make some comments on these weights. First, when the economy is cashless, $\overline{v}$ goes to infinity; and, therefore, the weight on the interest rate goes to zero. This is the standard case in which the optimal volatility of inflation and output gap is zero. Second, when money is introduced in the analysis through separable utility in consumption and real money, λ_i is not equal to zero. Therefore, there exists a trade-off between stabilizing inflation and the interest rate. Third, by considering non-separable utility (χ different from zero), the weight on the output gap diminishes, compared to the case of separable utility.

The optimal monetary policy problem should be solved subject to the constraints imposed by the model without the interest rate rule. The solution to this problem is found using a numerical procedure. By using 100 simulations of 100 years period length, the optimal volatility of the main economic variables is computed under two different scenarios ($\chi = 0.48$ and $\chi = 0$).

Table 5 presents the simulated standard deviations of the economic variables. The following results emerge. First, when utility is non-separable, the optimal volatility of output and real money balances is much higher. The intuition for this result is as follows. The introduction of non-separability in the utility function decreases the importance of output gap stabilization in favor of inflation and

[31] The abbreviation *t.i.p.* in the objective function stands for terms independent of policy.

interest rate stabilization. This also translates to higher volatility of output. Furthermore, since output affects money through the money demand equation, the volatility of real money increases as well. Second, the optimal volatility of the interest rate and real wages is lower. Third, the existence of real money balance effects does not affect significantly the optimal volatility of inflation. Fourth, notice that in the case of separable utility, the optimal volatility of inflation is not zero because money is in the utility function. In this case, as mentioned before, there exists a trade-off between stabilizing inflation and the interest rate. Clearly, this trade-off is solved in favor of inflation stabilization.

INSERT TABLE 5

4.5 The Reduction in the Size of Real Money Balance Effects, Greater Macroeconomic Stability and Financial Innovation

Since 1984, the U.S. economy and other industrialized economies have experienced a substantial decline of macroeconomic volatility. This phenomenon is known in the literature as "the Great Moderation". There exist many potential explanations for this phenomenon. Galí and Gambetti (2007) classify all of them into two groups. The first one suggests that the greater macroeconomic stability is due mainly to smaller shocks hitting the economy (good luck hypothesis). The second group attributes the reduction in macroeconomic volatility to changes in the structure of the economy and/or in the way policy has been developed. Three explanations can be distinguished in this group: better monetary policy (Clarida et al. (2000)), improved inventory management (Khan et al. (2002)) and financial innovation (Dynan et al. (2006)).

In this subsection, I show that the decrease in the size of real money balance effects can explain a significant fraction of the reduction in inflation and output volatility. In addition, I argue that this result supports financial innovation as a source of the Great Moderation. In order to illustrate the first point, I analyze the behavior of the model described in subsection 4.1, but assuming two different structures of the economy that only differ in the values of χ and η_i. The first one (which I refer to as Pre-1984 calibration) assumes that $\chi = 0.80$ and $\eta_i = 4.2$; while the second one (which I refer to Post-1984 calibration) sets $\chi = 0.38$ and $\eta_i = 8.8$. These two different structures are chosen such that the reduction in real money balance effects is consistent with my econometric estimates. The sub-sample stability analysis presented in section 3 suggests that the size of real money balance effects has decreased mainly due to a reduction in the elasticity of marginal utility of consumption with respect to real money balances. This is why the risk aversion coefficient is kept constant at 1 and the elasticity of marginal utility of consumption with respect to money is changed across the two calibrations (or periods). Additionally, in order to fit the cross equation restriction imposed by the MIU model (equation 16), a change in the elasticity of marginal utility of consumption with respect to money requires an adjustment of the interest rate semielasticity, given that the rest of parameters remain constant. This explains why it rises from 4.2 to 8.8.

INSERT TABLE 6

Table 6 presents the standard deviation of inflation and output generated by the model, considering the two different structures of the economy (one before 1984 and the other one after 1984). The Pre- 1984 volatilities are normalized to 1 in order to facilitate comparison. It can be seen that the reduction in the size of real money balance effects can account for 89 percent of the decline in output volatility and 50 percent of the decline in inflation volatility. This result suggests that the decrease of real money balance effects can explain quite well the reduction in output volatility, but that other explanations, such as better monetary policy, are necessary to fully explain the reduction of inflation volatility.

From previous analysis, and by a direct interpretation of the MIU model, it could seem that the decrease in the elasticity of marginal utility of consumption with respect to money is an alternative source of the Great Moderation. I claim that this is not the most appropriate way to understand the results driven by the previous simulation. As Walsh (2003) points out, the MIU approach has to be thought of as a shortcut for a fully specified model of the transactions technology faced by households that gives rise to a positive demand for money. Instead, the reduction in the size of real money balance effects should be interpreted as a result of the financial innovation that took place in U.S. in the early 1980's. In order to support this argument, I use the functional equivalence between the transaction cost model developed by Schmitt-Grohé and Uribe (2004) and the MIU model. By using this equivalence, χ can be expressed as:

$$\chi = \frac{\overline{v}(2s'(\overline{v}) + \overline{v}s''(\overline{v}))}{1 + s(\overline{v}) + \overline{v}s'(\overline{v})}$$

where $s(\overline{v})$ represents a transaction cost that is proportional to consumption purchases, $s'(\overline{v})$ denotes the first derivative of the transaction cost function with respect to money velocity and $s''(\overline{v})$ represents the second derivative of the same function. Given the previous expression, a plausible story that can explain the decrease in χ is a financial innovation that affects the transaction cost function in such a way as to generate a reduction in this parameter. Therefore, this analysis provides formal support to that developed by Dynan et al (2006), where they conclude that financial innovation is an important source of the greater stability in the economy.

5 Concluding Remarks

GMM joint estimation of the IS and LM curves, derived from a small structural MIU model, indicates that real money balance effects, arising from non-separable utility in consumption and real money, are still quantitatively important. This finding is consistent with recent structural VAR evidence found by Favara and Giordani (2009). However, it contrasts considerably with the results of previous studies by Woodford (2003) and Ireland (2004).

My estimation approach differs from the one used by Woodford in two respects. First, I use both the dynamics and the cross equation restrictions present in the IS and LM curves. Instead, Woodford only uses the cross equation restrictions. Second, I use a broader definition of money. With respect to Ireland's approach, the difference is that he estimates a larger model imposing the following three constraints on the structure of the economy that I do not employ. First, money enters simultaneously in the IS and AS curve. Second, equilibrium determinacy holds. Third, shocks follow a normal distribution.

A sub-sample stability analysis suggests that the size of real money balance effects is still significant but lower than it used to be before the beginning of the 1980´s. The main factor underlying of this reduction seems to be the decrease of the elasticity of marginal utility of consumption with respect to money. By using a functional equivalence between the MIU model and the transaction cost model developed by Schmitt-Grohé and Uribe (2004), it has been shown that the decrease in this elasticity can be interpreted as a change in the transaction cost technology that diminishes the importance of real money balances in the determination of consumption or aggregate demand.

There are four important implications of the econometric estimates for monetary policy analysis. First, money is not redundant in order to determine the evolution of inflation and output. Second, the existence of quantitatively important real money balance effects in a model with sticky prices and flexible wages can explain two stylized facts: the modestly procyclical real wage response to a monetary policy shock and the supply side effects of monetary policy. Third, the optimal monetary policy changes in the presence of real money balance effects of the magnitude estimated in this study. In particular, higher volatility of output and lower volatility of interest rate should be attained. Fourth, the reduction in the size of real money balance effects can account for a significant reduction in the volatility of inflation and output. By using the functional equivalence between the MIU model and the transaction cost model developed by Schmitt-Grohe and Uribe (2004), it has been shown that the last implication supports the view that financial innovation, through a technological progress in the transaction technology, could have been a source of the Great Moderation.

Finally, this paper uses the MIU approach in the estimation process for the following reason.

Given that the conclusion that real money balance effects play a minimal role in the monetary business cycle was derived by using this model and two different structural estimation techniques, the use of the same model allows a clear and direct comparison of my analysis with those of previous studies. Nonetheless, the MIU model has to be thought of as shortcut of a fully specified model of transaction technology. In this sense, the evidence provided in this paper suggests it would be worth exploring the development of models that provide plausible and clear stories that generate the MIU model with non-separable utility in consumption and real money balances. So far, there exist microfounded models that provide a framework to show that the evolution of the size of real money balance effects, arising from non-separable utility, is related to the evolution of the transaction technology. However, none of these models provides a clear understanding of how to link the transaction technology (in the form of a transaction cost function, for instance) with the transaction frictions we observe in reality.

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*Table*1

Estimates of the Structural Parameters : 1959 − 2004

Specification 1 :

	σ_c^{-1}	χ	σ_m^{-1}	$\frac{\chi}{\sigma_c^{-1}}$	η_c	η_i	ρ_ξ	μ	*J test*
Set 1	0.82	0.48	37.27	0.59	0.85	5.95	0.96	−0.03	0.36
	(0.24)	(0.09)	(6.19)	(0.12)	(0.15)	(0.98)	(0.01)	(0.01)	
Set 2	0.84	0.51	36.10	0.61	0.93	6.14	0.96	−0.03	0.08
	(0.30)	(0.11)	(8.56)	(0.16)	(0.18)	(1.45)	(0.01)	(0.01)	

Specification 2 :

	σ_c^{-1}	χ	σ_m^{-1}	$\frac{\chi}{\sigma_c^{-1}}$	η_c	η_i	ρ_ξ	μ	*J test*
Set 1	1.97	0.75	30.89	0.38	1.61	7.10	0.97	0.07	0.59
	(0.33)	(0.16)	(6.37)	(0.06)	(0.18)	(1.46)	(0.01)	(0.05)	
Set 2	1.76	0.58	23.60	0.33	1.64	9.29	0.97	0.09	0.25
	(0.33)	(0.14)	(5.70)	(0.07)	(0.23)	(2.24)	(0.01)	(0.07)	

Note : *Standard errors shown in brackets.*

Table 2

Estimates of the Structural Parameters : 1959 − 2004

(*Employing the Market Clearing Condition*)

Specification 1 :

	σ_y^{-1}	χ	σ_m^{-1}	$\frac{\chi}{\sigma_y^{-1}}$	η_y	η_i	ρ_ξ	μ	*J test*
Set 1	0.28	0.36	52.23	1.27	0.70	4.27	0.96	−0.02	0.52
	(0.14)	(0.07)	(10.19)	(0.54)	(0.12)	(0.83)	(0.01)	(0.01)	
Set 2	0.31	0.37	41.33	1.19	0.90	5.39	0.96	−0.03	0.24
	(0.16)	(0.07)	(9.52)	(0.37)	(0.18)	(1.24)	(0.02)	(0.02)	

Specification 2 :

	σ_y^{-1}	χ	σ_m^{-1}	$\frac{\chi}{\sigma_y^{-1}}$	η_y	η_i	ρ_ξ	μ	*J test*
Set 1	1.03	0.56	65.14	0.54	0.88	3.42	0.95	−0.01	0.69
	(0.12)	(0.12)	(16.05)	(0.10)	(0.12)	(0.84)	(0.01)	(0.01)	
Set 2	1.05	0.50	50.12	0.47	1.02	4.44	0.96	−0.01	0.33
	(0.17)	(0.12)	(15.83)	(0.16)	(0.16)	(1.40)	(0.02)	(0.01)	

Note : *Standard errors shown in brackets.*

Table 3

Sub − sample stability

Specification 1 :

Period	σ_c^{-1}	χ	σ_m^{-1}	$\frac{\chi}{\sigma_c^{-1}}$	η_c	η_i	ρ_ξ	μ	J test
1959–	0.87	0.73	45.55	0.85	1.05	4.85	0.94	−0.05	0.97
1979	(0.12)	(0.06)	(3.16)	(0.09)	(0.06)	(0.34)	(0.01)	(0.01)	
1980–	0.54	0.29	19.79	0.54	0.98	11.19	0.98	0.04	0.84
2004	(0.13)	(0.05)	(2.66)	(0.14)	(0.13)	(1.50)	(0.01)	(0.03)	

Specification 2 :

Period	σ_c^{-1}	χ	σ_m^{-1}	$\frac{\chi}{\sigma_c^{-1}}$	η_c	η_i	ρ_ξ	μ	J test
1959–	2.09	1.53	84.63	0.74	1.19	2.61	0.92	−0.02	0.97
1979	(0.24)	(0.21)	(11.13)	(0.05)	(0.07)	(0.34)	(0.01)	(0.01)	
1980–	1.81	0.38	17.24	0.21	1.50	12.76	0.98	0.33	0.88
2004	(0.39)	(0.06)	(2.24)	(0.05)	(0.12)	(1.66)	(0.01)	(0.15)	

Note : Standard errors shown in brackets.

Table 4

Calibration of Real Money Balance Effects

	Woodford	*Calibration1*	*Calibration2*
σ_y^{-1}	0.16	0.16	1.00
χ	0.01	0.49	0.49
η_y	1.00	1.00	1.00
η_i	28.00	6.92	6.54
$\overline{v}$	4.00	0.29	0.29
$\frac{\chi}{\sigma_y^{-1}}$	0.05	3.05	0.49

Table 5

Standard Deviations

(*In percentages*)

	Separable Utility	*Non − Separable Utility*
Inflation 1/	0.01	0.02
Output	2.36	4.15
Interest Rate 1/	0.46	0.33
Real Wage	2.36	1.93
Real Money	5.10	7.05

1/ *Standard deviation expressed in annual terms.*

Table 6

Changes in Volatility 1/

	Calibrated Model		*Data*	
	Pre 1984	*Post* 1984	*Pre* 1984	*Post* 1984
Inflation	1.00	0.71	1.00	0.41
Output	1.00	0.52	1.00	0.46

1/ *Standard deviations in the Pre* 1984 *period are normalized to* 1.

Figure 1: Response of Output and Real Wage when $\chi = 0.48$

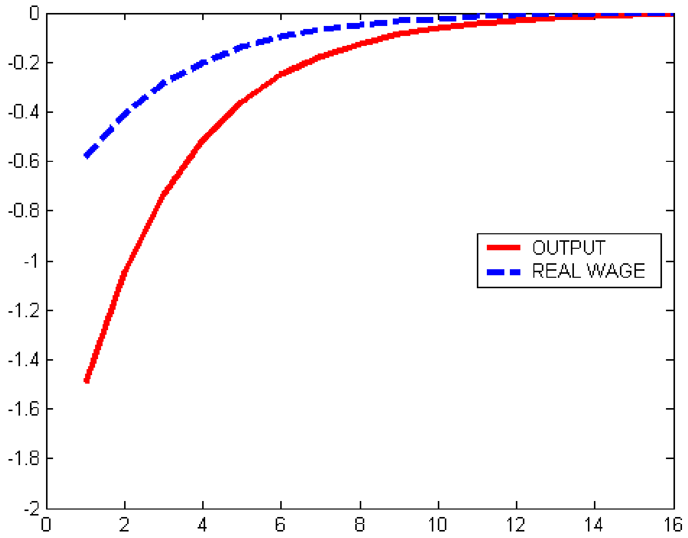

Figure 2: Response of Output and Real Wage when $\chi = 0$