ON THE REDISTRIBUTIVE EFFECTS OF INFLATION: AN INTERNATIONAL PERSPECTIVE*

Paola Boel
Sveriges Riksbank†

*I wish to thank Gabriele Camera, Julián P. Díaz and Randall Wright for useful comments and discussions. As well, I would like to thank seminar participants at the Chicago Fed Workshop on Money, Banking, Payments and Finance, the SAET Meetings at the University of Queensland, Sveriges Riksbank, the Federal Reserve Board and Università L. Bocconi. The views expressed in this paper are solely the responsibility of the author and should not be interpreted as reflecting the views of the Executive Board of Sveriges Riksbank.

†Sveriges Riksbank, Research Division, SE-103 37 Stockholm, Sweden (e-mail: paola.boel@riksbank.se)
Abstract

I use a microfounded model of money to quantify the redistributive effects of expected inflation in a sample of OECD countries. In doing so, I address two quantitative issues. First, I pin down money demand rigorously, which implies accounting for the possibility of policy breaks. I show that this has significant implications for both the quality of the fit as well as the measurements’ values. Second, I construct comparable estimates of wealth distribution across countries by using harmonized microdata from the Luxembourg Wealth Study. Two main results emerge from the analysis. First, in all countries considered inflation acts as a regressive tax. Second, the magnitude of such redistributive effects differs across countries and it depends not only on wealth distribution, but also on the curvature and the level of money demand for any given interest rate.

Keywords: Money, Heterogeneity, Redistribution, Calibration, Welfare Cost of Inflation

JEL codes: E4, E5
1 Introduction

What are the welfare costs induced by inflation? This has been a classic question in monetary economics ever since Bailey (1956). The consensus is that inflation and welfare are negatively correlated in a representative-agent model, but few studies so far have investigated the redistributive effects of expected inflation. Among them, Boel and Camera (2009) and Camera and Chien (2012) develop microfounded models of money to show that when money is the only asset, a faster rate of monetary expansion acts as a progressive tax that lowers wealth inequality. When an additional nominal asset can be traded, inflation acts as a regressive tax instead.1 These findings share similarities with Erosa and Ventura (2002) who, using a model with costly credit, find that inflation acts as a regressive consumption tax in the United States.

These results suggest that the redistributive effects of expected inflation depend on composition and distribution of wealth, both of which vary substantially across countries.2 Therefore, one should wonder how such differences might affect the redistributive impact of inflation. This issue has been largely overlooked by the literature so far and the focus has been almost solely on the United States with very few exceptions (e.g. the study for Canada of Chiu and Molico, 2010). The present study takes a first step at filling this gap, using the existing microfounded model of money in Boel and Camera (2009) to quantify the redistributive effects of expected inflation in a sample of OECD countries.

Specifically, the model is calibrated to all OECD economies for which sufficient data are available.3 In order to do so, two quantitative issues are addressed. First, I pin down money demand rigorously. This is of paramount importance since the welfare cost of inflation is defined as the area under the money demand curve that is lost as steady-state inflation increases, as in Bailey (1956). Given the extensive research concerned with the stability of money demand,4 this implies accounting for the possibility of policy breaks. I show that

---

1 In other microfounded models of money, Chiu and Molico (2010) and Chiu and Molico (2011) investigate the distributional effects of inflation in economies where money is the only asset.
2 See for example Wolff (1996) and Jantti et al. (2008).
3 The following quarterly data are necessary for the calibration: nominal GDP, price level, money supply and short-term interest rates. Moreover, annual microdata are used to derive information on financial wealth distribution. A detailed description of the data is available in the sections Quantitative Analysis and Data.
4 For a recent literature survey, see Sriram (2001).
this approach improves the quality of the fit when compared to the representative-agent study in Boel and Camera (2011), where the model actually failed to fit the data for some countries. Numerical values for the average welfare cost of inflation are also affected.

Second, I account for differences in 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 microdata 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. For all countries considered, I find that the share of household financial wealth held in liquidity (deposit accounts) decreases with income. There are, however, significant cross-country differences in terms of the magnitude of that share which should obviously have important implications for the redistributive effects of inflation.

Two main results emerge from the analysis. First, in all countries considered the direction of the redistributive effect is in line with the one documented for the United States in that inflation acts as a regressive tax. Second, the magnitude of such redistributive effects differs across countries and it depends not only on wealth distribution but also, and very importantly, on the curvature and the level of the money demand curve for any given interest rate. Therefore, inflation’s regressive effects are not necessarily stronger in a country with a more unequal wealth distribution.

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 for a heterogeneous economy. Section 4 concludes.

5Cyprus, Germany, Luxembourg and Sweden also participate in the LWS. I exclude them from my analysis because of data limitations.
2 The model

Consider the heterogeneous-agent model in Boel and Camera (2009), 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 $\rho$ 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 $u$, $\phi$ 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 $U'(q) = 1$.

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 $\pi$ 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:

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

(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

---

6In this section, I outline the key derivations of the model, but a more detailed presentation is available in the Appendix.
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 $\pi$. Similarly, let $y_\pi$ denote production in market one given $\pi$. Equilibrium ex-ante welfare for type $j$ is:

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

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 $\bar{m}_\pi$ 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 $\psi$ 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:

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

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

$$
\alpha_H(\frac{1}{\beta} - 1) = \frac{\alpha_H}{2} \left[ \frac{u'(c_H)}{p} - 1 \right]
$$
and ex-ante welfare for type $H$ agents is:

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

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 $(\pi - 1)\frac{\psi}{1 - \rho}\bar{m}_\pi$, 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, all of which participate in the Luxembourg Wealth Survey. 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 holdings as well as disposable income, all of which are necessary to calibrate 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 average 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 ten percent annual inflation as a comparison to an economy with no inflation or at the Friedman rule.

---

7Cyprus, 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.

8With a nominal asset the Friedman rule is not sustainable in the equilibrium considered, since it must be $\pi > \bar{\pi} > \beta$. 
3.1 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 $i$: $c = \left( \frac{\alpha}{2i+\alpha} \right)^{\frac{1}{1+\alpha}}$.

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 $\alpha$ is set so that the theoretical interest elasticity of money demand, denoted by $\varepsilon_m$, matches the empirical elasticity of money demand, which I estimate following Goldfeld and Sichel (1990). As shown in Boel and Camera (2009), $\varepsilon_m = \frac{2i\phi'(y)}{\alpha u''(c)}$ 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 $P$ is the nominal price level, $M$ is money supply, and $Y$ is real output.\footnote{Data 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 lack of data availability for M1. For all other countries, M1 is used instead.}

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 $L = \frac{m}{2pc+A}$.\footnote{Note that $\frac{m}{2pc+A}$ is the sum of output in the first and second market.}

Given the functional forms selected, money demand becomes $L = \frac{1}{\alpha/2+Ac-\gamma}$. 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, calibrated parameters and $R^2$ as a measure of the quality of fit of the model to the data.

Once I have identified the parameter vector $\Omega$, 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 $\pi$ and a lower inflation rate $z \in [\beta, \pi)$.

If I reduce $\pi$ to $z$ and adjust consumption in both markets by the proportion $\Delta_z$, then ex-ante welfare is defined by:

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

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

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

Notes: The values for net nominal interest rates ($i$) and net inflation rates ($\pi - 1$) are in percentage points on a quarterly basis; $\beta$ is the quarterly discount factor; $\varepsilon_m$ 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.

Figure 1 shows the quality of 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 $L = \frac{1}{\alpha/2 + Ac}$ with the calibrated parameters’ values.
Figure 1: Money Demand with Fitted Model

Panel A: Austria (1967q1-1998q4)

Panel B: Canada (1957q1-2008q4)
Panel C: Finland (1980q1-1998q4)

Panel D: Italy (1971q1-1998q4)
Panel E: Japan (1957q1-2009q4)

Panel F: Norway (1987q3-2009q4)
Panel G: United Kingdom (1969q2-2006q1)

Panel H: United States (1959q4-2009q4)
3.2 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 notices that in some instances the fitted model captures neither the curvature nor the level of money demand at a given interest rate even in cases where $R^2$ is positive. Japan, Italy, Norway 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 for the cases of Austria and Finland. Dates and policy changes responsible for such breaks are listed in Table 2. Note that, for all countries experiencing a policy break, the quality of the fit increases compared to Boel and Camera (2011) where for some countries the representative-agent model actually failed to fit the data.

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.\textsuperscript{11} 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. 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

\textsuperscript{11}“Bank of Italy - History.” \textit{Bank of Italy}. Web. 2012.
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.

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

<table>
<thead>
<tr>
<th>Country</th>
<th>Quarters</th>
<th>Break Explanation</th>
<th>$\varepsilon_m$</th>
<th>$\alpha$</th>
<th>$A$</th>
<th>$R^2$</th>
<th>Welfare Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>$\varepsilon_m$</td>
<td>$\alpha$</td>
<td>$A$</td>
<td>$R^2$</td>
<td>0%</td>
</tr>
<tr>
<td>Austria</td>
<td>1967q1-1998q4</td>
<td>No break</td>
<td>-0.248</td>
<td>0.09</td>
<td>1.17</td>
<td>0.26</td>
<td>0.37</td>
</tr>
<tr>
<td>Canada</td>
<td>1957q1-1982q3</td>
<td>M1 target end</td>
<td>-0.087</td>
<td>0.33</td>
<td>1.67</td>
<td>0.27</td>
<td>0.09</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>-0.402</td>
<td>0.05</td>
<td>0.77</td>
<td>0.66</td>
<td>0.74</td>
</tr>
<tr>
<td>Finland</td>
<td>1980q1-1998q4</td>
<td>No break</td>
<td>-0.212</td>
<td>0.18</td>
<td>0.66</td>
<td>0.70</td>
<td>0.52</td>
</tr>
<tr>
<td>Italy</td>
<td>1971q1-1994q3</td>
<td>BI Independence</td>
<td>-0.141</td>
<td>0.38</td>
<td>0.40</td>
<td>0.14</td>
<td>0.48</td>
</tr>
<tr>
<td></td>
<td>1994q4-1998q4</td>
<td></td>
<td>-0.113</td>
<td>0.30</td>
<td>0.61</td>
<td>0.13</td>
<td>0.25</td>
</tr>
<tr>
<td>Japan</td>
<td>1957q1-2001q1</td>
<td>QE start</td>
<td>-0.089</td>
<td>0.30</td>
<td>0.66</td>
<td>0.25</td>
<td>0.20</td>
</tr>
<tr>
<td></td>
<td>2001q2-2006q1</td>
<td>QE end</td>
<td>-0.103</td>
<td>0.00</td>
<td>0.28</td>
<td>0.54</td>
<td>0.07</td>
</tr>
<tr>
<td></td>
<td>2006q2-2009q4</td>
<td></td>
<td>-0.024</td>
<td>0.06</td>
<td>0.22</td>
<td>0.33</td>
<td>1.97</td>
</tr>
<tr>
<td>Norway</td>
<td>1987q3-1992q3</td>
<td>Krone devaluation</td>
<td>-0.812</td>
<td>0.01</td>
<td>0.16</td>
<td>0.79</td>
<td>2.19</td>
</tr>
<tr>
<td></td>
<td>1992q4-2009q4</td>
<td></td>
<td>-0.110</td>
<td>0.21</td>
<td>0.43</td>
<td>0.17</td>
<td>0.59</td>
</tr>
<tr>
<td>UK</td>
<td>1969q2-1992q3</td>
<td>ERM crisis</td>
<td>-1.220</td>
<td>0.01</td>
<td>0.92</td>
<td>0.18</td>
<td>0.51</td>
</tr>
<tr>
<td></td>
<td>1992q4-2006q1</td>
<td></td>
<td>-0.096</td>
<td>0.24</td>
<td>6.89</td>
<td>0.43</td>
<td>0.04</td>
</tr>
<tr>
<td>US</td>
<td>1959q1-1973q1</td>
<td>Bretton Woods end</td>
<td>-0.078</td>
<td>0.24</td>
<td>0.90</td>
<td>0.23</td>
<td>0.23</td>
</tr>
<tr>
<td></td>
<td>1973q2-2009q4</td>
<td></td>
<td>-0.084</td>
<td>0.30</td>
<td>1.24</td>
<td>0.40</td>
<td>0.15</td>
</tr>
</tbody>
</table>

Notes: Structural breaks in money demand are identified conducting Chow (1960) 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 Canada, Italy, Japan, Norway and the US the Chow test is significant at the 1% level and for the UK at the 5% level. Welfare costs are for 10% annual inflation relative to either 0% inflation or the Friedman rule (FR).

Figure 2 shows the quality of fit of the model to the data for the subsamples summarized in Table 2. Austria and Finland, for which no breaks have been identified, are not included.
Figure 2: Money Demand with Fitted Model and Structural Breaks
Panel C: Japan (1957q1-2009q4)

Panel D: Norway (1987q3-2009q4)
Panel E: United Kingdom (1962q2-2006q1)

Panel F: United States (1959q1-2009q4)
Once I have identified the structural breaks, I recalibrate the parameters $\alpha$ and $A$ for all subsets summarized in Table 2. This also allows me to determine how the welfare cost of inflation changed over time due to policy breaks. Results are in Table 2. In most countries considered, the welfare cost of inflation decreased over time due to an increased 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,\(^{12}\) 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 early 2006, 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 also recalibrate the parameters $\alpha$ and $A$ for the full-sample period as the weighted average of $\alpha$ and $A$ for the subsamples listed in Table 2. This allows me to pin down the average welfare costs of inflation for the full-sample period while still accounting for how parameters $\alpha$ 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 changed due to policy breaks. Second, the welfare cost of inflation appears to be positively correlated with the ratio $\alpha/A$. From an economic perspective, a higher ratio $\alpha/A$ implies a higher weight assigned to monetary market-one trade relative to market-two trade. Hence the higher welfare loss induced by inflation.

\(^{12}\)See Gomme (1998).
Table 3: Average recalibrated parameters and welfare costs for representative agent case.

<table>
<thead>
<tr>
<th>Country</th>
<th>Quarters</th>
<th>Recalibrated Parameters</th>
<th>Welfare Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>i</td>
<td>π − 1</td>
<td>β</td>
</tr>
<tr>
<td>Austria</td>
<td>1967q1-1998q4</td>
<td>1.48</td>
<td>1.03</td>
</tr>
<tr>
<td>Canada</td>
<td>1957q1-2008q4</td>
<td>1.54</td>
<td>1.03</td>
</tr>
<tr>
<td>Finland</td>
<td>1980q1-1998q4</td>
<td>2.45</td>
<td>1.28</td>
</tr>
<tr>
<td>Italy</td>
<td>1971q1-1998q4</td>
<td>2.90</td>
<td>1.38</td>
</tr>
<tr>
<td>Japan</td>
<td>1957q1-2009q4</td>
<td>1.24</td>
<td>1.11</td>
</tr>
<tr>
<td>Norway</td>
<td>1987q3-2009q4</td>
<td>1.62</td>
<td>0.64</td>
</tr>
<tr>
<td>UK</td>
<td>1969q2-2006q1</td>
<td>2.03</td>
<td>1.69</td>
</tr>
<tr>
<td>US</td>
<td>1959q1-2009q4</td>
<td>1.30</td>
<td>0.89</td>
</tr>
</tbody>
</table>

Notes: α and A are calculated as the weighted average of α and A for the subsamples listed in Table 2. For Austria and Finland no structural breaks are identified and therefore α and A are the ones listed in Table 1. The values for net nominal interest rates (i) and net inflation rates (π − 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).

### 3.3 Heterogeneity

In order 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 such that ρα_H + (1 − ρ)α_L = α for some given value ρ. Third, I use micro data from the Luxembourg Wealth Survey\(^{13}\) to pin down the empirical ratio of deposit accounts over total financial assets for different households’ income quintiles in the different countries considered. Fourth, I get a theoretical expression for the share of liquidity held by type H agents and denoted by \(\frac{\rho m_H}{m}\). Associating \(j = H\) to the top two income quintiles one gets ρ = 0.4. Fifth, I find the values α_L and α_H by matching the theoretical liquidity share to its empirical counterpart and using the mean preserving spread \(\rho α_H + (1 − ρ)α_L = α\).

\(^{13}\)For 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).
It is important to emphasize that cross-country comparisons of wealth 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 microdata from the *Luxembourg Wealth Study*. This is because the LWS is an international project that has collected household microdatabases from a sample of OECD countries, and has standardized the wealth concept and sampling frame. Specifically, the LWS reports harmonized data for household deposit accounts (DA),\(^{14}\) which I use as a measure of liquidity, total financial assets (TFA1)\(^{15}\) and disposable income (LIS.DPI)\(^{16}\). Table 4 reports the calculations for the empirical ratio of deposit accounts over total financial assets for different households’ income quintile.

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

*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).

As reported in Table 4, the share of deposit accounts over total financial assets decreases with income for all countries considered, even though its magnitude varies across countries. This implies 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 countries.

---

\(^{14}\)Deposit 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.).

\(^{15}\)Total financial assets (TFA1) are the sum of deposit accounts, bonds, stocks and mutual funds.

\(^{16}\)I 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.
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). 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.

Once I have the calibrated parameters $\alpha_L$ and $\alpha_H$ for all countries, using equation (2) and the same procedure delineated in (6) I can calculate the welfare costs of inflation for type H and type L agents for the case where money is the only asset. Similarly, using equations (2) and (5) I can do the same for the case where an additional nominal asset is available. Table 5 reports the results.

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

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, $\alpha_H$ and $\alpha_L$ are calibrated to match the average $\alpha$ 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, inflation acts as a
progressive tax in that the poor suffer more than the rich - in Italy, Japan, Norway and the United States the rich actually benefit from inflation. When instead I consider an economy with an additional nominal asset, inflation acts as a regressive tax so that rich agents benefit from inflation whereas poor ones suffer from it.

The magnitude of the redistributive effect, however, varies across countries. Moreover, inflation’s regressive impact does not depend only on the composition and distribution of financial wealth, but also on the curvature and level of money demand at any interest rate. For example, in the United States the redistributive effects are the least severe in the sample even though wealth is more unequally distributed. That is because money demand has flattened and shifted downwards over time. In Norway, instead, inflation’s redistributive impact is the strongest even with a less unequal wealth distribution because money demand has remained relatively high throughout the sample period.

4 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). In order to do so, two quantitative issues are addressed. First, I pin down money demand rigorously by accounting for the possibility of policy breaks. I show that this approach improves the quality of the fit when compared to the representative-agent study in Boel and Camera (2011), where the model actually failed to fit the data for some countries. Second, I account for differences in wealth distribution across countries by using harmonized microdata from the Luxembourg Wealth Study. For all countries considered, I find that the share of household financial wealth held in liquidity decreases with income. There are, however, significant cross-country differences in terms of the magnitude of that share.

Two main results emerge from this study. First, in all countries considered inflation acts as a regressive tax. Second, the magnitude of inflation’s redistributive effects differs across countries and it depends not only on wealth distribution but also on the curvature and the level of the money demand curve for any given interest rate. Therefore, inflation’s regressive effects are not necessarily stronger in a country with a more unequal wealth distribution.
The analysis also raises questions. In particular, one must wonder if the direction of inflation’s redistributive effects depends on the nature of the alternative asset considered and if results might change in an economy with real assets. The ongoing work in Boel and Díaz (2012) investigates this issue by extending the model with capital of Aruoba et al. (2011) to account for heterogeneity.
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:

$$W_j(m_{j,k}) = \max_{q_j, x_{j,k}, m'_j \geq 0} [U(q_j) - x_{j,k} + \beta V_j(m'_j)] \text{ s.t. } x_{j,k} = q_j + \pi m'_j - m_{j,k} - \tau$$  \hspace{1cm} (7)

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:

$$V_j(m_j) = \max m_j + \frac{\alpha_j}{2} [u(c_j) - c_j] + W_j(0)$$  \hspace{1cm} (8)

where the maximization is over $pc_j \leq m_j$. The relative prices in the two markets satisfy:

$$p = \phi'(y) = 1$$  \hspace{1cm} (9)

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

$$\tau = (\pi - 1)(\rho m_H + (1 - \rho)m_L)$$  \hspace{1cm} (10)

Money market clearing requires:

$$\frac{M}{p_2} = \rho m_H + (1 - \rho)m_L$$  \hspace{1cm} (11)

Goods market clearing in market two requires:

$$q^* = (1 - \rho)[\frac{\alpha}{2}(x_{L,s} + x_{L,b}) + (1 - \alpha)x_{L,n}] + \rho[\frac{\alpha}{2}(x_{H,s} + x_{H,b}) + (1 - \alpha)x_{H,n}]$$  \hspace{1cm} (12)

Goods market clearing in market one requires:

$$y = \rho \alpha_H c_H + (1 - \rho)\alpha_L c_L$$  \hspace{1cm} (13)
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

$$W_L(m_{L,k}) = \max_{q_{L,x_{L,k},m_L'} \geq 0} \left[ U(q_{L}) - x_{L,k} + \beta V_L(m_L') \right]$$
\hspace{1cm} (14)

s.t. \hspace{1cm} $x_{L,k} = q_{L} + \pi m_L' - m_{L,k} - \tau$

and

$$V_L(m_L) = \max m_L + \frac{\alpha_L}{2} [u(c_L) - c_L] + W_L(0), \hspace{1cm} (15)$$

where the maximization is over $p_{cL} \leq m_L$. Note that (14) and (15) are analogous to (7) and (8). Instead, an agent of type $H$ solves the following problem at the beginning of market two:

$$W_H(m_{H,k}) = \max_{q_{H,x_{H,k},b_H'} \geq 0} \left[ U(q_{H}) - x_{H,k} + \beta V_H(b_H') \right]$$
\hspace{1cm} (16)

s.t. \hspace{1cm} $x_{H,k} = q_{H} + \pi b_H' - m_{H,k} - \tau$

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

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

$$V_H(b_H) = \max \alpha_H b_H + \frac{\alpha_H}{2} [u(c_H) - c_H] + W_H(0) \hspace{1cm} (17)$$

where the maximization is over $p_{cH} \leq b_H$. The government budget constraint is:

$$\tau = (\pi - 1)(1 - \rho) m_L \hspace{1cm} (18)$$

Money market clearing requires:

$$\frac{M}{p_2} = (1 - \rho)m_L, \hspace{1cm} (19)$$

and the asset’s price satisfies:

$$\pi \psi b_H = \alpha_H b_H \hspace{1cm} (20)$$
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).

Norway (1982q1-2009q4). Money supply: M1 (14234); interest rate: government bond yield (14261), price deflator: CPI (14264); output: nominal GDP (14299B).

United Kingdom (1969q2-2006q1). Money Supply: break-adjusted M0, Bank of England (LP-MVUBNI); interest rate: treasury bill rate (11260C); price deflator: GDP deflator (11299BIR); output: nominal GDP, sa (11299B.C).

United States (1959q1-2009q4). Money supply: sweep-adjusted M1 (M1S from sweepmeasures.com, Cynamon et al., 2006); interest rate: treasury bill rate (11160C); price deflator: GDP deflator (11199BIR); output: nominal GDP, sa (11199B).
References


