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On the Redistributive Effects of Inflation: an International Perspective*

Paola Boel[†]

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Abstract

I calibrate the microfounded model in Boel and Camera (2009) to quantify the redistributive effects of inflation for a sample of OECD countries. In doing so, I address two important quantitative issues. First, using harmonized microdata from the *Luxembourg Wealth Study*, I provide an international comparison of the distribution of households' deposit accounts and financial assets. Second, I account for structural breaks when estimating money demand. I find that several results hold for the countries considered. First, the welfare cost of inflation changes over time, but the direction of the change varies across countries. Second, inflation acts as a regressive tax when a nominal asset other than money is held. Third, the magnitude of the redistributive effects differs across countries and it depends not only on wealth inequality, but also on the curvature and the level of the money demand curve. Last, I show that a subset of the population always prefers an inflationary policy when I extend the model to incorporate a political-economy equilibrium where agents can bargain over the inflation rate.

Keywords: Money, Heterogeneity, Friedman Rule, Welfare Cost of Inflation, Calibration

JEL codes: E4, E5

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1 Introduction

Several studies have shown that the redistributive effects of inflation depend on the size and on the composition of wealth, both of which vary across income levels. Among them, Erosa and Ventura (2002) show that inflation acts as a regressive tax in the United States, where the fraction of household wealth held in liquid assets decreases with income. Boel and Camera (2009) find a similar result in a microfounded model of money. The stream of literature with explicit microfoundations for money, however, has so far neglected to assess quantitatively the redistributive effects of inflation in countries other than the United States or Canada.¹ This paper constitutes a first step in addressing this matter for a wider sample of OECD countries.

The issue is non trivial for several reasons. First, any rigorous analysis of it must be based on comparable estimates of wealth distribution across countries. Such comparisons have been unreliable in the past since estimates of personal wealth are sensitive to the choice of the data source, the definition of wealth, and accounting conventions, all of which vary across countries. I overcome this limitation by using data from the *Luxembourg Wealth Study* (LWS), an international project that has collected household microdatabases from a sample of OECD countries, and has standardized the wealth concept and sampling frame. I am able to pin down the distribution of deposit accounts and financial assets for Austria, Canada, Finland, Italy, Japan, Norway, the United Kingdom and the United States.² For all countries considered, I find that the share of household financial wealth held in liquid assets decreases with income. There are, however, significant cross-country differences in terms of the magnitude of that share. For example, in the United States the top 10% hold approximately 10% of their financial wealth in liquid assets, but that fraction is as high as 83% in Japan. Such differences can obviously have important implications for the redistributive effects of inflation.

Second, money demand must be carefully estimated for the countries considered. This is particularly important because, in the tradition of Bailey (1956), the welfare cost of inflation is defined as the area under the money demand curve that is lost as steady-state inflation rate increases. Two previous studies based on the Lagos and Wright (2005) framework, such as Boel and Camera (2011) and Gomis-Porqueras et al. (2011), included money demand estimates for countries other than the United States, but neither study accounted for the possibility of structural breaks. I believe this issue should be addressed, given the extensive research concerned with the stability of money demand.³ Indeed, Boel and Camera (2011) suggest that the poor fit in some of the countries in their study might be a consequence of an unstable money demand due to policy breaks. I address this issue by testing for structural breaks in money demand. I find them to be significant for all but two of the countries considered (Austria and Finland) and I also identify the policy issue or economic shock that led to such structural changes. In doing so, I am also able to quantify how the welfare cost of inflation changed over time for the countries considered. I find Canada and Japan are the two countries for which the welfare cost of inflation increased over time. For other countries experiencing a break the welfare cost decreased instead, usually due to an increased monetary

¹See for example Chiu and Molico (2010), Chiu and Molico (2011) and Dressler (2011).

²Cyprus, Germany, Luxembourg and Sweden also participate in the LWS. I exclude them from my analysis because of data limitations.

³For a recent literature survey, see Sriram (2001).

policy independence.

Then, in order to quantify the redistributive effects of inflation I adopt the existing model in Boel and Camera (2009), which is based on Lagos and Wright (2005), in which agents can choose between money and an inflation-protected nominal asset providing consumption insurance. On a cross-country level, I find that two results hold. First, in all countries considered the *direction* of the redistributive effect is in line with the one documented for the United States. Specifically, inflation acts as a regressive tax for agents holding a nominal asset other than money. Second, the *magnitude* of such redistributive effects differs across countries and it depends not only on the levels of wealth inequality, but also on the the curvature and the level of the money demand curve. For example, in the United States, where money demand has flattened and shifted downwards over time, both the average welfare cost of inflation and its redistributive effects are lower than in a country like Canada where wealth is less unequally distributed but money demand is steeper.

Interestingly, I also find that in the Boel and Camera (2009) framework the optimal inflation rate for poor and rich agents is not necessarily the Friedman rule and it depends on the type of asset present in the economy. Specifically, I consider a political-economy equilibrium in which I let randomly selected representatives for the different types of agents bargain over the inflation rate, much like in Albanesi (2007). I find that if money is the only asset poor agents prefer an inflationary policy since lump-sum money transfers more than offset their inflation tax burden. When agents can hold an asset other than money, it is rich agents who prefer an inflationary policy since assets' returns are inflation protected and therefore they are not subject to the inflation tax.

The remainder of the paper is organized as follows. Section 2 summarizes the model economy. Section 3 discusses the quantitative analysis for the case of a representative agent and the heterogeneous economy. Section 4 discusses the political-economy equilibrium. Section 5 concludes.

2 The model

Consider the heterogeneous-agent model in Boel and Camera (2009),⁴ which is based on Lagos and Wright (2005). In each period there are two markets, denoted one and two. Agents are ex-ante heterogeneous in market-one trading shocks, with production and consumption being equally likely. The population is divided into two types $j = H, L$ in proportions ρ and $1 - \rho$, respectively.

Key notation is as follows. In market two of each period, an agent of type j consumes $q_j \geq 0$ goods and supplies $x_j \geq 0$ labor (equivalently, produces x_j goods), thus deriving utility $U(q_j) - x_j$. In market one, consumers of type j derive utility $u(c_j)$ from $c_j \geq 0$ consumption and all producers suffer the same linear disutility $\phi(y_j) = y_j$ from producing y_j goods. Let $\alpha_j \in (0, 1]$ denote the probability of trading on market one for any type j agent, with $0 < \alpha_L < \alpha_H \leq 1$. The functions u , ϕ and U satisfy the standard Inada conditions and $u(0) = U(0) = 0$. A star denotes the quantities that uniquely solve $u'(c) = 1$ and $U'(q) = 1$.

⁴In this section, I outline the key derivations of the model, but a more detailed presentation is available in the Appendix.

Agents are price takers. The government is the only supplier of fiat money, of which there is an initial stock $\bar{M} > 0$ and which grows deterministically at a constant gross rate π via lump-sum transfers. In stationary equilibrium, the gross growth rate of inflation equals the gross growth rate of the money supply.

When fiat money is the only asset, market-one consumption in a stationary monetary economy satisfies the following expression:

$$i = \frac{\alpha_j}{2} \left[\frac{u'(c_j)}{p} - 1 \right] \quad \text{for } j = H, L \quad (1)$$

where $i = \frac{\pi}{\beta} - 1$ denotes the net nominal interest rate and $p = \phi'(y) = 1$ denotes the equilibrium relative price between the two markets. Equation (1) defines two equations in two unknowns, c_H and c_L , which can be uniquely determined as a function of the model's parameters and the interest rate i . Note also that in this economy the equilibrium distribution of money has two mass points, with type H agents holding more money than type L . Both types are liquidity constrained as long as $i > 0$, in which case the allocation is inefficient. As nominal interest rates approach zero the allocation is efficient as it satisfies $u'(c_j) = 1$ for $j = H, L$.

Let $c_{j\pi}$ and $m_{j\pi}$ denote equilibrium consumption and money holdings for an agent of type j given the gross inflation rate π . Similarly, let y_π denote production in market one given π . Equilibrium ex-ante welfare for type j is:

$$(1 - \beta)V_{j\pi} = \frac{\alpha_j}{2} [u(c_{j\pi}) - c_{j\pi}] + U(q^*) - q^* + (\pi - 1)(\bar{m}_\pi - m_{j\pi}) \quad (2)$$

where q^* solves $U'(q^*) = 1$ and $\bar{m}_\pi = \rho m_{H\pi} + (1 - \rho)m_{L\pi}$ denotes average money holdings.

Note that inflation redistributes monetary wealth due to equilibrium real-balance heterogeneity since type L save less than the average \bar{m}_π but receive the same lump-sum transfer $(\pi - 1)\bar{m}_\pi$ as anyone else. Consequently, inflation redistributes monetary wealth from type H to type L .

When agents can buy consumption insurance in addition to money, the model economy changes as follows. In market two an intermediary exists that sells one-period nominal assets to the public at price ψ and that earns zero profits. In the following market one, buyers can redeem the asset spending its claims to money to buy consumption, while sellers can redeem it to cash its claims in the next market. Idle agents cannot participate in market-one trades, so they cannot redeem the asset. Thus, the asset becomes less attractive to type L who can trade less often.

Boel and Camera (2009) show that an equilibrium exists such that agents H hold only financial assets, while agents L hold only money. This is true provided that $\pi \in (\bar{\pi}, \tilde{\pi})$ where $\bar{\pi} = \beta + \alpha_H(1 - \beta)$ and $\tilde{\pi} = \beta + \alpha_H - \beta\alpha_L$. Hence, in this equilibrium $c_H = b_H/p$ and $m_H = 0$, while $c_L = m_L/p$ and $b_L = 0$. The expression for c_L is obtained from (1) as before, and ex-ante welfare for type L agents is:

$$(1 - \beta)V_L(0, \bar{m}_\pi) = \frac{\alpha_L}{2} [u(c_{L\pi}) - c_{L\pi}] + U(q^*) - q^* - (\pi - 1)\frac{\rho}{1 - \rho}\bar{m}_\pi \quad (3)$$

where $\bar{m}_\pi = (1 - \rho)m_{L\pi}$. The expression for c_H instead is obtained from:

$$\alpha_H \left(\frac{1}{\beta} - 1 \right) = \frac{\alpha_H}{2} \left[\frac{u'(c_H)}{p} - 1 \right] \quad (4)$$

and ex-ante welfare for type H agents is:

$$(1 - \beta)V_H(b_\pi, 0) = \frac{\alpha_H}{2}[u(c_{H\pi}) - c_{H\pi}] + U(q^*) - q^* + (\pi - 1)\bar{m}_\pi \quad (5)$$

Note that asset holdings of type H are not subject to the inflation tax. That is because the asset's expected return is $\alpha_H \frac{1}{\psi} = \pi$ and therefore it adjusts with inflation. This implies that inflation generates a wealth transfer from type L , who pay an inflation tax $(\pi - 1)\frac{\rho}{1-\rho}\bar{m}_\pi$, to type H , who receive a lump-sum transfer $(\pi - 1)\bar{m}_\pi$.

3 Quantitative analysis

In this section I calibrate the model in Boel and Camera (2009) for Austria, Canada, Finland, Italy, Japan, Norway, the United Kingdom and the United States, which I chose because they participate in the *Luxembourg Wealth Survey*.⁵ This is important because the LWS constitutes the first cross-country wealth database in existence and it provides harmonized microdata for deposit accounts holdings, financial assets holding as well as disposable income, all of which are necessary for calibrating the model's parameters.

I start the quantitative analysis by focusing on a representative-agent version of the Boel and Camera (2009) model with only money. I do so in order to determine the value of the preference parameters common across agents and I use the calibrated parameters to quantify the welfare cost of inflation for the countries considered. Then, I introduce heterogeneity and I study the redistributive impact of inflation. I do so for both the case where money is the only asset and the one where an alternative nominal asset is held. Throughout, I report the welfare cost of 10 percent annual inflation as a comparison to an economy with no inflation or at the Friedman rule.⁶

Calibration of common parameters. In the representative agent model $\alpha_j = \alpha$ for $j = H, L$. I consider standard functional forms: $u(c) = \frac{c^{1-\eta}-1}{1-\eta}$ with $\eta > 0$; $\phi(y) = \frac{y^\delta}{\delta}$ with $\delta \geq 1$; $U(q) = A \ln(q)$ which implies $q^* = A$. In a monetary equilibrium the relative price p satisfies $p = \phi'(y)$, $pc = m$, and $c = y$ satisfies the agent's Euler equation in (1). Thus, I can find c as a function of the model's parameters and the nominal interest rate i : $c = \left(\frac{\alpha}{2i+\alpha}\right)^{\frac{1}{\delta+\alpha-1}}$.

The vector of parameters to identify is therefore $\Omega = (\eta, \delta, \beta, \alpha, A)$. I set $\eta = 1$ and $\delta = 1$ so that preferences are homogeneous across all countries, but I calibrate the model to country-specific discount factors. The parameter α is set so that the theoretical interest elasticity of money demand, denoted by ε_m , matches the empirical elasticity of money demand, which I estimate following Goldfeld and Sichel (1990). As shown in Boel and Camera (2009), $\varepsilon_m = \frac{2i\phi'(y)}{\alpha c u''(c)}$ and for the functional forms selected $\varepsilon_m = -\frac{2i}{(2i+\alpha)\eta}$, where i is the average nominal quarterly yield on a money-market instrument.

Last, as is standard in this literature, I determine A to fit the real balances-income ratio $L = \frac{M}{PY}$, where

⁵Cyprus, Germany, Luxembourg and Sweden also participate in the LWS, but I excluded them from my analysis due to lack of data availability. Specifically, for Germany and Luxembourg, data on deposit accounts are not available in the LWS. For Sweden, M1 data are only available starting from 1998q1 and M0 data from 1995q2. For Cyprus, money-market interest rate data are only available starting from 1996q1.

⁶With a nominal asset the Friedman rule is not sustainable in the equilibrium considered, since $\pi > \bar{\pi} > \beta$.

P is the nominal price level, M is money supply, and Y is real output.⁷ As explained in Lagos and Wright (2005), this relationship can be interpreted as money demand in the sense that the desired real balances M/P are proportional to Y , with a factor of proportionality L that depends on the opportunity cost of holding cash, i . The theoretical expression for L in the model is $L = \frac{m}{\frac{\alpha}{2}pc+A}$, which, given the functional forms selected becomes $L = \frac{1}{\alpha/2+Ac^{-\delta}}$. I calibrate A by minimizing the distance between L in the data and in the model, given the calibrated parameters $(\eta, \delta, \beta, \alpha)$. Table 1 lists the values of elasticities and calibrated parameters for all countries considered.

Once I have the parameter vector Ω , I can quantify the welfare cost of inflation. The definition is standard and it follows the one in Lucas (2000). Therefore, the welfare cost of inflation should be interpreted as the percentage adjustment in consumption (in both markets) the representative agent would require to be indifferent between a steady state with gross inflation rate π and a lower inflation rate $z \in [\beta, \pi)$.

If I reduce π to z and adjust consumption in both markets by the proportion $\bar{\Delta}_z$, then ex-ante welfare is defined by:

$$(1 - \beta)V_z = \frac{\alpha}{2}[u(\bar{\Delta}_z c_z) - \phi(c_z)] + U(\bar{\Delta}_z q^*) - q^* \quad (6)$$

The welfare cost of having π instead of z inflation is the value $\Delta_z = 1 - \bar{\Delta}_z$ that satisfies $V_\pi = V_z$, where V_π is the one in (2) for the case of a representative agent. If $\Delta_z > 0$, then agents are indifferent between π inflation, or alternatively z inflation and consumption reduced by Δ_z percent.

Table 1: Calibrated parameters and welfare cost of inflation (representative agent model).

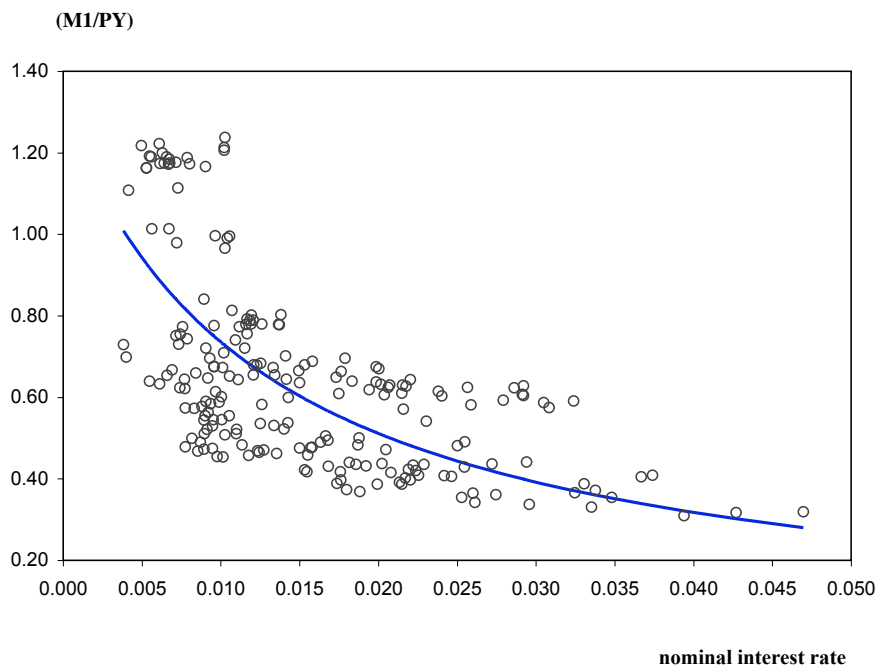
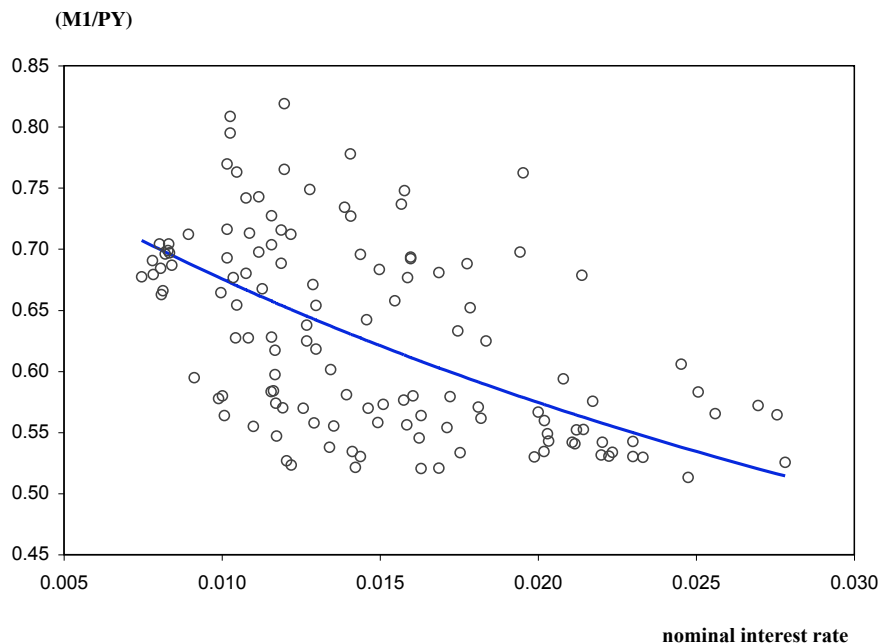
Country	Quarters	Calibrated Parameters							Welfare Cost	
		i	$\pi - 1$	β	ε_m	α	A	R^2	0%	FR
Austria	1967q1-1998q4	1.48	1.03	0.995	-0.248	0.09	1.17	0.26	0.37	0.39
Canada	1957q1-2008q4	1.54	1.03	0.995	-0.547	0.03	0.75	0.42	0.74	0.82
Finland	1980q1-1998q4	2.45	1.28	0.989	-0.212	0.18	0.66	0.70	0.52	0.60
Italy	1971q1-1998q4	2.90	1.38	0.985	-0.106	0.49	0.39	0.02	0.34	0.41
Japan	1957q1-2009q4	1.24	1.11	0.999	-0.151	0.14	0.48	0.20	0.54	0.54
Norway	1987q3-2009q4	1.62	0.64	0.990	-0.121	0.23	0.45	0.32	0.55	0.61
UK	1969q2-2006q1	2.03	1.69	0.997	-0.998	0.01	1.40	-1.12	0.33	0.36
US	1959q1-2009q4	1.30	0.89	0.996	-0.191	0.11	1.07	0.37	0.35	0.37

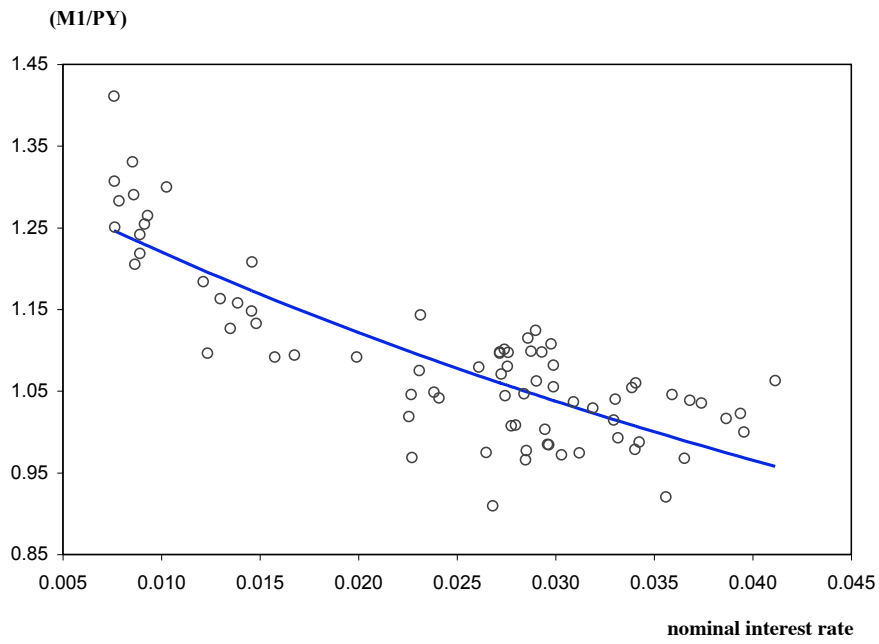
Notes: The values for net nominal interest rates (i) and net inflation rates ($\pi - 1$) are in percentage points on a quarterly basis; β is the quarterly discount factor; ε_m is the estimated interest elasticity of money demand. For the UK, M0 was used as the money supply measure, instead of M1. Welfare costs are for 10% annual inflation versus either 0% inflation or the Friedman rule (FR). Note that a negative R^2 (UK) is possible since the model is non linear.

⁷Data sources for all countries considered are described in the Appendix. The United Kingdom is the only country for which M0 is used as a measure of money supply due to data availability. For all other countries, M1 is used instead.

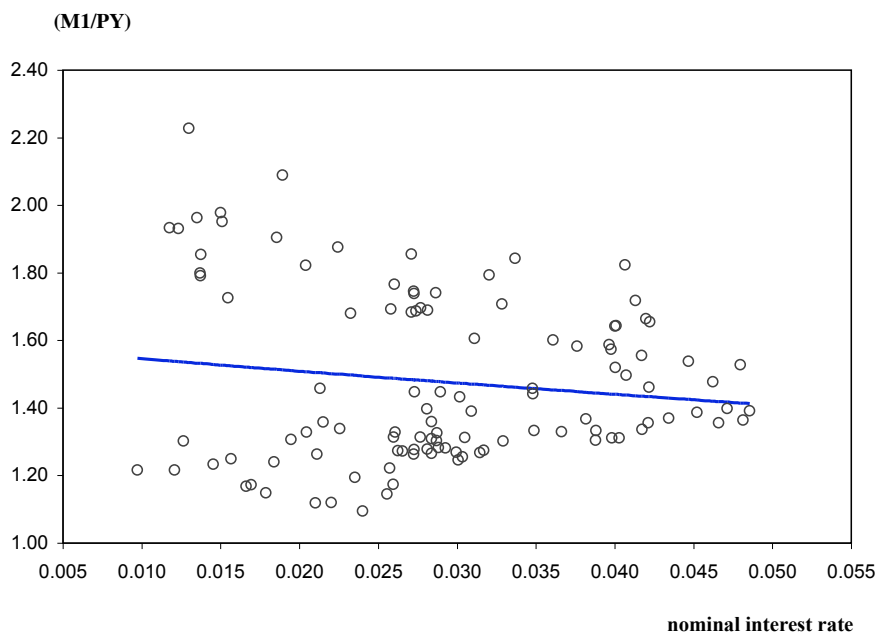
Figure 1 shows the quality of the fit of the model to the data with the calibrated parameters for the different countries. For each quarter, the observed ratio M/PY is plotted against the nominal interest rate i . The continuous line represents $L = \frac{1}{\alpha/2 + Ac^{-\delta}}$ with the calibrated parameters' values.

Figure 1: Money Demand with Fitted Model

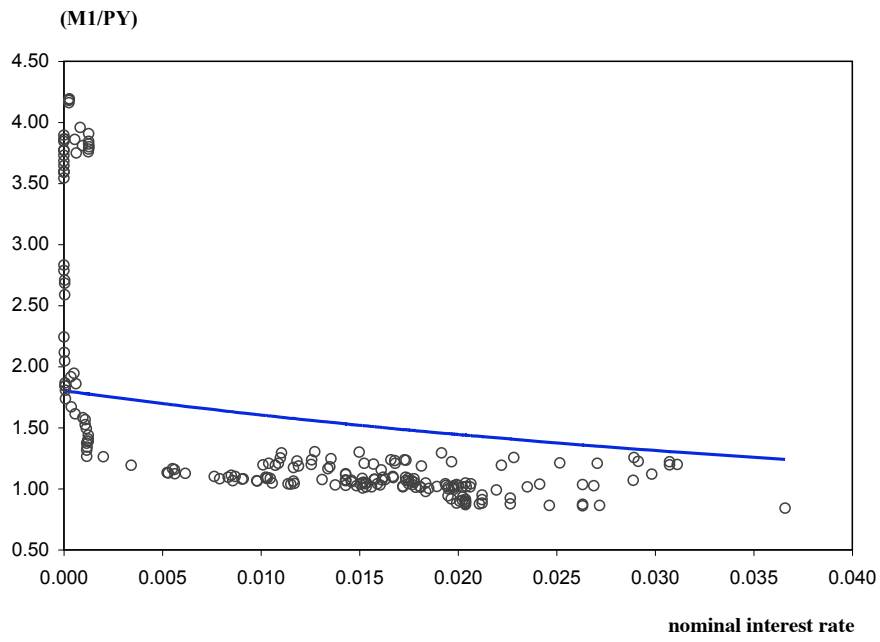




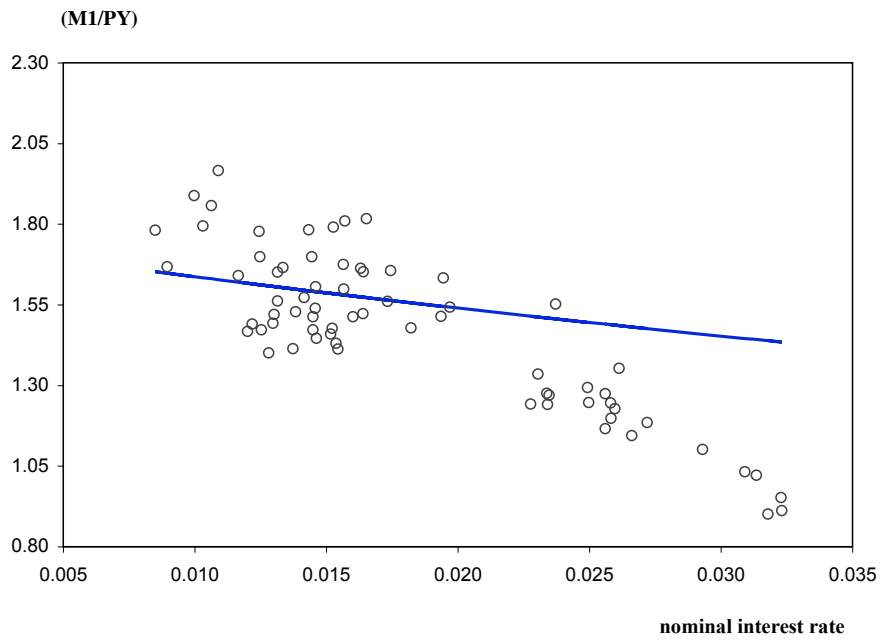
Panel C: Finland (1980q1-1998q4)



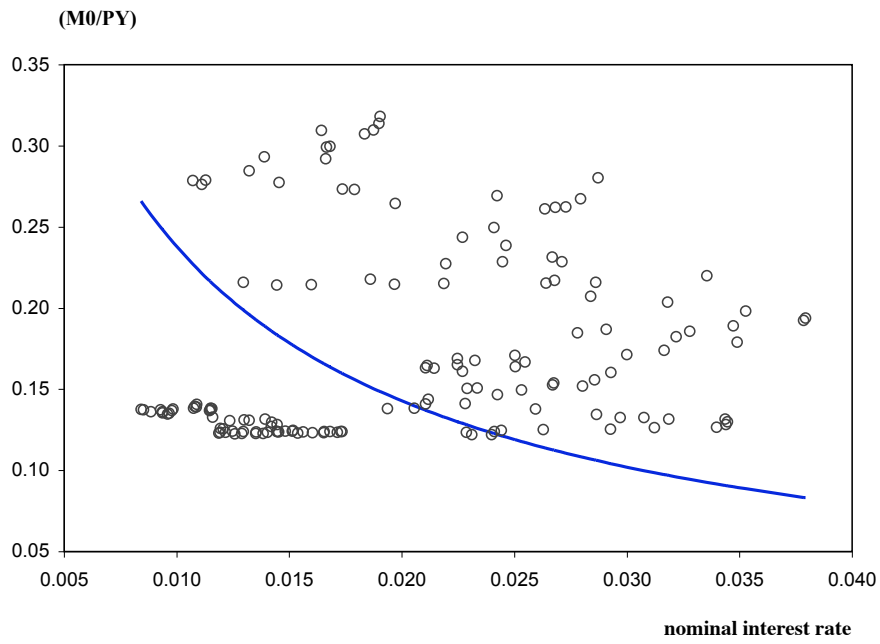
Panel D: Italy (1971q1-1998q4)



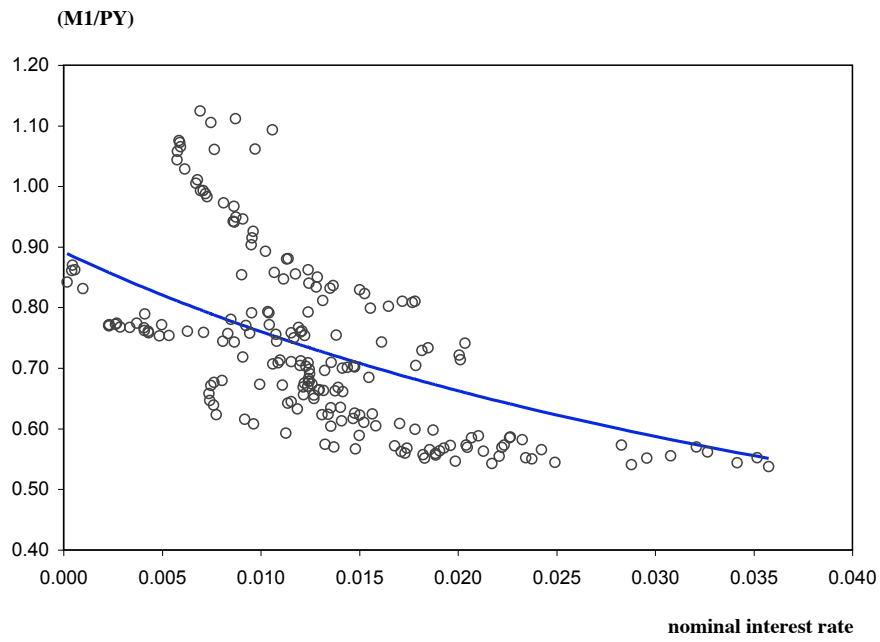
Panel E: Japan (1957q1-2009q4)



Panel F: Norway (1987q3-2009q4)



Panel G: United Kingdom (1962q2-2006q1)



Panel H: United States (1959q4-2009q4)

Structural breaks. The results in Table 1 would suggest that the model fails to fit the data only for the United Kingdom, given that R^2 is negative only for that one country. However, when visually examining Panels A-H in Figure 1, one can easily notice that the fitted model does not capture the exact shape and curvature of money demand even in cases where R^2 is positive. Japan, Italy, and the UK stand out in this respect. This should be a source of concern since the welfare cost of inflation is measured as the area under the money demand curve that is lost as steady-state inflation rate increases, following Bailey (1956). Therefore, a poor fit of money demand would lead to meaningless estimates of the welfare cost of inflation. In order to address this issue, I test for money demand stability by running Chow (1960) tests on the money demand equation specified in Goldfeld and Sichel (1990). I find significant structural breaks for all countries considered, except Austria and Finland.

Dates and reasons for such breaks are listed in Table 2, but a brief explanation is in order. In Canada, I find evidence of a break in the third quarter of 1982, which coincides with the end of the M1-targeting policy conducted by the Bank of Canada between 1975 and 1982. In Italy, the break occurs in the third quarter of 1994, which corresponds to the start of a new regime for the Bank of Italy. Indeed, Italy's central bank was given full independent power to set official interest rates in 1992, but it only stopped participating in government securities auctions in the summer of 1994.⁸

For Japan, I find evidence of two structural breaks, one in the first quarter of 2001 and the other in the third quarter of 2006. The first coincides with the start of the “quantitative easing” policy implemented by the Bank of Japan which reduced the overnight call rate to zero, and the second with the end of the same policy in March 2006. In Norway, the break occurs in the last quarter of 1992. In December 1992, the Norwegian krone was allowed to float after being pegged since 1986 and interest rates, which had previously increased sharply to defend the peg, decreased rapidly after the devaluation. In the United Kingdom, the break is due to the end of the European Exchange Rate Mechanism (ERM) in the third quarter of 1992, which coincides with the start of an inflation targeting regime in the country. Last, in the United States the break occurs in the first quarter of 1973. This corresponds to the end of the Bretton Woods agreement, since major currencies began to float against each other by March 1973.

⁸“Bank of Italy - History.” *Bank of Italy*. Web. 2012.

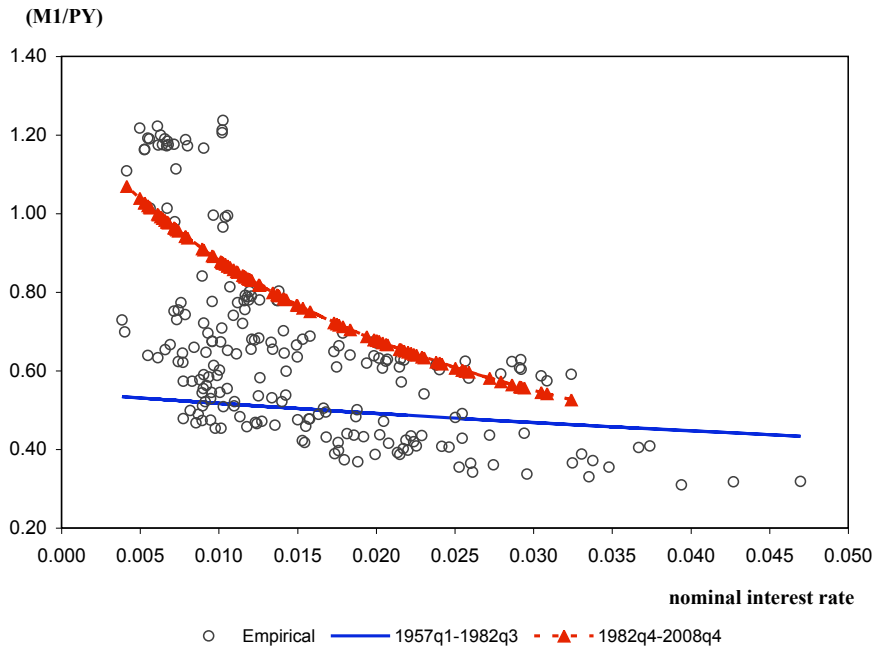
Table 2: Money demand structural breaks, recalibrated parameters and welfare costs of inflation for subsamples.

Country	Quarters	Break Explanation	Calibrated Parameters				Welfare Cost	
			ε_m	α	A	R^2	0%	FR
Austria	1967q1-1998q4	No break	-0.248	0.09	1.17	0.26	0.37	0.39
Canada	1957q1-1982q3	M1 target withdrawn	-0.087	0.33	1.67	0.27	0.09	0.09
	1982q4-2008q4		-0.402	0.05	0.77	0.66	0.74	0.87
Finland	1980q1-1998q4	No break	-0.212	0.18	0.66	0.70	0.52	0.60
Italy	1971q1-1994q3	Central bank independence	-0.141	0.38	0.40	0.14	0.48	0.60
	1994q4-1998q4		-0.113	0.30	0.61	0.13	0.25	0.26
Japan	1957q1-2001q1	Quantitative easing start	-0.089	0.30	0.66	0.25	0.20	0.20
	2001q2-2006q1	Quantitative easing end	-0.103	0.00	0.28	0.54	0.07	0.16
	2006q2-2009q4		-0.024	0.06	0.22	0.33	1.97	2.03
Norway	1987q3-1992q4	Krone devaluation	-0.812	0.01	0.16	0.79	2.19	4.21
	1993q1-2009q4		-0.110	0.21	0.43	0.17	0.59	0.63
UK	1969q2-1992q3	ERM crisis	-1.220	0.01	0.92	0.18	0.51	0.54
	1992q4-2006q1		-0.096	0.24	6.89	0.43	0.04	0.04
US	1959q1-1973q1	Bretton Woods end	-0.078	0.24	0.90	0.23	0.23	0.23
	1973q2-2009q4		-0.084	0.30	1.24	0.40	0.15	0.15

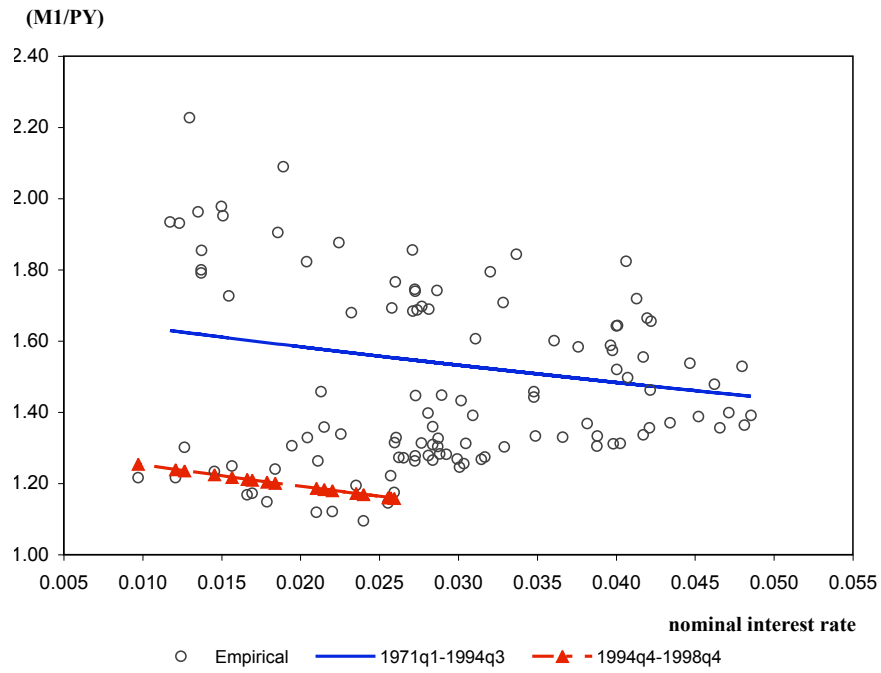
Notes: Structural breaks in money demand are identified conducting Chow tests on the regression for money demand specified in Goldfeld and Sichel (1990). No evidence of structural breaks is found for Austria and Finland. For the UK, the Chow test is significant at a 5% level and for Canada, Italy, Japan, Norway and the US, it is significant at a 1% level. Welfare costs are for 10% annual inflation relative to either 0% inflation or the Friedman rule (FR).

Figure 2 shows the quality of the fit of the model to the data for the subsamples summarized in Table 2. Note that Austria and Finland, for which no breaks have been identified, are not included in Figure 2.

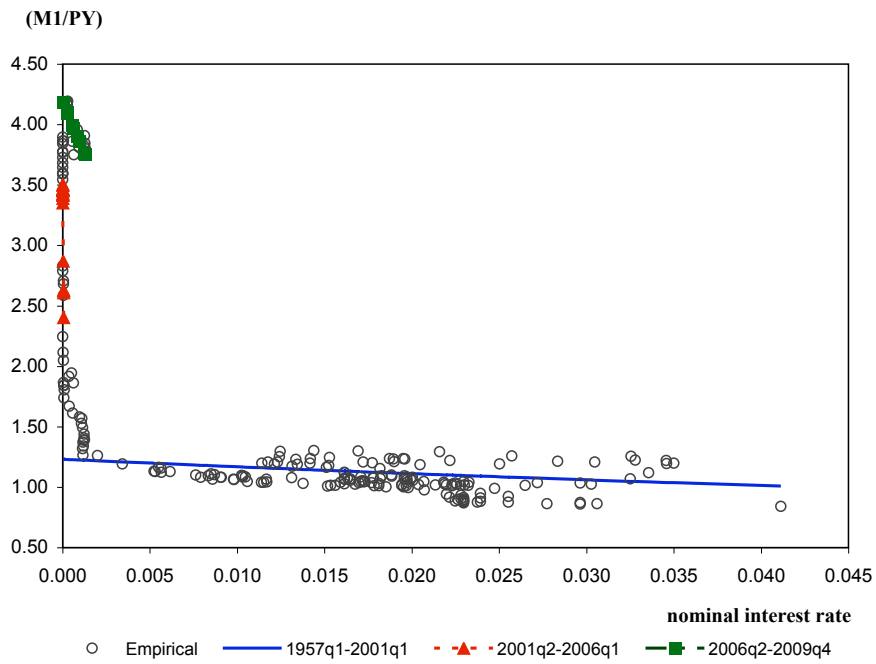
Figure 2: Money Demand with Fitted Model and Structural Breaks



Panel A: Canada (1957q1-2008q4)

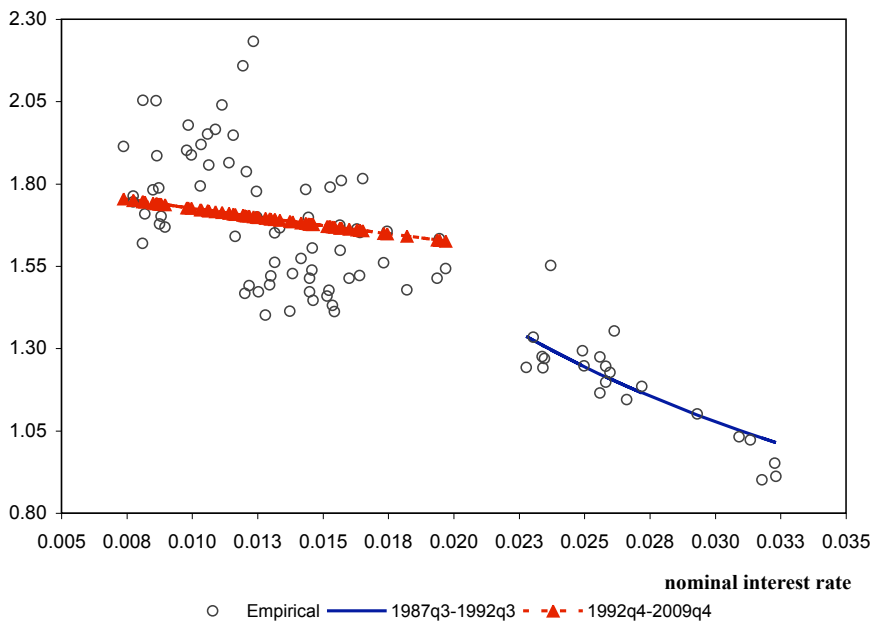


Panel B: Italy (1971q1-1998q4)



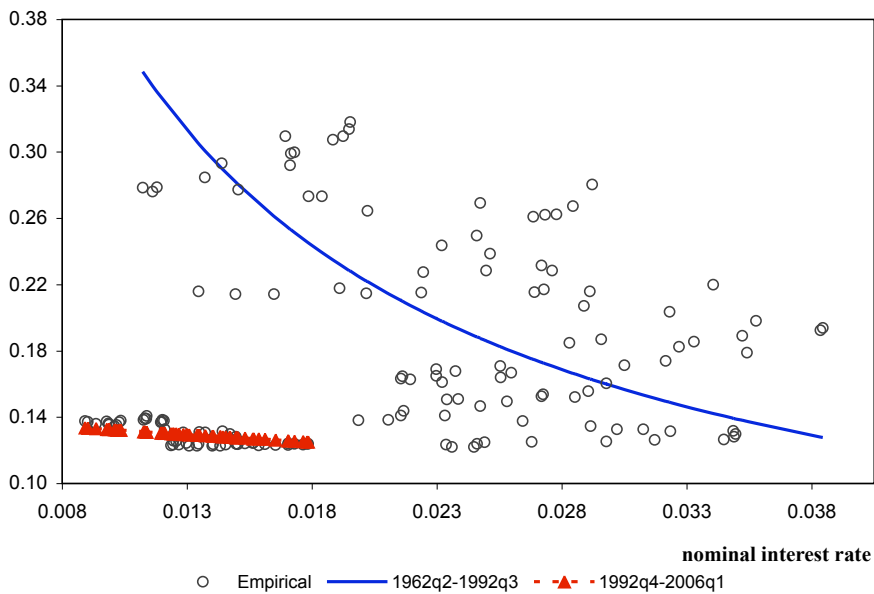
Panel C: Japan (1957q1-2009q4)

(M1/PY)

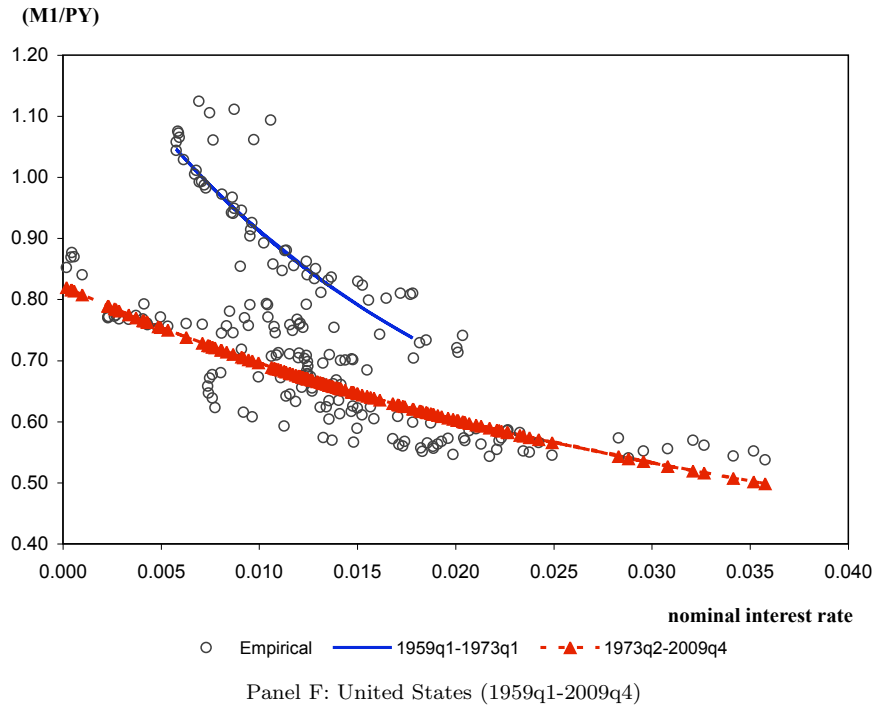


Panel D: Norway (1987q3-2009q4)

(M0/PY)



Panel E: United Kingdom (1962q2-2006q1)



I then recalibrate the parameters η and A for all subsets identified and summarized in Table 2. This allows me to determine how the welfare cost of inflation changed over time due to policy breaks. Results are in Table 2. Interestingly, in most countries considered the welfare cost of inflation decreased over time and the decrease was due to an increase in monetary policy independence. In Italy, the United Kingdom and the United States this increased independence coincided with a downward shift in money demand. In the case of Norway, instead, money demand shifted leftward due to a sharp decrease in interest rates when the krone was allowed to float.

Canada and Japan stand out as somewhat different. In Canada, where M1 had decreased by 28 percent between 1975 and 1982,⁹ the welfare cost of inflation increased due to an upward shift in M1 after the money-targeting policy ended in 1982. In Japan, instead, the welfare cost of inflation decreased sharply during the quantitative-easing experiment due to an almost vertical money demand. By the end of the experiment in 2006, however, the ratio M/PY had increased by 98 percent compared to the first quarter of 2001, thus implying an upward shift in money demand which led to a higher welfare cost of inflation.

For each country considered, I then recalibrate the parameters η and A for the full-sample period as the weighted average of η and A for the subsamples listed in Table 2. This allows me to pin down the welfare costs of inflation for the full-sample period while still accounting for how parameters η and A changed over time. Two aspects of the results, which are summarized in Table 3, are worth mentioning. First, the welfare cost of inflation for the full sample is lower (except for Italy) when we take into account how the calibrated parameters change due to policy breaks. Second, the welfare cost of inflation appears to be positively correlated with the ratio η/A . Graphically, the parameters η and A capture the curvature and the level of money demand respectively. From an economic perspective, a higher ratio η/A implies a higher weight assigned to monetary market-one trade relative to market-two trade. Hence the higher welfare loss induced by inflation.

⁹See Gomme (1998).

Table 3: Average recalibrated parameters and welfare costs for representative agent case.

Country	Quarters	Recalibrated Parameters					Welfare Cost	
		i	$\pi - 1$	β	α	A	0%	FR
Austria	1967q1-1998q4	1.48	1.03	0.995	0.09	1.17	0.37	0.39
Canada	1957q1-2008q4	1.54	1.03	0.995	0.19	1.21	0.23	0.24
Finland	1980q1-1998q4	2.45	1.28	0.989	0.18	0.66	0.52	0.60
Italy	1971q1-1998q4	2.90	1.38	0.985	0.36	0.43	0.44	0.53
Japan	1957q1-2009q4	1.24	1.11	0.999	0.26	0.59	0.27	0.27
Norway	1987q3-2009q4	1.62	0.64	0.990	0.16	0.37	0.87	0.98
UK	1969q2-2006q1	2.03	1.69	0.997	0.09	3.09	0.14	0.14
US	1959q1-2009q4	1.30	0.89	0.996	0.29	1.15	0.16	0.17

Notes: η and A are calculated as the weighted average of η and A for the subsamples listed in Table 2. For Austria and Finland no structural breaks are identified and therefore η and A are the ones listed in Table 1. The values for net nominal interest rates (i) and net inflation rates ($\pi - 1$) are in percentage points on a quarterly basis; β is the quarterly discount factor. Welfare costs are for 10% annual inflation relative to either 0% inflation or the Friedman rule (FR).

Heterogeneity. To measure the redistributive effects of inflation I proceed as follows. First, I fix the common preference parameters (η, δ, β, A) to the values calibrated for the representative agent model. Second, I fix the average trading friction to the value α from the representative agent model and then consider mean preserving spreads $\rho\alpha_H + (1 - \rho)\alpha_L = \alpha$ for some given value ρ . I calibrate (ρ, α_L, α_H) using micro data from the *Luxembourg Wealth Survey*.¹⁰ Specifically, the LWS reports harmonized data for household deposit accounts (DA),¹¹ which I use as a measure of liquidity, total financial assets (TFA1)¹² and disposable income (LIS_DPI).

First of all, I use the LWS to pin down the empirical ratio of deposit accounts over total financial assets for different households' income quintiles.¹³ As reported in Table 4, such ratio decreases with income for all countries considered, even though its magnitude varies across countries. This is important because it shows that the model in Boel and Camera (2009), in which "rich" agents prefer to hold inflation-protected assets over cash, describes a feature of wealth distribution common across all countries I am analyzing.

Of course, when looking at Table 4, one notices that Japan stands out as somewhat different, since the ratio of deposit accounts over total financial assets stays pretty much constant across income quintiles. This should not come as a surprise, since it is a known fact that the average Japanese household has a financial balance sheet that is far more conservative than that of the representative household in other industrialised countries, as reported in Nakagawa and Yasui (2009). I do believe, however, that the model in Boel and Camera (2009) can still be used to analyze Japan given that the ratio of deposit accounts over total financial assets is lower for the top two income quintiles than for the lower six.

¹⁰For the countries where LWS microdata are available for more than one year, data should be interpreted as averages across all years available. Data availability is as follows: Austria (2002), Canada (1999), Finland (1994 and 1998), Italy (2002 and 2004), Japan (2003), Norway (2002), United Kingdom (2000), United States (1994, 1997, 2000, 2003 and 2006).

¹¹Deposit accounts (DA) include transaction accounts, savings accounts and term deposits or CDs (i.e. bank deposits, current account deposits, bank savings, postal bank deposits, etc.).

¹²Total financial assets (TFA1) are the sum of deposit accounts, bonds, stocks and mutual funds.

¹³I use data on disposable income instead of gross income due to data availability, since the LWS does not provide data on gross income for Austria and Italy.

Table 4: Deposit accounts' share of total financial assets by disposable income quintiles.

Country	Lowest 20%	Second 20%	Third 20%	Fourth 20%	Highest 20%
Austria	0.861	0.816	0.784	0.716	0.657
Canada	0.536	0.523	0.469	0.392	0.211
Finland	0.818	0.734	0.729	0.659	0.376
Italy	0.818	0.754	0.663	0.577	0.433
Japan	0.892	0.874	0.891	0.817	0.843
Norway	0.853	0.807	0.749	0.663	0.416
UK	0.623	0.569	0.558	0.486	0.467
US	0.395	0.289	0.265	0.172	0.110

Notes: Deposit accounts (DA) include transaction accounts, savings accounts and term deposits or CDs. Total financial assets (TFA1) are the sum of deposit accounts, bonds, stocks and mutual funds. Data availability is as follows: Austria (2002), Canada (1999), Finland (1994 and 1998), Italy (2002 and 2004), Japan (2003), Norway (2002), United Kingdom (2000), United States (1994, 1997, 2000, 2003 and 2006).

I also use LWS data to pin down the share of deposit accounts held by households in different income quintiles. In terms of the model $\frac{\rho m_H}{\bar{m}}$ is the share of liquidity held by type H agents. Associating $j = H$ to the top two income quintiles one gets $\rho = 0.4$, and the values α_L and α_H are found by matching the theoretical liquidity share to its empirical counterpart and using the mean preserving spread $\rho\alpha_H + (1 - \rho)\alpha_L = \alpha$. Once I have the calibrated parameters α_L and α_H , I can determine the welfare costs of inflation for type H and type L agents for both the case where money is the only asset and the one where an additional nominal asset is available. Table 5 reports the results for all countries considered.

Table 5: Redistributive effects of inflation (economy with only money and economy with additional nominal asset).

Country	$0.4m_H/\bar{m}$	α_L	α_H	Welfare Cost			
				Only Money		Additional Asset	
				Lowest 60%	Highest 40%	Lowest 60%	Highest 40%
Austria	0.611	0.017	0.199	0.008	0.842	0.636	-0.261
Canada	0.578	0.026	0.429	0.012	0.692	0.701	-0.310
Finland	0.582	0.037	0.401	0.142	1.119	1.347	-0.573
Italy	0.623	0.035	0.858	-0.016	1.171	1.929	-0.520
Japan	0.550	0.027	0.603	-0.021	1.024	1.434	-0.569
Norway	0.591	0.024	0.374	-0.041	1.913	2.083	-0.677
UK	0.621	0.021	0.193	0.021	0.315	0.263	-0.124
US	0.940	0.001	0.714	-0.675	0.933	0.108	-0.020

Notes: Theoretically, $\rho m_H/\bar{m}$ denotes the share of liquid assets held by type H agents. For the calibration exercise, type L and type H agents are interpreted as households belonging to the lowest 60% and the highest 40% of the income distribution respectively, so that $\rho = 0.4$. For all countries considered, α_H and α_L are calibrated to match the average α listed in Table 3 and the share of deposit accounts held by households belonging to the four highest income deciles. Data for the distribution of deposit accounts are collected from the *Luxembourg Wealth Survey*. Welfare costs are for 10% annual inflation relative to 0% inflation.

I find that the welfare cost of anticipated inflation is unevenly distributed across the population in all countries considered. When money is the only asset considered, inflation acts as a progressive tax in that

the poor suffer more than the rich. In Italy, Japan, Norway and the United States they even benefit from inflation. When instead I consider an economy augmented with an inflation-protected asset, inflation acts as a regressive tax and rich agents benefit from inflation whereas the poor agents are hurt from it.

Interestingly, the magnitude of the redistributive effect does not depend only on the distribution of financial wealth, but also on the curvature and level of money demand. For example, in the United States, where money demand has flattened and shifted downwards over time, both the average welfare cost of inflation and its redistributive effects are lower than in a country like Canada where wealth is less unequally distributed but money demand is higher and steeper.

4 Political Economy Equilibrium

Given the redistributive effects of inflation, I believe it is important to investigate which monetary policy would be advocated by type H and type L agents in this environment. I follow Albanesi (2007) to determine the optimal gross inflation choice through a Nash bargaining process. Specifically, in market two of each period two randomly selected representatives for type H and type L agents bargain over π , and θ represents the bargaining power for type H agents. The threat point policy is such that if agents do not agree, they are banned from financial markets in the next period only. Thus, they will not be able to use either money or the nominal asset and they will be excluded from market-one trade for that one period. The timing of events in each market two is as follows:

- 1 An agent of type j enters market two with m_{jk} real money holdings, where $k = n, s, b$ denotes the idiosyncratic trade shock experienced in market one (n if idle, b for buyer, s for producer).
- 2 Randomly-selected representatives of each type of agent bargain over the optimal gross inflation rate π taking the threat point as given. The bargaining problem that must be solved is:

$$\text{Max}_{\pi} [W_H(m_{H,k}) - \hat{W}_H(m_{H,k})]^\theta [W_L(m_{L,k}) - \hat{W}_L(m_{L,k})]^{1-\theta} \quad (7)$$

where $\hat{W}_j(m_{j,k})$ is the threat point for $j = H, L$.

- 3 Agents trade in the centralized market and choose money (or asset) holdings for next period.

In what follows, I will examine two different bargaining problems - one for the case where money is the only asset, and one for the case with an additional nominal asset.

Money is the only asset. When both type H and type L agents are using money, the definition of equilibrium is as follows:

Definition 1. A stationary equilibrium for this economy is a list $(\pi, c_j, y_j, q_j, x_{jk}, m_j, p_{1,t}, p_{2,t})$ such that: (i) taking V_j, W_j and the threat point \hat{W}_j as given, $\pi = \pi^*$ solves the bargaining problem in (7); (ii) taking π as given, the agent's problems in (18) and (19) are solved, (20) is satisfied, the government budget constraint in (21) and the market clearing conditions in (22), (23) and (24) hold.

The following proposition characterizes the monetary policies preferred by type H and type L agents.

Proposition 1. *When money is the only asset, type H agents prefer a deflationary policy ($\beta \leq \pi < 1$) whereas type L agents prefer an inflationary policy ($\pi > 1$).*

Proof. Note that in steady state $W_j(m_{j,k}) = U(q^*) - q^* - \pi m_j + m_{j,k} + \tau + \beta[m_j + \frac{\alpha_j}{2}[u(c_j) - c_j] + W_j(0)]$,¹⁴ where $\tau = (\pi - 1)(\rho m_H + (1 - \rho)m_L)$. The threat point \hat{W}_j for the bargaining problem is the lifetime utility for an agent of type $j = H, L$ when no agreement is reached over the inflation rate and therefore an agent j is excluded from market-one trade only for the next period. Therefore, $\hat{W}_j(m_{j,k}) = U(q^*) - q^* + m_{j,k} + \beta W_j(0)$ and the bargaining problem in (7) becomes:

$$\text{Max}_{\pi} [(\beta - \pi)m_H + \tau + \beta \frac{\alpha_H}{2}[u(c_H) - c_H]]^{\theta} [(\beta - \pi)m_L + \tau + \beta \frac{\alpha_L}{2}[u(c_L) - c_L]]^{1-\theta} \quad (8)$$

If type H agents have all the bargaining power, then $\theta = 1$ and the problem in (8) becomes:

$$\text{Max}_{\pi} (\beta - \pi)m_H + \tau + \beta \frac{\alpha_H}{2}[u(c_H) - c_H] \quad (9)$$

The F.O.C. for the problem in (9) is:

$$-m_H + (\beta - \pi) \frac{dm_H}{d\pi} + \bar{m} + (\pi - 1) \frac{d\bar{m}}{d\pi} + \beta \frac{\alpha_H}{2}[u'(c_H) - 1] \frac{dc_H}{d\pi} = 0 \quad (10)$$

where $\bar{m} = \rho m_H + (1 - \rho)m_L$. I know from (1) that $(\beta - \pi) \frac{dm_H}{d\pi} = \beta \frac{\alpha_H}{2}[u'(c_H) - 1] \frac{dc_H}{d\pi}$ and therefore (10) becomes $-m_H + \bar{m} + (\pi - 1) \frac{d\bar{m}}{d\pi} = 0$, so that $(\rho - 1)(m_H - m_L) + (\pi - 1) \frac{d\bar{m}}{d\pi} = 0$. I know from (1) that $\frac{\pi - \beta}{\beta} = \frac{\alpha_j}{2} \left[\frac{u'(c_j)}{\phi'(y)} - 1 \right]$. From the implicit function theorem, this implies that $\frac{dm_j}{d\pi} < 0$ and therefore $\frac{d\bar{m}}{d\pi} < 0$. Hence, since I know from (1) that $m_H > m_L$ it has to be that type H agents choose $\pi < 1$. If instead type L agents have all the bargaining power, $\theta = 0$ and the problem in (8) becomes:

$$\text{Max}_{\pi} (\beta - \pi)m_L + \tau + \beta \frac{\alpha_L}{2}[u(c_L) - c_L] \quad (11)$$

The F.O.C. for the problem in (11) is:

$$-m_L + (\beta - \pi) \frac{dm_L}{d\pi} + \bar{m} + (\pi - 1) \frac{d\bar{m}}{d\pi} + \beta \frac{\alpha_L}{2}[u'(c_L) - 1] \frac{dc_L}{d\pi} = 0 \quad (12)$$

The expression in (12) can be simplified and it becomes $\rho(m_H - m_L) + (\pi - 1) \frac{d\bar{m}}{d\pi} = 0$. Since $\frac{d\bar{m}}{d\pi} < 0$ and $m_H > m_L$ it has to be that type L agents choose $\pi > 1$. ■

Additional nominal asset. In this case I focus on an equilibrium where type H agents hold only the nominal asset and type L only money, so that $b_H > m_H = 0$ and $m_L > b_L = 0$. The definition of equilibrium is as follows:

¹⁴See Appendix for details.

Definition 2. A stationary equilibrium for this economy is a list $(\pi, c_j, y_j, q_j, x_{jk}, m_j, b_j, p_{1,t}, p_{2,t}, \psi)$ such that: (i) taking V_j, W_j and the threat point \hat{W}_j as given, $\pi = \pi^*$ solves the bargaining problem in (7); (ii) taking π as given, the agent's problems in (25), (26), (27) and (28) are solved, (20) and (31) are satisfied, the government budget constraint in (29) and the market clearing conditions in (23), (24) and (30) hold.

The following proposition characterizes the monetary policies preferred by different types of agents when money and an alternative nominal asset coexist in this economy.

Proposition 2. Consider the case where the economy is augmented with an alternative nominal asset. If $\pi \in (\bar{\pi}, \tilde{\pi})$ where $\bar{\pi} = \beta + \alpha_H(1 - \beta)$ and $\tilde{\pi} = \beta + \alpha_H - \beta\alpha_L$, type L agents prefer a deflationary policy ($\beta \leq \pi < 1$) whereas type H agents prefer an inflationary policy ($\pi > 1$).

Proof. I am now considering an equilibrium where $b_H > m_H = 0$ and $m_L > b_L = 0$. Note that in order for this to be true, it must be that $\pi \in (\bar{\pi}, \tilde{\pi})$ where $\bar{\pi} = \beta + \alpha_H(1 - \beta)$ and $\tilde{\pi} = \beta + \alpha_H - \beta\alpha_L$. If that is the case, the bargaining problem is analogous to the one in (8) for type L agents. The lifetime utility for an agent of type H, however, is different as it is affected by her asset choice, i.e. $W_H(m_{H,k}) = [U(q^*) - q^* - \pi\psi b_H + m_{H,k} + \tau + \beta[\alpha_H b_H + \frac{\alpha_H}{2}[u(c_H) - c_H] + W_H(0)]]^{15}$. Note that since now $m_H = 0$ it must be that $\tau = (\pi - 1)(1 - \rho)m_L$. Threat points remain the same. So, the bargaining problem becomes:

$$\text{Max}_{\pi} [(\beta\alpha_H - \pi\psi)b_H + \tau + \beta\frac{\alpha_H}{2}[u(c_H) - c_H]]^{\theta} [(\beta - \pi)m_L + \tau + \beta\frac{\alpha_L}{2}[u(c_L) - c_L]]^{1-\theta} \quad (13)$$

If type H agents have all the bargaining power, then $\theta = 1$ and the problem in (13) becomes:

$$\text{Max}_{\pi} (\beta\alpha_H - \pi\psi)b_H + (\pi - 1)(1 - \rho)m_L + \beta\frac{\alpha_H}{2}[u(c_H) - c_H] \quad (14)$$

Note that in equilibrium $\psi = \frac{\alpha_H}{\pi}$ and therefore $\pi\psi = \alpha_H$. Thus, the F.O.C. for the problem in (14) is:

$$(1 - \rho)m_L + (\pi - 1)(1 - \rho)\frac{dm_L}{d\pi} = 0 \quad (15)$$

Since $\frac{dm_L}{d\pi} < 0$ it must be that type H agents choose $\pi > 1$. In the case instead where type L agents have all the bargaining power, $\theta = 0$ and the problem in (13) becomes:

$$\text{Max}_{\pi} [(\beta - \pi)m_L + (\pi - 1)(1 - \rho)m_L + \beta\frac{\alpha_L}{2}[u(c_L) - c_L]] \quad (16)$$

The F.O.C. for the problem in (16) is:

$$-m_L + (\beta - \pi)\frac{dm_L}{d\pi} + (1 - \rho)m_L + (\pi - 1)(1 - \rho)\frac{dm_L}{d\pi} + \beta\frac{\alpha_L}{2}[u'(c_L)\frac{dc_L}{d\pi} - \frac{dc_L}{d\pi}] = 0 \quad (17)$$

The expression in (17) can be simplified since from (1) I know that $(\beta - \pi)\frac{dm_L}{d\pi} = \beta\frac{\alpha_L}{2}[u'(c_L)\frac{dc_L}{d\pi} - \frac{dc_L}{d\pi}]$. Thus, (17) becomes $-\rho m_L + (\pi - 1)(1 - \rho)\frac{dm_L}{d\pi} = 0$. Since $\frac{dm_L}{d\pi} < 0$ it must be that type L agents choose $\pi < 1$. ■

¹⁵See Appendix for details.

5 Final remarks

This study quantifies the redistributive effects of inflation for a sample of OECD countries by calibrating the microfounded model in Boel and Camera (2009), which is based on Lagos and Wright (2005). Two important quantitative issues are addressed. First, I pin down the distribution of deposit accounts and financial assets across countries using harmonized micro data from the *Luxembourg Wealth Study*. I find that the share of household financial wealth held in liquid assets decreases with income, but there are significant cross-country differences in terms of the magnitude of that share. Second, I estimate money demand carefully by accounting for structural breaks and I show that such breaks exist and are significant for all countries considered except for Austria and Finland.

Several results hold. First, the welfare cost of inflation changes over time, but the direction of the change varies across countries, with Canada and Japan being the only two countries experiencing an increase. Second, inflation can act as a regressive tax, similarly to what is documented for the United States. Third, the magnitude of the redistributive effects differs across countries and it is affected not only by wealth inequality, but also by the curvature and by the level of the money demand curve. Last, I extend the model in Boel and Camera (2009) to incorporate a political-economy equilibrium where randomly selected representatives for the different agents' types can bargain over the inflation rate. I show that in such equilibrium there is always a subset of the population that prefers an inflationary policy.

This analysis also raises questions. Specifically, one must wonder whether the redistributive effects of inflation observed when agents can choose between money and an inflation-protected nominal asset would still hold in an economy with real assets. Boel and Díaz (2012) address this issue by extending the model with capital of Aruoba et al. (2011) to account for heterogeneity and by then calibrating the model economy to a sample of OECD countries.

Appendix

1. Relevant equations for model where money is the only asset

At the beginning of market two, an agent of type j faces the following problem:

$$\begin{aligned} W_j(m_{j,k}) &= \max_{q_j, x_{j,k}, m'_j \geq 0} [U(q_j) - x_{j,k} + \beta V_j(m'_j)] \\ \text{s.t.} \quad & x_{j,k} = q_j + \pi m'_j - m_{j,k} - \tau \end{aligned} \tag{18}$$

and therefore $W_j(m_{j,k}) = U(q^*) - q^* - \pi m'_j + m_{j,k} + \tau + \beta V_j(m'_j)$.

At the beginning of market one she faces the following problem:

$$V_j(m_j) = \max m_j + \frac{\alpha_j}{2} [u(c_j) - c_j] + W_j(0) \tag{19}$$

where the maximization is over $pc_j \leq m_j$.

The relative prices in the two markets satisfy:

$$p = \phi'(y) = 1 \tag{20}$$

The money growth rate (i.e., the inflation rate) is controlled via per-capita lump-sum transfers τ in market two. The government budget constraint therefore is:

$$\tau = (\pi - 1)(\rho m_H + (1 - \rho)m_L) \tag{21}$$

Money market clearing requires:

$$\frac{M}{p_2} = \rho m_H + (1 - \rho)m_L \tag{22}$$

Goods market clearing in market two requires:

$$q^* = (1 - \rho) \left[\frac{\alpha}{2} (x_{L,s} + x_{L,b}) + (1 - \alpha)x_{L,n} \right] + \rho \left[\frac{\alpha}{2} (x_{H,s} + x_{H,b}) + (1 - \alpha)x_{H,n} \right] \tag{23}$$

Goods market clearing in market one requires:

$$y = \rho \alpha_H c_H + (1 - \rho) \alpha_L c_L \tag{24}$$

2. Additional equations for model with nominal asset

In this case I focus on an equilibrium in which $b_H > m_H = 0$ and $m_L > b_L = 0$. We already know that in order for this to be true, it must be that $\pi \in (\bar{\pi}, \tilde{\pi})$ where $\bar{\pi} = \beta + \alpha_H(1 - \beta)$ and $\tilde{\pi} = \beta + \alpha_H - \beta\alpha_L$. In this case, an agent of type L solves problems

$$\begin{aligned} W_L(m_{L,k}) &= \max_{q_L, x_{L,k}, m'_L \geq 0} [U(q_L) - x_{L,k} + \beta V_L(m'_L)] \\ \text{s.t.} \quad & x_{L,k} = q_L + \pi m'_L - m_{L,k} - \tau \end{aligned} \quad (25)$$

and

$$V_L(m_L) = \max m_L + \frac{\alpha_L}{2} [u(c_L) - c_L] + W_L(0), \quad (26)$$

where the maximization is over $pc_L \leq m_L$. Note that (25) and (26) are analogous to (18) and (19).

Instead, an agent of type H solves the following problem at the beginning of market two:

$$\begin{aligned} W_H(m_{H,k}) &= \max_{q_H, x_{H,k}, b'_H \geq 0} [U(q_H) - x_{H,k} + \beta V_H(b'_H)] \\ \text{s.t.} \quad & x_{H,k} = q_H + \pi\psi b'_H - m_{H,k} - \tau \end{aligned} \quad (27)$$

and therefore $W_H(m_{H,k}) = U(q^*) - q^* - \pi\psi b'_H + m_{H,k} + \tau + \beta V_H(b'_H)$.

At the beginning of market one, instead, an agent of type H solves the following problem:

$$V_H(b_H) = \max \alpha_H b_H + \frac{\alpha_H}{2} [u(c_H) - c_H] + W_H(0) \quad (28)$$

where the maximization is over $pc_H \leq b_H$.

The government budget constraint is:

$$\tau = (\pi - 1)(1 - \rho)m_L \quad (29)$$

Money market clearing requires:

$$\frac{M}{p_2} = (1 - \rho)m_L, \quad (30)$$

and the asset's price satisfies:

$$\pi\psi b_H = \alpha_H b_H \quad (31)$$

Data

The analysis has been conducted using the quarterly data listed below. All data are from the International Financial Statistics unless otherwise noted. GDP and money supply are in local currencies.

Austria (1967q1-1998q4). Money supply: M1 (12234); interest rate: money market rate (12260B); price deflator: GDP deflator (12299BIP); output: nominal GDP, sa (12299B).

Canada (1957q1-2008q4). Money supply: M1 (15634); interest rate: treasury bill rate (15660C); price deflator: GDP deflator (15699BIR); output: nominal GDP, sa (15699B).

Finland (1980q1-1998q4). Money supply: M1 (OECD); interest rate: money market rate (17260B); price deflator: GDP deflator (17299BIP); output: nominal GDP (17299BIP).

Italy (1971q1-1998q4). Money supply: Money supply: M1 (13634); interest rate: money market rate (13660B), price deflator: CPI (13664), output: nominal GDP (13699B.C).

Japan (1957q1-2009q4). Money supply: M1, sa (IFS, National Definition) (15859MAC); interest rate: money market rate (15860B); price deflator: GDP deflator (15899BIR); output: nominal GDP, sa (15899B.C).

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