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The quantity theory of money, 1870-2020

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Abstract
This study re-assesses the validity of the quantity theory of money (QTM) for the very long sample, 1870 to 2020, for 18 industrial countries using the dataset from Jordà et al. (2017). It considers structural changes in the economic and financial sectors and changes in monetary policy frameworks. Three findings are presented. First, the results from panel cointegration tests show that the long-run relationship between excess money growth and inflation holds if longer runs of data are used. Second, panel regressions confirm the presence of long and variable lags in the monetary policy transmission, as predicted by Milton Friedman. For the full sample, the average speed of adjustment from excess money growth to inflation in industrial countries was about two years amid heterogeneity across time and countries. Third, the results show that over recent decades, structural change - coinciding with the Great Moderation and, in part, reflecting changes in payment technologies - has led to a collapse of QTM.

JEL codes: B16, B23, E40, E50, N1

Keywords: Excess money growth, Great Moderation, payment technologies, structural change, panel cointegration tests.

Non-technical summary

The quantity theory of money (QTM) is a central tenet of monetary economics. According to QTM, money growth is an essential driver of inflation. Many textbooks suggest that the long-run relationship between money growth and inflation is reliable across time and countries. Milton Friedman famously discovered that inflation is "always and everywhere a monetary phenomenon" and that monetary policy actions "affect economic conditions only after a lag that is both long and variable". Robert Lucas emphasized that the monetary pillar of central bank policy decisively contributed to reducing inflation when it was too high. The existence of a close link between money growth and inflation was often debated. The Keynesian and New Keynesian schools suggested that money is endogenous to the economy, and causality would run from inflation to money growth. Since the 1990s, many central banks have switched to the inflation-targeting strategy that emphasizes forecasts of future inflation and economic growth based on macroeconomic models in which money is an endogenous variable. As the study shows, these strategic choices of independent central banks also reflect underlying changes in the validity of empirical long-run relationships, notably the collapse of QTM in the post-1985 sample.

Previous empirical research has assessed QTM based on several approaches: (i) cross-sectional studies of the relationship between (longer run) average money growth and inflation rates across countries, (ii) time series analyses of the relationship between money growth and inflation in individual economies, and (iii) panel analyses of the relationship between money growth and inflation rates for different country groups and periods. This study re-assesses the validity of QTM for the very long sample, 1870 to 2020, for a panel of 18 industrial countries. Compared with previous studies on the subject, it covers a longer sample of 150 years, focuses on industrial countries, goes beyond measuring correlations, and looks into structural change in the relationship owing to massive changes in the economic and financial sector, payment technologies, and monetary policy frameworks. It also advances the methodology by employing estimation techniques that are robust to cross-sectional dependence, an issue that was widely ignored in earlier tests of QTM.

The empirical analysis uses excess money growth as a measure of the money supply since, from a medium-term perspective, excess money growth - the difference between money growth and real GDP growth - should be more closely linked to inflation. It provides empirical results distinguishing between narrow and broad monetary aggregates. Applying unit root tests for 18 industrial countries, it can be shown that long-run price homogeneity is supported, but medium-run price homogeneity typically does not hold for industrial countries, that issues of bi-directional causality could be present, and that velocity shocks led to departures from OTM. This tentative finding suggests that Friedman's famous dictum that inflation is always and everywhere a monetary phenomenon may not be supported by the data. However, approaches that extract the low-frequency component from money growth and inflation suggest that the correlation between both variables suggests that the correlation between both variables is fairly close amid heterogeneity across countries and monetary aggregates.

The empirical approach of this study is to apply the Common Correlated Effects Pooled Mean Group (CCEPMG) technique to estimate the long-run coefficient on the link between excess money growth and inflation, thereby addressing the issue. Within this approach, I examine time variation by estimating the regressions for different subsamples, providing rolling window regressions of the CCEPMG estimates, and modifying long-run restrictions to distinguish between cross-country and individual country results. In addition, I provide estimates on the interest rate elasticity from a cointegrated money demand model using panel Fully Modified Ordinary Least Squares (FMOLS) and Dynamic OLS to show that changes in the payment technology influenced the long-run relationship between money growth and inflation.

Three main findings are presented. First, the results from panel cointegration tests show that the long-run relationship between excess money growth and inflation holds if longer runs of data are used. Second, panel regressions confirm the presence of long and variable lags in the monetary policy transmission, as predicted by Milton Friedman. For the full sample, the average speed of adjustment from excess money growth to inflation in industrial countries was about two years amid heterogeneity across time and countries. Third, the results show that over recent decades, structural change - coinciding with the Great Moderation and, in part, reflecting changes in payment technologies - has led to a collapse of QTM. However, given the nature of the identified structural break, it appears to be difficult to predict reliably when the long-run relationship will become closer again.

1. Introduction

The quantity theory of money (QTM) is a central tenet of monetary economics and became the workhorse model of the Monetarist school in the 20th century.[1] It postulates a stable long-run link between the quantity of money and prices and implies that money growth is a key driver of inflation over longer horizons. In its original formulation, money growth was thought to exert a causal influence on inflation. Pioneering studies in monetary economics have stressed that money growth is essential for monetary policy and that a central bank should follow a money growth rule to achieve price stability. Milton Friedman (1961, 1970) famously discovered that inflation is "*always and everywhere a monetary phenomenon*" and that monetary policy actions "*affect economic conditions only after a lag that is both long and variable*". Lucas (2006) emphasized that the monetary pillar of central bank policy decisively contributed to reducing inflation when it was too high. In the 1970s and 1980s, central bankers and researchers paid much attention to the quantity equation, and many countries pursued monetary targeting as their monetary policy strategy (see Table 1). Towards the end of the 20th century, severe velocity shocks occurred, thus violating the constant money velocity assumption of the quantity theory. Monetary targeting has widely lost relevance in central banking practice because central bankers can no longer confidently use monetary aggregates as leading indicators for future inflation. Most central banks in advanced and emerging countries today target inflation or exchange rates. The research question of this study is twofold. First, as has been asked in many earlier studies, does QTM still hold in industrial countries? Second, has the long-run relationship between money growth and inflation varied over time around important structural changes? An answer to those two questions promises to improve our understanding of whether money growth may warrant special attention by central bankers.

The existence of a close link between money growth and inflation was often challenged in the literature. First and foremost, the Keynesian and New Keynesian schools disputed this point, arguing that money is endogenous and causality would run in the opposite direction, i.e., from inflation to money growth.[2] In response, Lucas (1980 and 1996) suggested that the link between money growth and inflation may not be found in the data owing to statistical noise and would be better visible from the low-frequency inflation and money growth components. Second, economic shocks may impact inflation and money growth differently. This was the case during the Great Moderation and the period of increased globalization, which contributed to systematic declines in inflation in many countries (Rogoff, 2003). Three explanations for why the long-run relationship between money growth and inflation is

[1] The relationship was already known in the 16th century, as evident from early works by Nicolaus Copernicus. It was restated by classical economists (e.g., David Hume, John Locke, Jean Bodin and David Ricardo) and further refined by Irving Fisher and Milton Friedman in the 20th century. See Schnabel (2023).
[2] See for example Kaldor (1989) and later Woodford (2008).

vulnerable dominate the literature: changes in policy regimes (Lucas, 1980; Rolnick and Weber, 1997), financial innovation, and institutional changes, including technological innovation concerning payment systems (Bordo and Jonung, 1981; Siklos, 1993; McCallum and Nelson, 2011), and changes in monetary policy frameworks from (intermediate) monetary to inflation targeting, which helped central banks to better anchor inflation expectations in line with an inflation target (De Grauwe and Polan, 2005; Teles et al., 2016). However, these factors cannot explain that coinciding with higher inflation following the COVID-19 pandemic that started at the end of 2019, the link between money growth and inflation strengthened again (Borio et al., 2023).

***** insert Table 1 here *****

This study provides a reassessment of QTM based on panel approaches and using the dataset from Jordà et al. (2017) for 18 industrial countries that allow to conduct tests for the very long sample from 1870 to 2020. The empirical analysis focuses on excess money growth as a measure of the money supply since, from a medium-term perspective, excess money growth – the difference between money growth and real GDP growth – should be more closely linked to inflation (Deutsche Bundesbank, 2005; Roffia and Zhagini, 2007; Borio et al., 2023).[3] I first check the time series properties of the variables by applying unit root tests for 18 industrial countries. The results show that an I(2) modeling strategy is not indicated (Juselius, 2021; Assenmacher and Beyer, 2020; Jung and Carcel Villanova, 2020). Second, I conduct tests for cross-section dependence (Pesaran, 2004 and 2015) and find that this issue needs to be addressed in the empirical specification of the panel cointegration model. To this end, I apply the Common Correlated Effects Pooled Mean Group (CCEPMG) technique by Pesaran et al. (2006) to estimate the long-run coefficient on the link between excess money growth and inflation. Within this approach, I examine time variation by estimating the regressions for different subsamples and providing rolling window regressions of the CCEPMG estimator. Moreover, I examine country heterogeneity by relaxing the assumption of a unitary coefficient between excess money growth and inflation to hold in all industrial countries simultaneously. Furthermore, I assess whether changes in the payment technology influenced the long-run relationship and provide estimates on the interest rate elasticity from a cointegrated money demand model using panel Fully Modified Ordinary Least Squares (FMOLS) and Dynamic OLS following the approach by Teles et al. (2018).

Three findings are presented. First, the results from panel cointegration tests show that the long-run relationship between excess money growth and inflation holds if longer runs of data are used. Second, panel regressions confirm the presence of long and variable lags in the monetary policy transmission, as predicted by Milton Friedman. For the full sample, the average speed of adjustment

[3] In qualitative terms, the results for the long-run relationship are similar for money and excess money growth.

from excess money growth to inflation in industrial countries is estimated to be about two years amid heterogeneity across time and countries. Third, the results show that over recent decades, structural change - coinciding with the Great Moderation and, in part, reflecting changes in payment technologies - has led to a collapse of QTM.

This study contributes to the literature as follows. First, many empirical studies (e.g., Friedman, 1969; McCandless and Weber, 1995; Barro, 2007; McCallum and Nelson, 2011) found that the long-run relationship between money growth and inflation holds across time and countries, as can be demonstrated based on correlations with long-run averages of both series are plotted (see Chart 1). As explained in McCallum and Nelson (2011), tests of QTM based on scatterplots of inflation and money growth using country averages or longer-run moving averages of time series are potentially flawed since they ignore cross-country differences in velocity and GDP. Moreover, most of these studies examined QTM based on samples after World War II. This study goes beyond measuring correlations and explicitly tests for QTM using panel cointegration approaches and adds a historical dimension using historical data of 150 years for industrial countries.

*****Insert Chart 1 here*****

Second, few empirical studies suggested that the long-run relationship between money growth and inflation could be time-varying for larger country groups. Notable exceptions are studies based on country approaches for the United States and the United Kingdom (e.g., Benati, 2005; Sargent and Surico, 2008). This study provides tests of QTM for several samples and applies rolling regressions, considering that economic regimes, structural change, and monetary policy frameworks may have changed the long-run relationship.

Third, earlier studies testing QTM using panel cointegration techniques have widely ignored the possible presence of cross-sectional dependence (CSD), which could invalidate the estimation results (e.g., De Grauwe and Polan, 2005; Teles et al., 2018; Gertler and Hofmann, 2018). The present study finds CSD to be present in samples covering industrial countries and applies panel cointegration techniques that have been shown to account for CSD. It, therefore, fills a gap in the literature.

This paper is structured as follows. Section 2 briefly explains QTM, and section 3 describes the data and econometric approach. Section 4 provides empirical results on the long-run link between excess money growth and inflation and section 5 concludes.

2. The quantity theory of money

A natural starting point for the empirical analysis of the link between money growth and inflation is the quantity equation of money:

$$M\,V = P\,Y^r \quad (1)$$

where M is the money supply, V is money velocity, Y^r is real expenditure (typically measured by GDP), and P is the price level (measured by the GDP deflator or national consumer prices (CPI)).

A well-known implication of the quantity theory is that in the long run (i.e., if V and Y^r are fixed), the price level is proportional to the money stock, and there is no link between money growth and real variables. The empirical literature has focused on the point that "*a given change in the quantity of money induces … an equal change in the rate of price inflation*" (Lucas, 1980).[4] Whether money is the only influence driving price developments and whether a central bank can control the money supply to exploit the long-run link has been controversial in the literature. Money neutrality may hold in the long term but not in the short term. The long-run equilibrium relationship (1) may not hold owing to the effects of other factors that temporarily affect price dynamics and drive them away from the equilibrium. For example, money holdings may be affected by temporary portfolio shifts by investors. Moreover, money velocity may change in response to changes in interest rates and the level of real income.

The literature suggests that excess money growth, i.e., nominal money in excess of real GDP, is more closely related to inflation. To this end, the following formulation of the quantity equation in growth rates has been widely used in empirical tests:

$$\Delta m - \Delta \mathrm{yr} = \Delta p - \Delta v \quad (1a)$$

where Δ denotes (annual) growth rates, small letters denote logs, and "excess" money growth refers to the annual growth rate of the money stock adjusted for trend GDP growth (in real terms). Velocity is assumed to be stationary.

Lucas (1980 and 1996) suggested that the link between money growth and inflation may not be found in the data owing to statistical noise. It would be better visible from the low-frequency inflation and money growth components. Applying statistical filtering methods to the data, it is possible to disentangle the "low-frequency component" of money growth and inflation data, which captures more persistent, trend-like movements, from the "high-frequency component", which reflects erratic or transitory developments. Chart 2 illustrates the long-run comovement between money growth and inflation for 18 industrial countries between 1900 and 2000. I use the low-frequency component in money growth (narrow and broad, respectively) and inflation (consumer prices), which was computed by applying the bandpass filter by Christiano and Fitzgerald (2003). The chart suggests the presence of a close correlation between (narrow and broad) money growth and inflation at very low frequencies for

[4] Lucas (1980) also examined a second implication, i.e. whether a given change in the quantity of money induces an equal change in nominal rates of interest. McCandless and Weber (1995) also examined the link between money growth and real GDP growth and found no correlation.

the entire span of available data subject to some heterogeneity across countries and monetary aggregates.[5] Furthermore, it illustrates that trend money growth tends to lead inflation systematically. Both observations align with earlier evidence for the US (Lucas, 1980; Sargent and Surico, 2011) and the UK (Benati, 2005). These illustrations suggest that the link between money growth and inflation may apply to all industrial countries amid heterogeneity across time and countries.

*****Insert Chart 2 here*****

In addition, the literature has shown that different payment technologies may influence the long-run relationship between money growth and inflation. This argument assumes that the cash optimization behavior of the private sector changes over time, leading to systematically lower cash holdings relative to the value of the actual goods transactions. When testing the validity of the quantity theory, this argument can be taken into account by correcting the long-run relationship for the effect if one assumes balanced growth for consumption, wages, and output (Attanasio et al., 2002; Teles et al., 2016):

$$\Delta m_i - \Delta yr_i + \alpha \Delta \mathrm{rs}_i = \Delta p_i \qquad (2)$$

where small letters denote a variable in logs, i denotes a country, rs is the (nominal) short-term interest rate, and the other notations are as above. Any potential implication from cash optimization of the private sector on the long-run relationship is captured by the term measuring the interest elasticity α. Two principal payment technologies can be distinguished. According to Baumol-Tobin (Baumol, 1952; Tobin, 1956), a transaction technology has constant cash flows over time, and the interest rate elasticity α should have a theoretical value of ½. Following Miller-Orr (Miller and Orr, 1966), a transaction technology has to capture random fluctuations in cash flows, and the interest rate elasticity α should be set at a lower value of ⅓.

3. Empirical approach

Existing approaches to test for a long-run link between money growth and inflation can be classified into three categories: a) studies testing QTM on a country-by-country basis (e.g., Juselius, 1999; Sargent and Surico, 2008; Assenmacher-Wesche and Gerlach, 2007; Benati, 2021; Amisano and Fagan, 2013), b) cross-section analyses (e.g., McCandless and Weber, 1995; Barro, 2007), and c) studies based on panel data, which exploit simultaneously the cross-section and the time series information contained in the data (e.g., De Grauwe and Polan, 2005; Teles et al., 2018; Gertler and Hofmann, 2018). Studies belonging to the first group sometimes use long runs of data and face difficulties arising from the incomparability of economic and financial systems across time. Moreover, findings from single

[5] Owing to data gaps in the dataset, the charts for broad money in Belgium start after World War II.

countries cannot be easily compared with those of other countries. Cross-sectional studies treat all countries the same and generally do not allow for regime changes in individual countries. Moreover, tests of the QTM based on scatterplots of inflation and money growth using country averages or longer-run moving averages of time series could be flawed because cross-country differences in velocity and GDP are ignored. Some of these issues can be better addressed in panel approaches. However, an important assumption for the validity of panel regression techniques is cross-sectional independence and inter-cross-sectional homogeneity. Both issues may arise when testing QTM.

When working with macro panels, the potential presence of cross-sectional dependence needs to be addressed. While this is not an issue in time series analysis, individual units in macro panels need not be cross-sectionally independent. The presence of CSD has consequences for testing and estimation, even under stationarity. Estimators can be inconsistent if the source of CSD is correlated with the regressors, and inference may be invalid when CSD is sufficiently strong. Panel unit-root tests that do not explicitly account for it are invalid under CSD (for details, see Chudik and Pesaran, 2015). Similar conclusions hold for panel cointegration tests that do not account for CSD (Breitung and Pesaran, 2008).

Testing the validity of the quantity theory may also face some limitations concerning the correct measurement of money growth or inflation. First, consumer price indices are typically used for this purpose. Still, they are subject to several biases (substitution bias, quality bias, new goods bias, and outlet substitution bias). However, the implied measurement errors of true inflation are relatively small (Wynne and Sigalla, 1996). Second, there can be problems related to the definition of money.[6] Pure financial transactions (e.g., equity purchases) are not part of the measure of transactions but may influence money growth (Humphreys, 1974). In addition, financial innovation may affect the behavior of monetary aggregates, and shifts in payment technologies would influence money velocity (McCallum and Nelson, 2011). Furthermore, suppose a currency has a strong international role (like the US dollar; see Bertaut et al., 2021). In that case, money growth will reflect transactions in other economies that are not accounted for in measures of domestic real income. Some of these effects cancel out in a cross-section. Famous researchers have argued that the Divisia approach to calculating monetary aggregates would be best suited to test the quantity theory (Barnett, 1980; Lucas, 2000). However, long-run series of such aggregates are unavailable for many countries, and this point is usually not critical for assessing the long-run relationship between money growth and inflation.

[6] An issue is whether the selected measure of money is a good proxy for good transactions in the economy, a point that has led many researchers to favor narrow over broad monetary aggregates when testing the quantity theory of money.

3.1 Data and unit root tests

This study uses annual data on money (narrow and broad), inflation (consumer prices), and nominal GDP for 18 industrial countries from the Jordà-Schularick-Taylor "Macrohistory Database" (for details, see Jordà et al., 2017).[7] Narrow monetary aggregates are M0 or M1, whereas broad monetary aggregates are M2 or M3. Inflation refers to the annual change in the national consumer price index. Short-term interest rates are typically interbank rates, money market rates, or deposit rates (three months maturity), and long-term interest rates refer to government bonds (with a maturity of typically ten years). The German hyperinflation of 1923 was associated with a massive increase in inflation and money growth that was not observed in other industrial countries.

Table 2 shows descriptive statistics for money growth, inflation, real GDP growth, and (nominal) interest rates for the entire sample from 1870 to 2020 and three subsamples (1870-1945, 1945-1985, and 1985-2020). These subsamples have been chosen so that it is possible to distinguish between the early central banking period (including two world wars and hyperinflation in Germany), the post-world wars period, and the period since the Great Moderation (including the switch to inflation targeting). The comparison reveals that there is considerable variation over time and across countries. Importantly, it shows a pronounced decline in all variables considered over the most recent sample starting in 1985, an effect that has been widely attributed to the Great Moderation (Bernanke, 2004).

***** Insert Table 2 here *****

Before turning to the estimation, we conduct several tests on the data. First, to determine whether there is cross-sectional dependence in the data, the test proposed by Pesaran (2015) can be applied. The null hypothesis of weak cross-sectional dependence is tested against the alternative hypothesis of strong cross-sectional dependence. Sufficiently weak CSD does not pose serious problems for conventional estimation, and strict cross-sectional independence is likely an unrealistic assumption for most real-world data. The test statistic of the Pesaran CSD test was originally designed to test residuals of panel data models but it also allows to detect CSD in the time series of the dependent and explanatory variables and to decide on an appropriate unit root and cointegration test. In that case, the Pesaran CSD test can be applied as well. Table 3 shows the results from the Pesaran (2015) test for weak CSD against the alternative of strong cross-sectional dependence. We find strong evidence that the assumption of cross-section independence is violated for all variables considered.

***** Insert Table 3 here *****

Second, the literature proposes several unit root tests. In a time series context, it is popular to test

[7] The dataset includes the following countries: Australia, Belgium, Canada, Denmark, Finland, France, Germany, Ireland, Italy, Japan, Netherlands, Norway, Portugal, Spain, Sweden, Switzerland, United Kingdom and United States.

the stationarity properties of variables by running a set of unit root tests on variables for individual countries (e.g., Augmented Dickey-Fuller tests, Phillips-Perron tests). While first-generation tests assume cross-sectional independence (e.g., MW tests by Maddala and Wu, 1999), second-generation panel unit root tests account for cross-sectional dependence. A popular panel unit-root test for cross-sectional dependence is an augmented version of the test suggested by Im et al. (2003) and proposed by Pesaran (2007). The procedure for this test is based on augmenting the usual augmented Dickey–Fuller (ADF) regression for each series with the lagged cross-sectional mean and its first difference to capture the cross-sectional dependence. The individual ADF statistics are then averaged. The null hypothesis of homogeneous nonstationarity (unit root) is tested against the heterogeneous alternative. Second-generation panel unit-root tests have recently been extended to incorporate additional econometric complexities. Pesaran et al. (2013) extended the CIPS test from Pesaran (2007) to account for multiple common factors. Lee et al. (2016) extended this test for structural breaks. However, small-sample properties are only satisfactory for T larger than fifty.

Table 4 summarizes the results from formal unit root tests.[8] All unit root tests overwhelmingly reject the null hypothesis of a unit root for money growth, inflation, (real) GDP growth, and the interest-rate spread. Second-generation panel unit root tests find that short- and long-term interest rates are stationary, while conventional unit root tests would suggest that they are non-stationary. Additional panel breakpoint tests of the relationship between excess money growth and inflation, applying the procedure described in Ditzen et al. (2021), detect breaks for narrow (broad) money in 1929 (1921) related to a global economic crisis (post-World War I recession that was followed by German hyperinflation) and in 1944 (1938) coinciding with the end (beginning) of the second world war but not thereafter.

***** Insert Table 4 here *****

Third, panel Granger causality tests allow me to assess the direction and strength of the statistical influence of money growth and inflation. I conduct conventional panel Granger causality tests and find for narrow and broad monetary aggregates and measures of excess money growth the presence of feedback effects from inflation.[9] Gertler and Hofmann (2018) conducted mean group Granger causality tests for a larger sample of countries and the period 1950 to 2011 using the approach of Pesaran and Smith (1995), i.e. they average over the individual country estimates and find the predictive power of lagged money growth for inflation decreased over time, especially after 1994.

Hence, the following empirical analysis can assume that we are dealing with stationary data series.

[8] I have used the Stata MULTIPURT package developed by Eberhardt (2011). The precise statistics of the unit root tests are available upon request.
[9] Results are available from the author upon request.

Moreover, the econometric issue of CSD in panels must be addressed since neglecting it could lead to biased estimates and spurious inference of panel cointegration approaches. [10]

3.2 Modelling money growth and inflation using a VAR model

A starting point for the analysis of the long-run link between money growth an inflation is a p-dimensional vector autoregressive model (VAR) of order k (Juselius, 2006) with no restrictions:

$$X_t \; = \Pi_1 X_{t-1} \; + \Pi_2 X_{t-2} \; + \cdots + \Pi_k X_{t-k} \; + \Phi D_t + \epsilon_t \,, with\; t = 1, \dots, T, \tag{3}$$

where the data vector is given by X_t =[m_t, p_t, yr_t, r_t, RO_t], m denotes nominal money balances (in logs), p is the price level derived from CPI (in logs), yr is real GDP (in logs), rs is a nominal interest rate, RO is the own rate of return on money balances (the term r-RO denotes the opportunity cost of holding money), D_t refers to a vector of impulse dummies, Π_i are coefficient matrices, and ε_t is a vector of disturbance terms.[11]

Long-run price homogeneity implies that the nominal money stock and prices move together in the long run. Long-run price homogeneity holds in the below model if c_{11}=c_{22} implying that (m_t-p_t) is integrated of order one (I(1)). The property holds if real money (in logs) is integrated of order one (I(1)) and money growth and inflation are cointegrated. Unit root tests (see Table 4) suggest that long-run price homogeneity for the individual countries and the panel as a whole holds empirically. If long-run price homogeneity holds, the system has no I(2) trends and the following representation can be chosen to illustrate the implications of QTM (see Juselius, 2006, chapter 2):

$$\begin{bmatrix} m_t \\ p_t \\ yr_t \\ rs_t \\ RO_t \end{bmatrix} = \begin{bmatrix} c_{11} & d_{12} \\ c_{21} & d_{22} \\ 0 & d_{32} \\ 0 & d_{42} \\ 0 & d_{52} \end{bmatrix} \begin{bmatrix} \sum u_{1i} \\ \sum u_{2i} \end{bmatrix} + \begin{bmatrix} g_1 \\ g_2 \\ g_3 \\ 0 \\ 0 \end{bmatrix} [t] + statistical\ component, \tag{4}$$

where u_{ji} are stochastic trends, and c_{ji}, d_{ji}, and g_i are coefficients.

As suggested by Juselius (2006), Friedman's dictum that inflation is always and everywhere a monetary phenomenon requires that medium-run price homogeneity holds in addition to long-run price

[10] Several ways exist to correct for cross-sectional dependence. Common strategies include demeaning the data before running a regression (e.g., Solberger, 2011), the inclusion of time fixed-effects (e.g., Eibinger et al., 2024), and using the Common Correlated Effect Pooled Mean Group (CCEPMG) estimator (Pesaran, 2006) or the Augmented Mean Group (AMG) estimator (Eberhardt, 2012).

[11] Note that Assenmacher and Beyer (2020) and Jung and Carcel Villanova (2020) also include a wealth variable in the vector X. Wealth variables are typically I(2) variables and their inclusion, which may be of special relevance for examining broad money, would have required the use of an I(2) modelling framework.

homogeneity. This property implies a common trend drives real money stock and real income. Medium-run price homogeneity is a testable implication in the above model. It holds if it can be shown that money velocity (in logs) (m_t-p_t -yr_t) is stationary (I(0)), i.e., if $d_{11} = d_{32}$.

3.3 Panel Cointegration approaches to test for QTM

The Common Correlated Effects Pooled Mean Group (CCEPMG) estimator by Pesaran (2006) addresses correlation across panel members due to unobserved common time-specific effects. While this issue was ignored in an earlier test of QTM by Gertler and Hofmann (2018) using a maximum likelihood panel estimator Pooled Mean Group estimator (PMG), I address this issue and otherwise broadly follow their estimation strategy, which I extend to a very long sample.

The panel regression constrains long-run coefficients to be the same, allowing short-run coefficients and error variances to differ across cross-sectional units. In the specification below, countries only differ regarding short-term adjustment and the dynamics around that long-run relationship. Panel estimates of the long-run coefficient are obtained through the mean group procedure by averaging over the individual country estimates. Additional terms capturing cross-section averages have been included to account for cross-section dependence, i.e., the mean of inflation and excess money growth of all countries. I estimate the following panel regression in the form of an error-correction model:[12]

$$\Delta\pi_{it} = \alpha_{0,i} + \phi_i(\pi_{it-1} - \theta\,(\Delta\mathrm{m} - \Delta\mathrm{yr})_{it-1}) + \sum_{j=0}^{p} \delta_{ij}\Delta(\Delta\mathrm{m} - \Delta\mathrm{yr})_{it-j} + \alpha_i\overline{\pi}_t +$$

$$\beta_i(\overline{\Delta m - \Delta yr})_t + \varepsilon_{it} \qquad (5)$$

notations as above, where π is annual inflation and (Δm-Δyr) measures excess money growth and the fixed effect $\alpha_{0,i}$ can be assumed to be random across countries in this specification, p is the maximum lag, and δ_{ij} are the country-specific coefficients for the current and lagged changes in excess money growth and the country-specific error term ε_{it} captures fluctuation in the velocity. Variables with a bar denote averages of the dependent variable and excess money growth across countries, computed at every time period t. Equation (5) is estimated with three lags for all variables, as suggested by the Bayesian information criterion.

The panel cointegration approach can be used to assess the validity of QTM in all 18 industrial countries, which requires the coefficient θ to be equal to one. The existence of a stable, long-run

[12] The equation has been derived from an autoregressive distributed lag model (ARDL). Pesaran et al. (2001) show that the existence of long-run level relationships between two or more variables is not limited to the case of I(1) variables, but also applies to the case of I(0) variables. According to the unit root tests reported in Table 4, the variables in our analysis are I(0).

relationship between inflation and excess money growth requires the significance of ϕ_i. In the above error-correction specification, the size of the coefficient ϕ_i measures the adjustment speed of inflation to excess money growth.

Furthermore, it can be tested whether QTM holds in individual countries i, which implies that θ_i=1, while θ=1 is not required. I estimate the following panel regression in the form of an error-correction model:

$$\Delta\pi_{it} \;=\; \alpha_{0,i} + \phi_i(\pi_{it-1} - \theta_i\,(\Delta\mathrm{m} - \Delta\mathrm{yr})_{it-1}) + \sum_{j=0}^{p} \delta_{ij}\Delta(\Delta\mathrm{m} - \Delta\mathrm{yr})_{it-j} + \alpha_i\overline{\pi}_{it} \; + \beta_i(\overline{\Delta m - \Delta yr})_{it} + \varepsilon_{it} \qquad \text{(5a)}$$

notations as above and variables with a bar denote averages of the dependent variable and excess money growth for country i, computed at every time period t.

4. Empirical results

4. 1 Results by country from a VAR model

Chart 3 shows velocity developments by country relative to a long-run mean of 100 years for (narrow and broad) money. This chart documents that in almost every country considered deviations of velocity from a longer-run trend are observed coinciding with the Great Moderation in the mid-1980s. The country-by-country inspection also illustrates that some velocity deviations from the longer-run trend occurred at different points in time. Large deviations happened during the two world wars, but surprisingly, the collapse of the Bretton-Woods system in 1971 did not trigger massive distortions in velocity trends. Unit root tests for money velocity can be used to assess medium-run price homogeneity. The results in Table 4 show that medium-run homogeneity does not hold for monetary aggregates in the 18 industrial countries considered since money velocity is typically not found to be a stationary variable. The (log of) narrow and broad money velocity is in most countries integrated of order one (i.e., non-stationary), with the possible exception of broad money in Denmark, Ireland, and Sweden. Based on the finding that medium-term price homogeneity is violated for a large majority of industrial countries, in line with earlier results by Juselius (1996), this tentatively suggests that Friedman's famous dictum that inflation is always and everywhere a monetary phenomenon may not be supported by the data.

*****Insert Chart 3 here*****

4. 2 Results from Panel Cointegration approaches

4.2.1 Panel Cointegration Tests for QTM

I use the Common Correlated Effect Pooled Mean Group (CCEPMG) estimator to address the cross-sectional dependence of the error terms for the total sample of 150 years, thus removing a possible bias in the coefficient estimates and ignoring that velocity shocks may have impacted countries similarly for economic reasons.[13] The coding of the CCEPMG for an error-correction model follows Ditzen (2018).

Table 5 shows the results if the cross-sectional long-run restriction θ=1 is imposed across all countries. For narrow and broad monetary aggregates, the strong significance of the coefficient ϕ related to the error-correction term confirms a long-run cointegration relationship between excess money growth and inflation for the full sample. The size of ϕ has the interpretation to measure the speed of adjustment following shocks that drive the system away from the long-run relationship. A coefficient of -0.3 (-0.4) suggests an average speed of adjustment of around three (two and a half) years for narrow (broad) monetary aggregates during the full sample from 1870 to 2020. The long-run coefficient θ measuring the long-run link between excess money growth and inflation is significant at the 1%-level. Its value for the full sample is estimated to be 0.94 for narrow and 0.88 for broad monetary aggregates, i.e., close to the coefficient of 1 implied by QTM.[14] This confirms the validity of QTM if longer runs of data are used. The coefficient is slightly higher for narrow money than for broad money, in line with theoretical arguments suggesting that QTM works better for liquid assets. The p-value of the CD test shows that even when the CCEPMG specification is used, cross-sectional dependence may still be present for the full sample, though it is absent for most subsamples, especially for broad money.

Table 5 also shows that the estimates changed over three sub-samples: 1870-1945 (early years), 1945-1985 (post-world wars), and 1985-2020 (recent decades). The results suggest that the link between excess money growth and inflation was closest during the post-war sample 1945-1985, during which the coefficient θ had the highest value for narrow and broad monetary aggregates (estimated to be 0.84 for narrow money and 0.72 for broad money). The link between excess money growth and inflation was already present during the early years (1870-1945), during which many countries participated in the Gold Standard. The link strengthened in the post-world wars period, especially for narrow money, thus supporting the hypothesis that QTM works better for international monetary systems of fixed exchange rates, given that the Bretton-Woods system of fixed exchange rates between the countries considered started after World War II and was discontinued in 1971. Over recent decades coinciding with the Great Moderation (i.e., after 1985), the long-run link collapsed, as is visible from the estimate of the long-run coefficient θ that is close to zero (i.e., the complete absence of the link between excess money growth and inflation). Together with the insignificant coefficient of the error-correction term ϕ for the last subsample, this result implies for the group of all industrial countries a rejection of QTM over the last

[13] Results applying the PMG estimator as in Gertler and Hofmann (2018) are available from the author.
[14] The PMG estimates (not shown here but available from the author), which can be considered as a robustness check despite the violation of cross-sectional independence, broadly confirm the above results.

35 years. The observed time-variation of θ suggests that structural change occurred in the mid-1980s. The sizeable coefficients of θ for the early years with two world wars imply that the relationship was persistent during the wars and that the collapse of QTM over recent decades had other reasons.

The subsample results for ϕ suggest that the adjustment speed to money supply shocks was faster before World War II and slower thereafter, both for narrow and broad money. It decreased from an average of around two (less than one and a half) years during 1870-1945 for narrow (broad) money to an average of four (three) years in the sample 1945-1985. The coefficient estimate for the error-correction term for the sample since 1985 is insignificant, suggesting the absence of a cointegration relationship for that period.

***** Insert Table 5 here *****

To assess changes in the relationship over time, I conduct a rolling window estimation based on Equation (5) with a sufficiently large window size of 30 years for both narrow and broad monetary aggregates to obtain smooth and significant parameters. As shown in chart 4 (upper panel), the results for θ detect two breaks in the relationship for narrow money aggregates: one break around 1945, after World War II, when the link between inflation and money growth strengthened substantially coinciding with the creation of the Bretton-Woods system of international fixed-exchange rates; another break around the early 1970s following the collapse of the Bretton-Woods system, when the link weakened, and θ declined strongly. Chart 4 (lower panel) shows that the above breaks in the long-run relationship also apply to broad money, with the regime shift away from QTM observed somewhat later, coinciding with the beginning of the Great Moderation. This analysis suggests that an important structural break in the long-run relationship coincided with the Great Moderation and before inflation targeting strategies became popular in industrial countries in the 1990s.[15]

Insert Chart 4 here

Chart 5 shows that the above results are robust if the long-run restriction is relaxed and only assumed to hold in individual countries (θ_i=1) rather than in all countries. For this specification, cross-sectional dependence is fully absent for each sample and for both narrow and broad money, as confirmed by CD-tests. The results for the coefficient θ suggest that the link between narrow money and inflation was closest during the post-war sample 1945-1985, during which the coefficient had the highest value. In contrast, for broad money, the link was, on average, slightly closer in the pre-world wars period than afterwards. In both cases, the relationship collapsed in the sample coinciding with the Great Moderation. Compared to the regression with the cross-section restriction on θ=1 (Table 5), the results for ϕ suggest

[15] The PMG estimates (not showen here but available from the author), which can be considered as a robustness check despite the violation of cross-sectional independence, broadly confirm the above results.

that the average adjustment speed to money supply shocks for the full sample was somewhat faster and closer to two years. That parameter also confirms that the adjustment speed was faster before World War II and slower thereafter, both for narrow and broad money.

***** Insert Chart 5 here *****

Chart 6 reveals that the above results mask considerable country heterogeneity. However, they confirm again that structural change in all industrial countries coincided with the Great Moderation, with Australia being a possible exception if broad money is considered. The results show the existence of a long-run link between 1870 and 1985 for most industrial countries, amid variation over time and with the notable exceptions of Denmark, Germany, and the Netherlands, for which the link has been very weak historically for narrow money. For broad money, the results suggest that the relationship was close for most euro area countries (except the Netherlands),[16] Canada, Sweden, Switzerland, and the United Kingdom. For Australia and the United States, the link was closer in the post-war sample but not before, while for Denmark the inverse was the case.

Insert Chart 6 here

4.2.2 Is there an influence from payment technologies?

Teles et al. (2016) suggest that a rejection of QTM in empirical tests may be due to the neglect of the distorting effects of structural change in payment technologies. To assess the point for our long sample of 18 industrial countries, I repeat their exercise and estimate the interest rate elasticity in a money demand framework by estimating a cointegrated panel regression for narrow monetary aggregates for which the influence of payment technologies is better visible.[17] For the full sample 1870–2020, the interest rate elasticity α is estimated to be around 0.25, i.e., relatively close to the theoretical value of 0.33, identifying the Miller–Orr technology and significantly below the value of 0.50 for the Baumol-Tobin technology. However, the results show that until the sample ended in 1985, cash technologies resembled the Baumol-Tobin technology, and only thereafter, a massive shift towards technologies that are less cash intensive is observable. It is in line with the hypothesis that payment technologies may matter in explaining structural change with the tendency to undermine the validity of QTM in most industrial countries. In part, this observation could also reflect changes in the equilibrium interest rate (r*), which was exceptionally high from 1970 to 1995 and extremely low in recent decades. After the Global Financial Crisis of 2008 interest rates approached the zero lower bound in many industrial countries (e.g., Kiley, 2020). [18]

[16] For broad money in Belgium money growth data before 1980 were missing so that for Belgium no precise evaluation can be provided.
[17] The detailed results are available from the author.
[18] An alternative explanation is the increasing relevance of wealth effects, which are not captured by our analysis.

5. Conclusion

QTM implies that money growth is a key driver of inflation. Based on long time series of 150 years for 18 industrial countries, this study has reassessed QTM. Using panel cointegration models that account for cross-sectional dependence, the empirical results from this study support the validity of QTM if longer runs of data are used. However, over recent decades, structural change - coinciding with the Great Moderation and, in part, reflecting changes in payment technologies - has led to a collapse of QTM. Panel cointegration regressions confirm the presence of long and variable lags in the monetary policy transmission, as predicted by Milton Friedman, subject to heterogeneity across time and countries. Given the nature of the identified structural breaks, it appears to be difficult to predict reliably when the long-run relationship will become closer again. This would require forecasting the end of the Great Moderation and the end of the process, leading to less cash-intensive payment systems. Over recent decades, most major industrial countries have shifted to inflation targeting and abandoned the prominent role of money in policy-making. As the study has shown, these strategic choices of independent central banks also reflect underlying changes in the validity of empirical long-run relationships, notably the collapse of QTM in the post-1985 sample. Future research could extend the present approach to include wealth effects and apply the tests to a larger sample of countries that also include low- and middle-income countries that were less influenced by the Great Moderation and advances in payment technologies.

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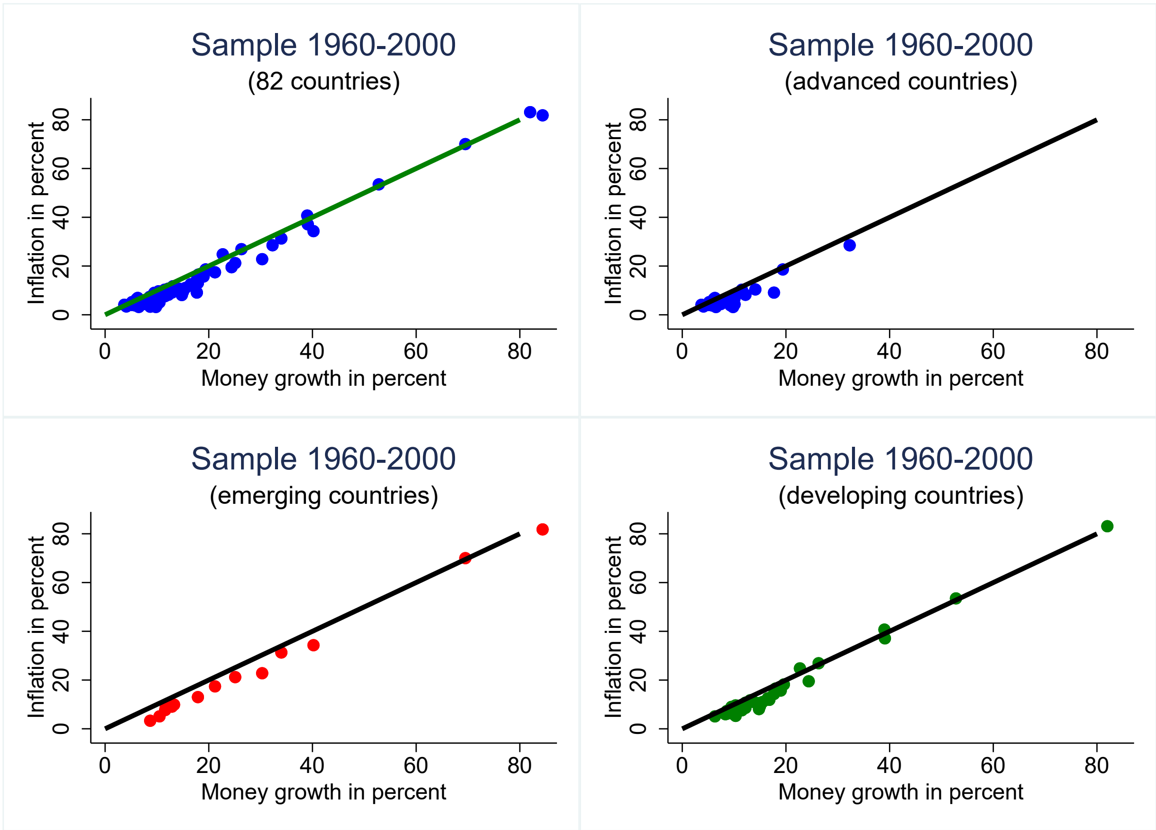
Annex: Charts and Tables

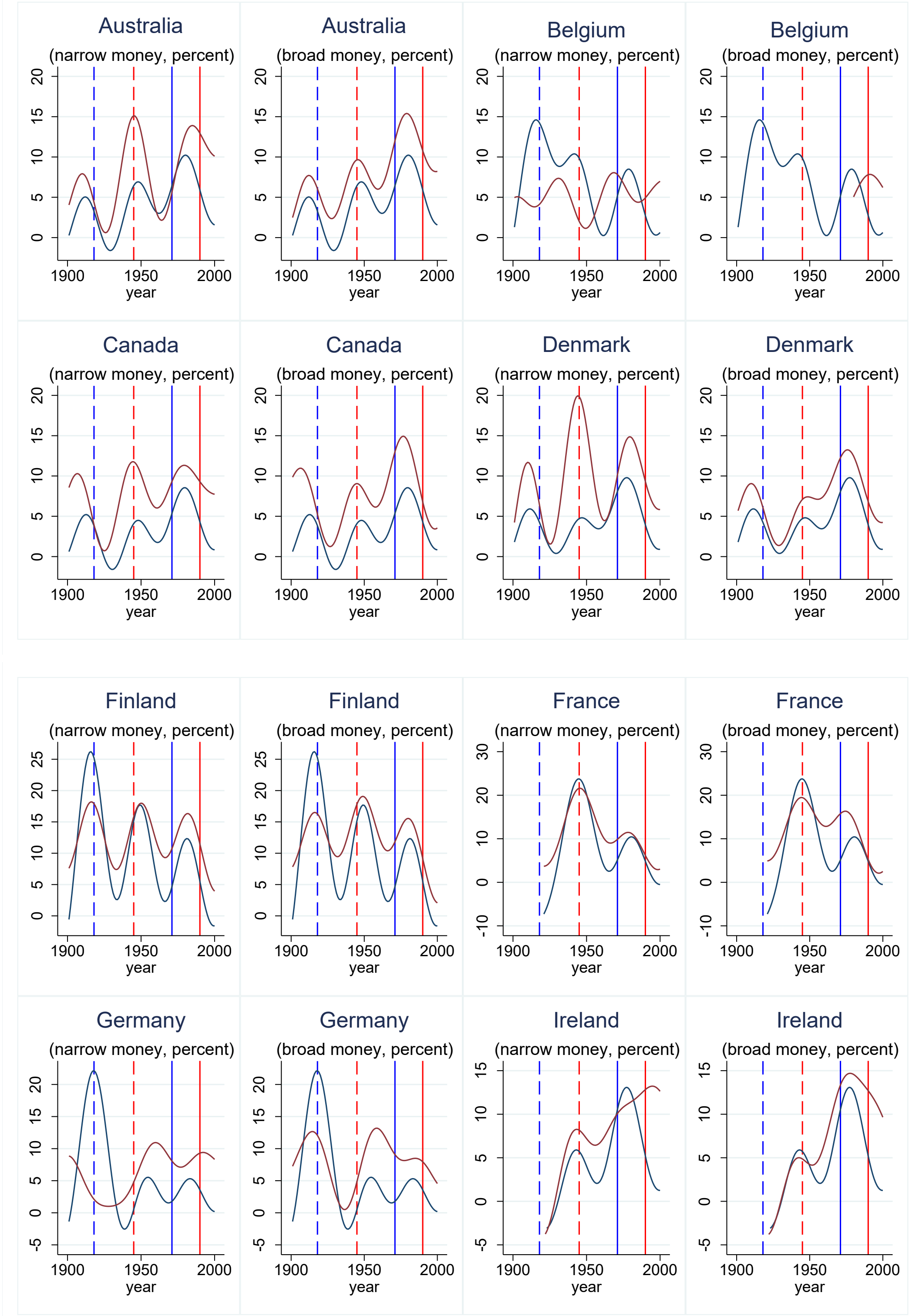
Chart 1: Money growth and inflation – across country groups

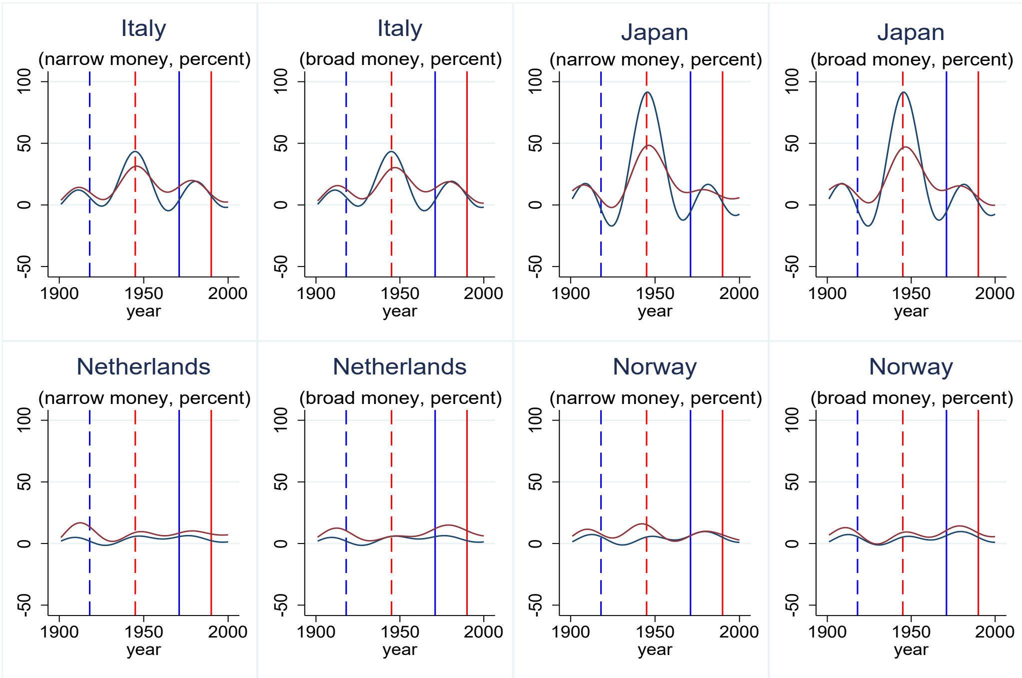


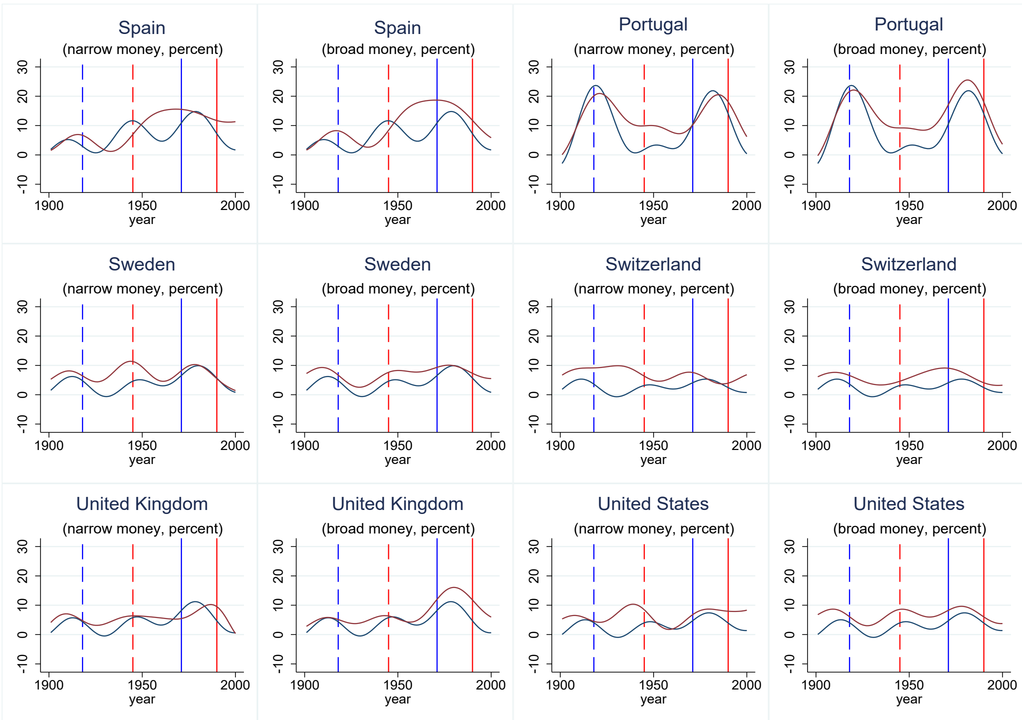
Source: Data from Barro (2007).

Notes: The green (black) diagonal line is a 45-degree line. The figure shows the long-run relationship between average money growth (measured by currency) and average inflation (measured by CPI) in a sample of 82 countries between 1960 and 2000 (of which 27 advanced, 14 emerging, and 41 developing countries).

Chart 2: The long-run co-movement between money and inflation: 1900 to 2000





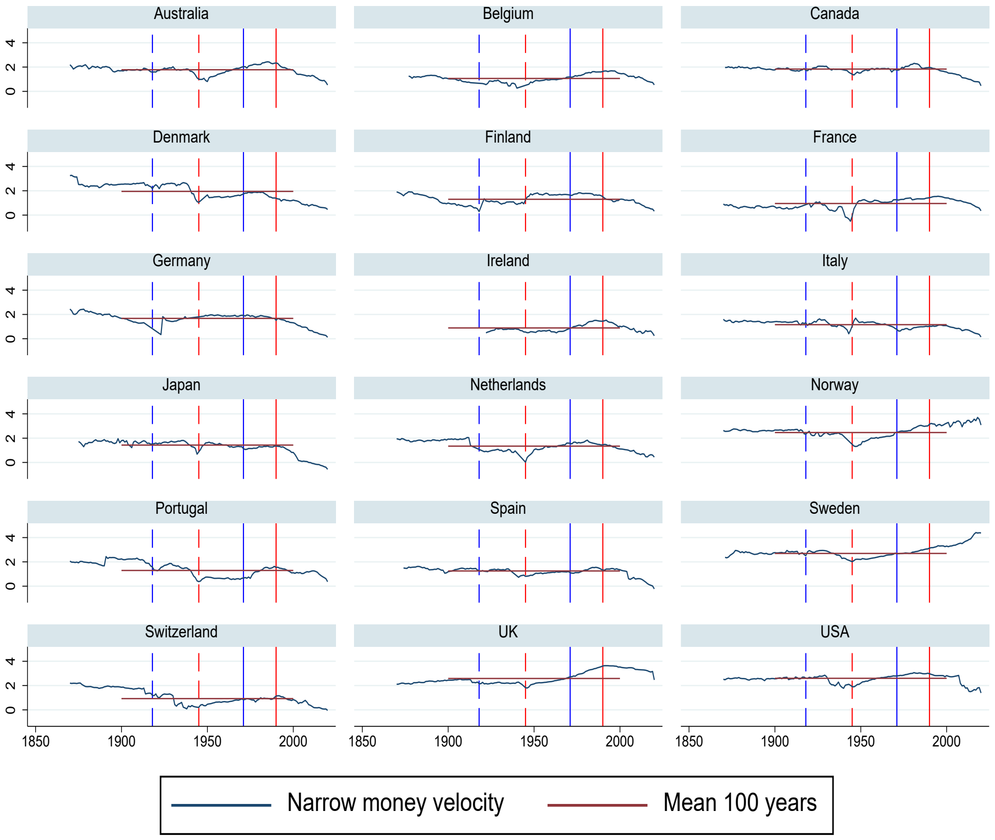


Source: Data from Jordà et al. (2017).

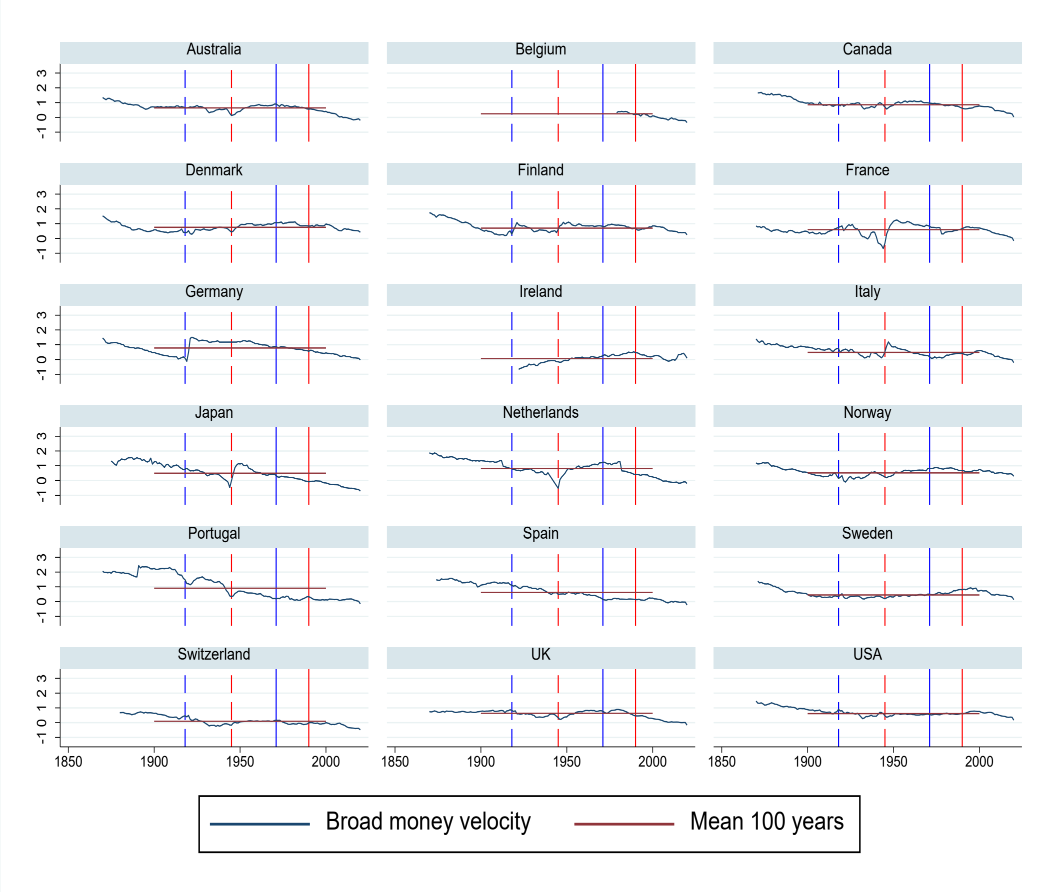
Notes:The y-axis is in percent. Christiano-Fitzgerald's (2003) bandpass filter with a maximum periodicity of 30 years for money (red line) and inflation (blue line), as measured by consumer prices; blue dashed vertical line: end of World War I; red dashed vertical line: end of world war II; blue solid vertical line: breakdown of Bretton Woods system; red solid vertical line: beginning of the IT strategy. For broad money growth in Belgium, data were only available from 1980.

Chart 3: Money velocity relative to its long-run mean

a) Narrow money



b) Broad money

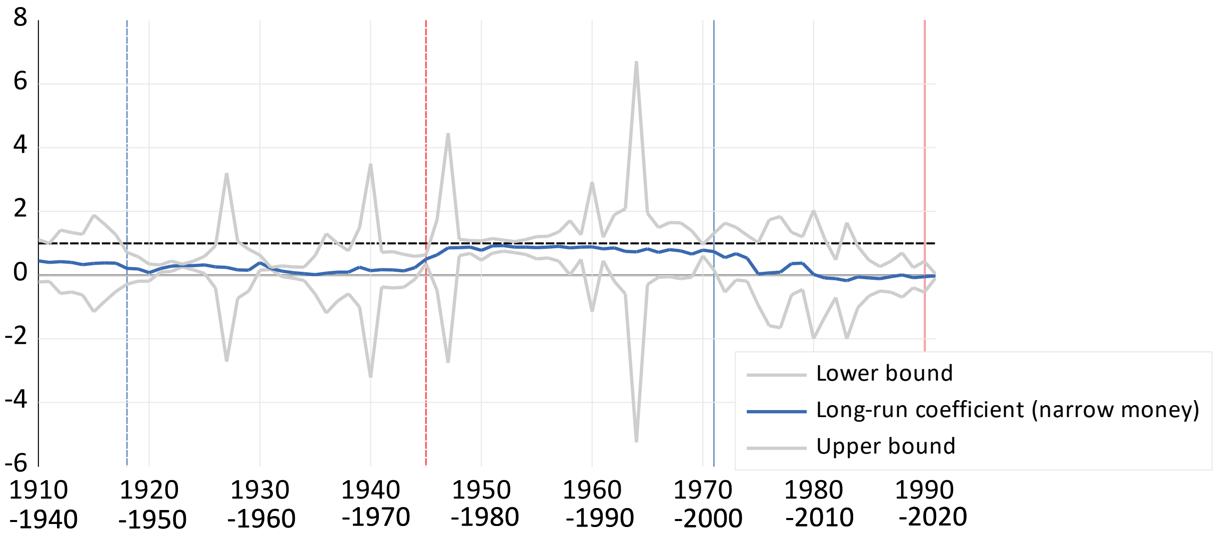


Source: Data from Jordà et al. (2017).

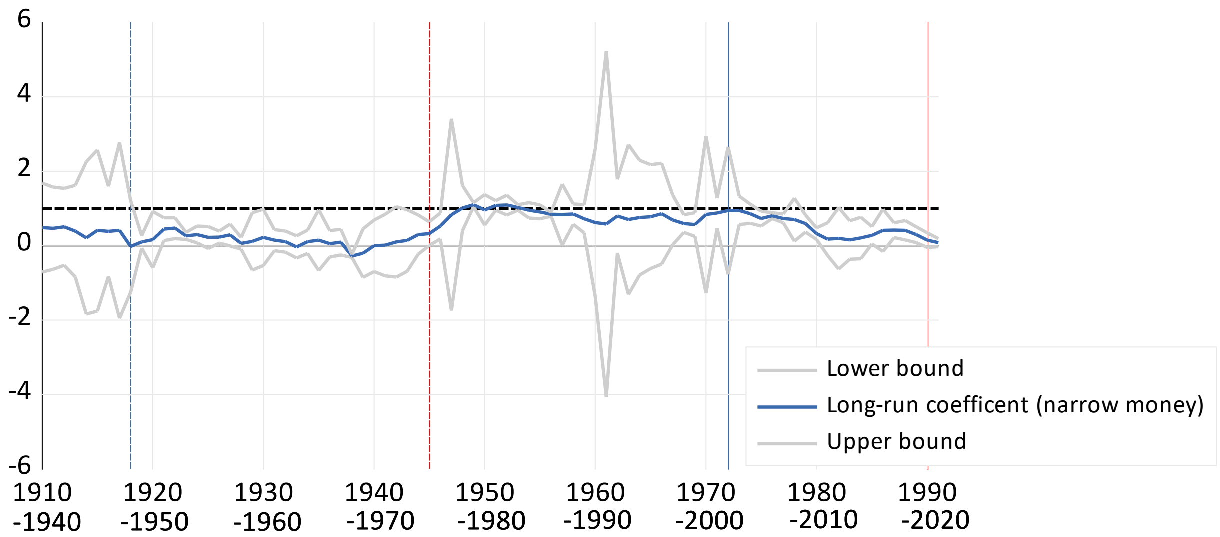
Notes: The y-axis is in percent; the x-axis shows the year. Velocity is shown in logs; blue dashed vertical line: end of World War I; red dashed vertical line: end of World War II; blue solid vertical line: breakdown of Bretton Woods system; red solid vertical line: beginning of the IT strategy.

Chart 4: Rolling window estimates for narrow and broad money (30-year window)

a) Narrow money

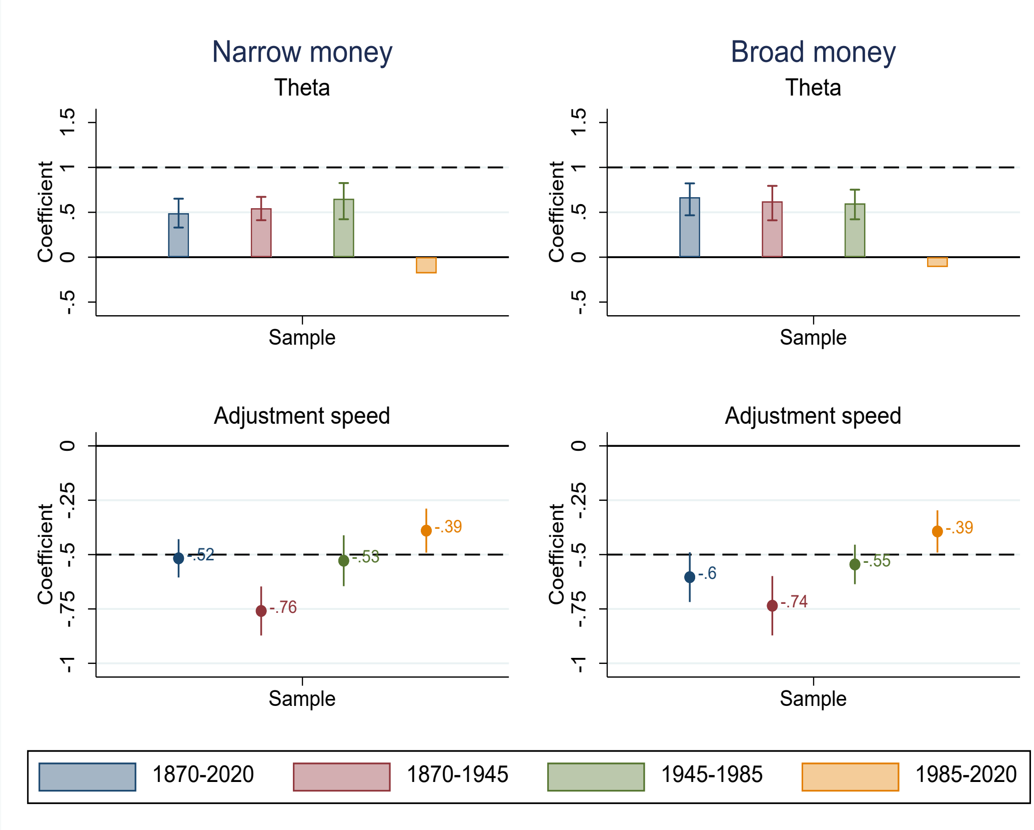


b) Broad money



Notes: The y-axis is in percent; the x-axis shows the years. Long-run impact of money growth on inflation with two standard error bands. Based on rolling window CCEPMG estimation of equation (5) and assuming a random fixed effect across countries. Sample 1910 to 2020. The dashed line illustrates a coefficient of 1, as stipulated by the quantity theory of money; blue dashed vertical line: end of World War I; red dashed vertical line: end of World War II; blue solid vertical line: breakdown of Bretton Woods system; red solid vertical line: beginning of the IT strategy.

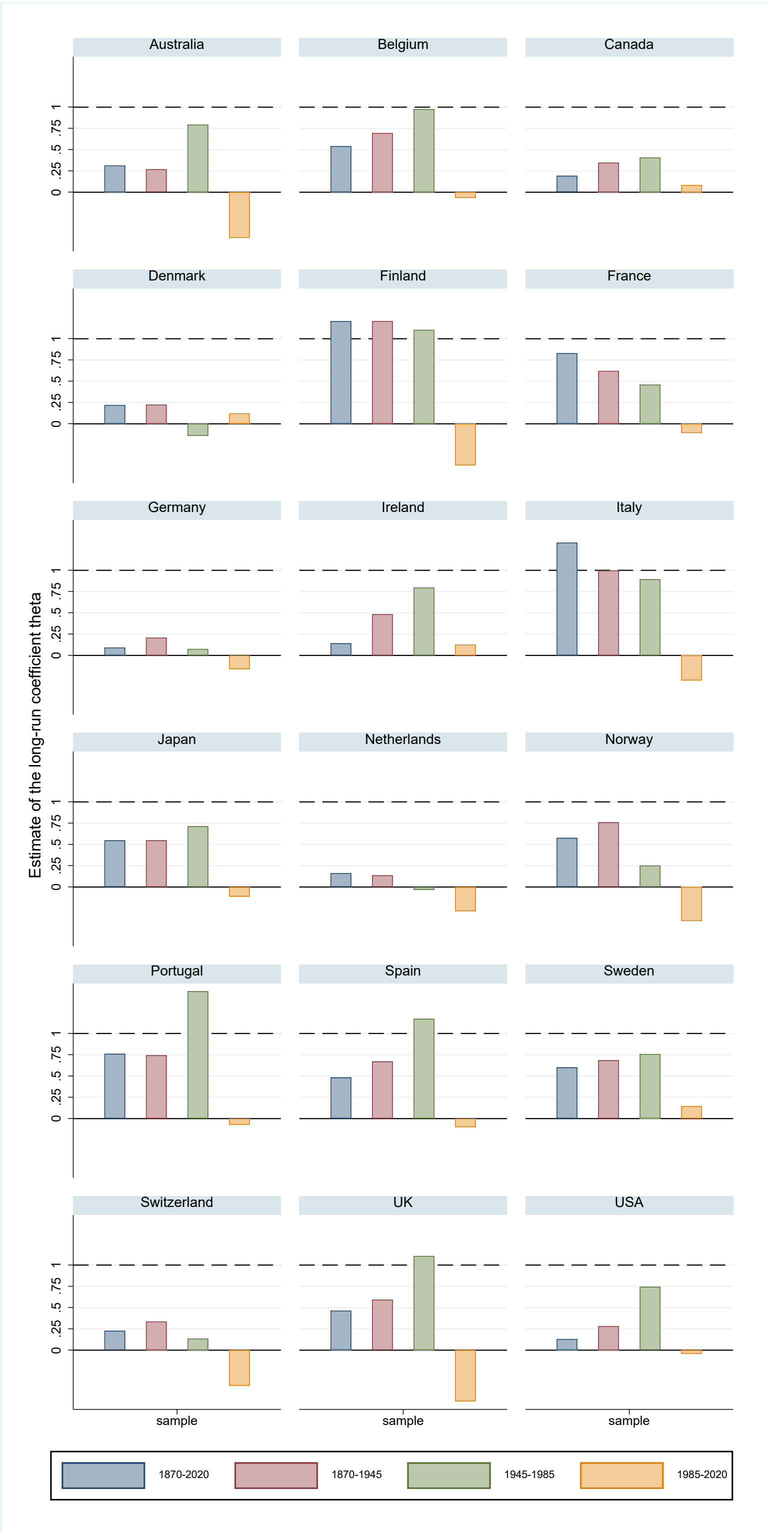
Chart 5: QTM across samples: long-run coefficient and adjustment speed



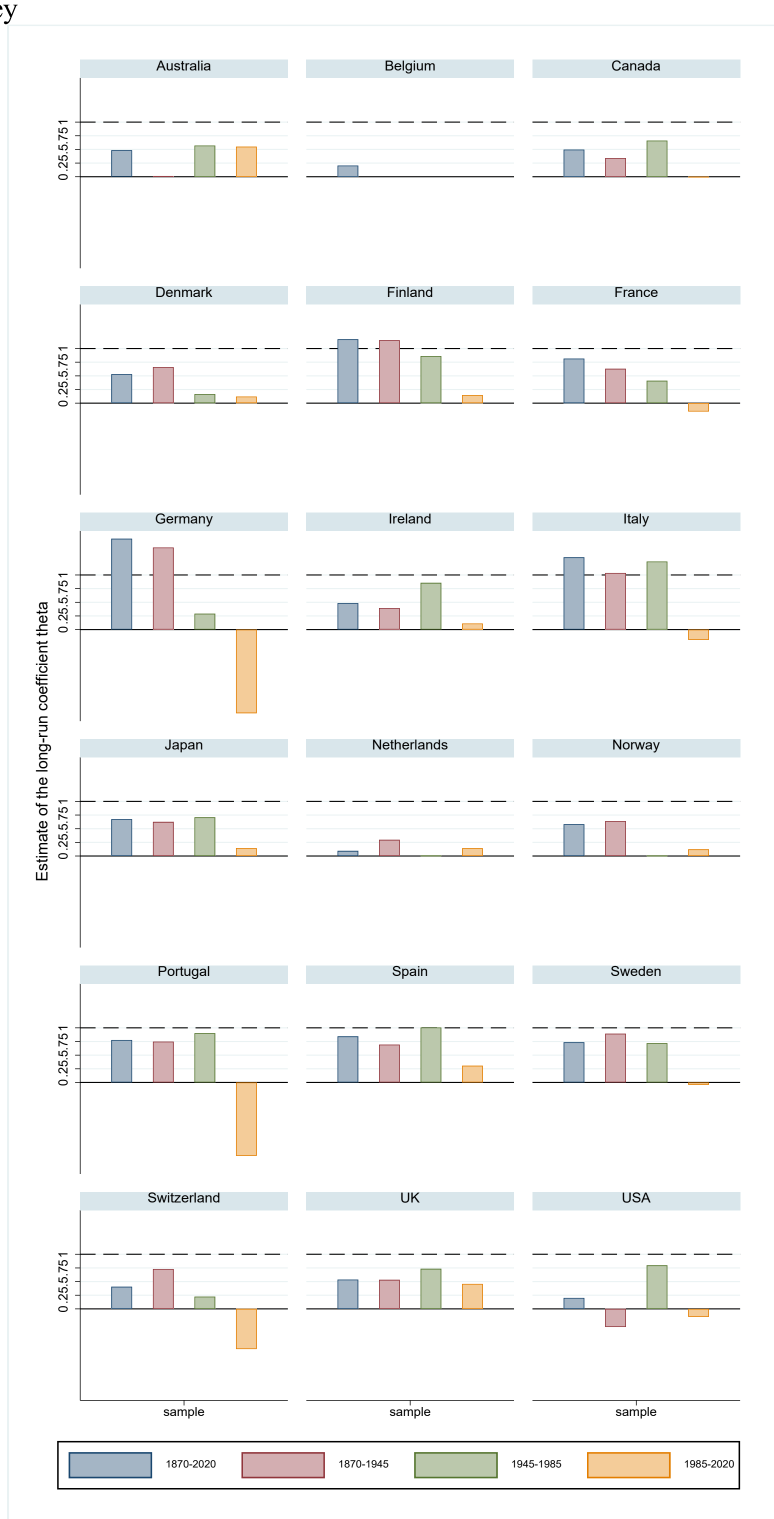
Notes: The y-axis shows the level of the coefficient; the x-axis refers to the sample. Long-run impact of money growth on inflation and error-correction adjustment with 95% confidence interval. Based on CCEPMG estimation of equation (5a). The solid line illustrates a coefficient of 1, as stipulated by the quantity theory of money; a dashed horizontal line illustrates a coefficient of -0.5, implying an average speed of adjustment of two years. The observation for 1923 was excluded owing to hyperinflation in Germany.

Chart 6: QTM for the individual industrial countries and across samples

a) Narrow money



b) Broad money



Notes: The y-axis shows the level of the coefficient; the x-axis refers to the sample. Long-run impact of money growth on inflation. Based on CCEPMG estimation of equation (5a) with no cross-sectional effects. The dashed line illustrates a coefficient of 1, as stipulated by the quantity theory of money; for broad money, no data for Belgium was available until 1980. The observation for 1923 was excluded owing to hyperinflation in Germany.

Table 1: Intermediate monetary targets in industrial countries

Country	Intermediate target	First announcement	Discontinued in
Australia	M3	1976	1985
Canada	M1	1975	1982
France(1)	M2, M3	1977	1999
(West-) Germany	Central bank money, M3	1974	1999
Italy(2)	M2	1974	1999
Switzerland	Base money, M1	1975	1999
United Kingdom(3)	Sterling M3, M0	1976	1987
United States(4)	M1B, M2	1975	1993

Notes: (1) Between 1973 and 1976, Banque de France operated with internal targets for M3; (2) Italy mostly announced targets for credit rather than money; (3) In October 1985, the target for M3 was temporarily suspended; (4) In February 1987 discontinued to set M1 targets, after 1993 monitoring ranges for M2 and M3 growth were still provided in the bi-annual testimony before Congress.

Table 2: Descriptive statistics by sample

Variable	1870 to 2020		1870 to 1945		1945 to 1985		1985 to 2020	
	Mean	Std.dev.	Mean	Std.dev.	Mean	Std.dev.	Mean	Std.dev.
Narrow money growth	8.03	12.11	6.95	14.30	9.75	9.31	8.17	9.90
Broad money growth	8.49	22.63	7.87	31.98	11.54	8.92	6.35	4.88
Inflation	5.13	33.34	5.51	47.20	7.01	9.35	2.24	1.97
Real GDP growth	3.08	10.53	2.10	13.47	5.53	8.24	2.28	3.46
Short-term interest rates	4.67	3.34	4.20	1.89	5.98	3.96	3.97	4.04
Long-term interest rates	5.45	3.17	4.60	2.02	7.16	3.73	5.10	3.4

Notes: Figures in percent. The observation for 1923 was excluded owing to hyperinflation in Germany.

Table 3: Test for weak cross-sectional dependence

Variable	Levels		First differences	
	Statistic	p-values	Statistic	p-value
Log of narrow money	15.85	0.00	11.37	0.00
Log of narrow money (real)	-2.74	0.01	10.89	0.00
Log of broad money	19.29	0.00	5.89	0.00
Log of broad money (real)	13.12	0.00	10.89	0.00
Log of (CPI) price index	20.52	0.00	17.31	0.00
Log of GDP	19.89	0.00	17.05	0.00
Log of GDP (real)	17.93	0.00	10.27	0.00
Short-term interest rates	19.38	0.00	7.62	0.00
Long-term interest rates	20.32	0.00	10.52	0.00

Notes: Results are for the full sample 1870 to 2020 (balanced panel, i.e., adjusted for missing values). The observation for 1923 was excluded owing to hyperinflation in Germany. The test follows Pesaran (2015). The null hypothesis of cross-sectional dependence is tested against the alternative of strong cross-sectional dependence.

Table 4: Time series properties for 18 industrial countries

	Country-by-country		Panel			
Variable	**I(1)**	**I(0)**	**I(1)**	**I(0)**	**I(1)**	**I(0)**
Log of narrow money (nominal, real)	X		X		X	
Log of broad money (nominal, real)	X		X		X	
Log of (CPI) price index	X		X		X	
Log of GDP (nominal, real)	X		X		X	
Short-term interest rate (1)	X		X			X
Long-term interest rate	X		X			X
Spread (long-term minus short-term rate)		X		X		X
Real interest rate		X		X		X
Annual narrow money growth		X		X		X
Annual broad money growth		X		X		X
Annual inflation rate (CPI)		X		X		X
Annual GDP growth (nominal, real)		X		X		X
Narrow money velocity	X		X		X	
Broad money velocity (2)	X		X		X	

Notes: Results are for the full sample 1870 to 2020 with some data gaps, as in the dataset from Jordà et al. (2017); all variables except interest rates and annual growth rates are in logs. Unit root tests in the first two columns summarize the results from Dickey-Fuller tests and Phillips-Perron tests with four lags for each of the 18 industrial countries. Panel unit root tests in columns three and four refer to first generation tests by Maddala and Wu (199) that assume cross-section independence and column five and six refer to second generation tests by Pesaran (2007) that capture cross-section dependence. (1) country result could be I(0) in Germany, the Netherlands, Switzerland, and the United States. (2) country result could be I(0) in Denmark, Ireland, and Sweden. CIPS test without trend suggests that result could be I(0).

Table 5: Money growth and inflation: CCEPMG estimation

Variable	1870-2020	1870-1945	1945-1985	1985-2020	1870-2020	1870-1945	1945-1985	1985-2020
	Narrow money				Broad money			
Long run	0.94***	0.62***	0.84***	-0.04	0.88***	0.65***	0.72***	0.05
	(0.30)	(0.15)	(0.31)	(0.13)	(0.21)	(0.24)	(0.16)	(0.40)
Error correction	-0.28***	-0.50***	-0.25***	-0.24	-0.37***	-0.78***	-0.32**	-0.14
term	(0.12)	(0.11)	(0.15)	(0.18)	(0.11)	(0.23)	(0.16)	(0.62)
L0	-0.01	-0.01	-0.17***	0	-0.02	-0.08	0.14***	0.01
	(0.08)	(0.07)	(0.03)	(0.01)	(0.06)	(0.06)	(0.03)	(0.01)
L1	-0.06**	-0.02	-0.10***	0.01	-0.08***	-0.03	-0.17***	0.02
	(0.03)	(0.04)	(0.04)	(0.01)	(0.04)	(0.05)	(0.03)	(0.01)
L2	-0.04	-0.06**	-0.13***	0.01	-0.05*	-0.01	-0.15***	0
	(0.03)	(0.03)	(0.04)	(0.01)	(0.03)	(0.03)	(0.04)	(0.01)
L3	0	-0.03**	-0.03	-0.01	-0.03**	0.03	-0.08***	0
	(0.02)	(0.02)	(0.03)	(0.01)	(0.02)	(0.03)	(0.02)	(0.01)
Observations	2326	1033	600	576	2260	1047	578	576
CDP test	0	0	0.596	0	0	0.257	0.510	0.125
Adj. R-squared	0.78	0.83	0.03	0.07	0.79	0.84	0.10	0.26

Notes: Standard errors are in parentheses. *, **, *** denotes the significance of a coefficient or test statistics at the 10%, 5%, and 1% levels respectively. Long-run coefficients and the error-correction coefficient from the Common Correlated Effect Pooled Mean Group (CCEPMG) estimation based on Eq. (5). L0 to L2 refers to the coefficients of the current and lagged changes in excess money growth. The CDP test is the p-value of the test for weak cross-sectional dependence by Pesaran (2015). Outliers related to German hyperinflation and Belgium's missing broad money growth data before 1945 were excluded.

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