Central Banks: Evolution and Innovation in Historical Perspective*

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Economics Working Paper 17105

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September 2017

Central banks have evolved for close to four centuries. This paper argues that for two centuries central banks caught up to the strategies followed by the leading central banks of the era; the Bank of England in the eighteenth and nineteenth centuries and the Federal Reserve in the twentieth century. It also argues that, by the late 20th century, small open economies were more prone to adopt a new policy regime when the old one no longer served its purpose whereas large, less open, and systemically important economies were more reluctant to embrace new approaches to monetary policy. Our study blends the quantitative with narrative explanations of the evolution of central banks. We begin by providing an overview of the evolution of monetary policy regimes taking note of the changing role of financial stability over time. We then provide some background to an analysis that aims, via econometric means, to quantify the similarities and idiosyncrasies of the ten central banks and the extent to which they represent a network of sorts where, in effect, some central banks learn from others.

* The authors are grateful to Maria Sole Pagliari for research assistance in collecting the data for this study. Comments on earlier drafts by the late Allan Meltzer, our discussant, Jan-Egbert Sturm, the Editors, and participants at the April 2017 Riksbank Conference, are gratefully acknowledged.

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JEL Code: E02, E31, E32, E42, E58
Keywords: monetary policy regimes, inflation, small open economies

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Abstract:

In this paper we discuss the genesis and early international expansion of the bank issued credit card. Empirical evidence documents the limits of a single firm building a proprietary network, because success came to a constellation of participants that combined three characteristics namely a critical mass of both retail customers and retail merchants; the capacity to adopt and implement new technological solutions; and the ability to forge resilient collaboration across national borders. This evidence provides further support to the importance of collaboration in retail financial services as means to appropriate network externalities. We also argue that initial conditions for this industry had greater implications for long-term success than has been acknowledged by other conceptual and empirical studies (in particular the literature around two-sided markets, which has focused attention on the determinants of the interchange fee).

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1. Introduction

Central banks have evolved for close to four centuries. Their evolution was initially tied up with meeting the fiscal needs of nascent states to finance government expenditures in wars and to market the government's debt. This was certainly true of the Riksbank, originally named the Bank of the Estates of the Realm and created in 1668 and often referred to as the first central bank[1], and even the Bank of England created in 1694, in the midst of King William III's war with France.[2]

They were not initially called central banks but rather banks of issue. The term central bank only came into use in the late nineteenth century. Henry Thornton (1802) was arguably one of the first to lay down concepts of central banking, including the role of autonomy.[3] Later in the nineteenth century central banks played a key role in managing the gold standard (i.e. following the "rules of the game").

The era of the Gold Standard, which in one form or another was to last until the 1920s, also saw the publication of Bagehot's *Lombard Street* (1873) which suggested that a central bank should be seen as a guarantor of financial stability by being a lender of last resort.[4]

The definition of financial stability has changed significantly over time. In the eighteenth and nineteenth centuries it meant avoiding or managing banking panics, that is, serving as a lender of last resort to the banking system and the payments

[1] The Riksbank was formed as a successor to its predecessor Stockholm Banco. It didn't immediately fund the government but did so later. See (Fregert (2017).
[2] As Bagehot (1873) famously remarked: "It was founded by a Whig government because it was in desperate need of money, …".
[3] "To suffer the solicitations of merchants or the wishes of government to determine the measure of bank issues is unquestionably to adopt a very false principle of conduct." (Thornton 1802).
[4] Perhaps best captured by Bagehot's view that "money would not manage itself".

system. This changed in the twentieth century with the adoption of the real bills doctrine, followed by the Federal Reserve in its early years. The real bills doctrine urged a central bank to head off an asset price boom because it would lead to inflation, then depression and deflation (Meltzer 2003, chapter 1). More recently, financial stability encompasses both being a lender of last resort and preventing imbalances that will lead to asset price booms and busts. Also the role of lender of last resort has expanded to include the entire financial system not just the banking system.

The pace of central bank creation intensified in the nineteenth century reflecting a number of forces including the fiscal motive, the maintenance of specie convertibility and managing financial crises, especially towards the end of the century. The Banks founded included the Banque de France (1800), the Norges Bank (1816)[5], the First and Second Banks of the United States (1791 and 1816), the Bank of Japan (1882), the Banca d'Italia (1893), and eventually the US Federal Reserve (1913). A few other central banks (e.g., the Reichsbank (1873), and the Swiss National Bank (1907)) reflected attempts to centralize the currency issue and facilitate financial transactions.

Central banks, because of their special status of having government charters and because of their size, evolved into bankers' banks and later into lenders of last resort. The Bank of England is generally viewed as the first central bank to successfully develop as a lender of last resort as is discussed in the Narrative Appendix in the NBER Working Paper version of this chapter. However, other early central banks such

[5] A political element played a role here as well because of the failed finances of Denmark which at the time had jurisdiction over Norway. See, for example, Qvigstad (2016).

as the Riksbank, and the Banque de France, engaged in rescue operations in the nineteenth century. Indeed, the Banque de France in 1889 arranged a lifeboat operation of the Comptoir D' Escompte involving other commercial banks to provide the resources to keep the bank afloat before a recapitalization could be arranged. The Banque used very little of its own resources in the rescue but guaranteed the participants in the event of losses (Hautcoeur, Riva, and White 2014). According to the authors, the idea for the famous lifeboat rescue by the Bank of England of Barings bank in 1890 in London came from the French operation the year before. In the late twentieth century the Federal Reserve adopted the Too Big to Fail doctrine (Bordo 2014) but its first use goes back to several big bailouts in Germany in 1931 (Bordo and James 2015). Thus, as we show below, with the LLR function as with other central bank functions there was considerable learning among the central banking community. Indeed, we provide some suggestive evidence of a relationship among ten central banks that has all the markings of a network of a kind. In addition, along with the lender of last resort function, they evolved as both providers and protectors of the payments system.

In the twentieth century central banks took on the role of stabilizing the macroeconomy (i.e., maintaining price stability), stabilizing the business cycle and maintaining full employment. Since the 2007-2008 crisis central banks have also been given responsibility for financial stability, namely defusing financial imbalances and asset price booms before they destabilize the economy. In so doing central banks have only reprised a variant of a role that explains why many were created in the first place (e.g., see De Kock 1974).

The dual requirements of a monetary policy geared towards stable economic outcomes and a financial stability remit have always created challenges and this is nowhere more evident than in recent years with central banks greatly expanding their interventions in the financial system while struggling to meet inflation objectives.

We consider the role of central banks in designing economic policy strategy and regime choices. Table 1 from Siklos (2002, Table 1.2) lists the year of origin and the primary motivation for the creation of 21 central banks in what are now referred to as advanced economies (AE). That Table is updated to provide a few more details about the 10 central banks that are the focus of the present study. If we exclude the European Central Bank (ECB), we find that the gap between the first central bank created (Sweden in 1668) and the last one (Canada in 1934) is 266 years. As noted above, in most cases, there was a fiscal motivation (e.g., war finance) or an attempt to stem the incidence of financial crises, that is, a financial stability imperative that largely explains the creation of several central banks. The lender of last resort function, often thought of as the *raison d'être* of central banking, grew in importance in the late nineteenth and twentieth century.

Our study blends the quantitative with narrative explanations of the evolution of central banks. Our quantitative analysis covers the period from 1870 to 2015. The chosen sample reflects data limitations as well as the fact that central banks before that period did not resemble the institutions we know today. Nevertheless, where appropriate, we also examine data since the 17th century.

We begin in section 2 by providing an overview of the evolution of monetary policy regimes taking note of the changing role of different meanings of financial stability over time. In section 3, we then provide some background to an analysis that aims, via econometric means, to quantify the similarities and idiosyncrasies of the ten central banks and the extent to which they represent a network of sorts where, in effect, some central banks learn from others. The empirical evidence is presented in section 4. We examine a wide variety of evidence focusing on the behavior of inflation differentials of various kinds, their determinants in a panel setting. We also consider some counterfactuals that ask what inflation and real GDP performance might have looked like in select economies in our data set had central banks appeared on the scene earlier than was actually the case. Additional counterfactuals also consider how inflation and economic growth might have evolved had inflation targeting not been introduced in some of the countries that eventually adopted this monetary policy strategy.

Small open economies are especially useful harbingers of reform and change in central banking, most clearly during the second half of the twentieth century, particularly in the aftermath of the Bretton Woods system which arguably represents the last gasp of large economies dictating the monetary policy strategy of smaller and more open economies. The small open economies evince greater responsiveness to shocks emanating from the global and dominant economies over time. They also often experience crises whose duration is less persistent but happen frequently enough to prompt changes in how monetary policy is carried out. The combination of these two findings suggests a greater willingness to change course when it is needed.

Overall, however, the economies considered remain crisis prone in spite of the introduction and greater sophistication of monetary policy and central banking. Financial crises impose considerable economic costs even if these may have declined with improvements in central banking. Also, because of, or in spite of, exchange rate systems the influence of central banks is global. Finally, section 5 concludes by summarizing lessons learned and the current prospects for central banks.

In spite of notable developments in our understanding of how macroeconomies function and how they respond to shocks, policy makers continue to search for common features and hence a basis for cooperation across the many financial crises that have plagued the global economy over the centuries. Unfortunately, this kind of strategy does not bode well for the future of central banking for at least four reasons. First, financial crises are not alike except in so far as they all, to a greater or lesser extent, create significant to severe economic costs. Second, the central bank remains a critical institution within government. Autonomy or independence cannot prevent governments from eventually getting the monetary policy they want. Third, unless the pendulum swings back to greater sharing of sovereignty across countries, an unlikely scenario as this is written, domestic imperatives will ultimately dictate central banks behavior. As a result, they will cooperate but only if it is beneficial for them to do so. Finally, even if financial crises of the kind experienced in 2007-8 (GFC) and 2010-12 (Eurozone sovereign debt crisis) are a thing of the past, political economy considerations are unlikely to relegate to history booms and busts in financial and business cycles.

As the current recovery in the real economy continues and the stance of monetary policy tightens the likelihood that central banks will face a litmus test rises. And it is quite possible that the next time will be different and central banks will lose their prominence among the institutions responsible for carrying out stabilization policies. Early indications are that this is already happening (e.g., see Geithner 2016).

2. The Ebb and Flow of Policy Regimes

As is the case with many other institutions that evolve over time certain features come to dominate before receding into the background as other more important forces emerge. The same is true of central banks. While the supporting role in the fiscal realm dominated the early history of many central banks this receded into the background as financial crises and real shocks led to larger and more volatile business cycle movements than governments were willing to tolerate. To be sure there were fiscal implications from a change in the role of the central bank but the shift implied that monetary authorities would henceforth stand squarely between financial markets and other major economic stakeholders.

Business cycle volatility combined with the ever present desire to maintain some form of price stability have also played a critical role in the evolution of central banking. As Paul Volcker, former FOMC Chairman, once pointed out: "No doubt several factors have contributed to enhancing the reputation of central banks. However, given the responsibility for monetary policy, shifting perceptions with respect to the importance of price stability must have been the most important." (Volcker 1990)

Once governments began to intervene more heavily to reduce the amplitude of business cycle movements central banks moved from being subservient in the face of fiscal demands to eventually becoming a bulwark against fiscal pressures for monetary accommodation that would threaten to spill over into intolerably high inflation rates. Of course, recent successes in limiting excessive inflation need not imply that a permanent solution has been found, as we shall see. Indeed, any conquest of inflation must be weighed against the current fashion in government at maintaining a stable and sustainable fiscal policy. Were this view to change it is difficult, again based on the historical experience, to see how central banks can stand in the way of eventually accommodating the fiscal stance the politicians want.[6]

Beginning approximately in the 1950s, and culminating in the 1990s, central banks around the world became more autonomous. After World War II many countries adopted a full employment objective or nationalized their central banks so that they could serve as a tool of macroeconomic policy (e.g., the US in 1945). This significantly changed the mandate of central banks. Some, like the Fed, were required by legislation to follow a dual mandate –to maintain both price stability and full employment. In the US in the 1950s the Fed, under its chairman William McChesney Martin, attached primary importance to price stability. He believed that price stability would encourage economic growth and high employment (e.g., see Bremner 2004).

[6] Even the German Bundesbank, celebrated as the model of central bank autonomy, was, as article 12 of the 1957 Law states (since replaced when the Bundesbank joined the European System of Central Banks): "The Deutsche Bundesbank shall be bound, in so far as is consistent with its functions, to support the general economic policy of the Federal government." (Deutsche Bundesbank 1957, pg. 120). Needless to say, when the government's and the central bank's policies are inconsistent conflicts emerge and the Bundesbank is no stranger to these.

By the mid-1960s, however, with the ascent of Keynesian thinking in the economics profession in the US administration and inside the Federal Reserve, the goal of price stability was made subservient to that of full employment. Similar shifts in thinking occurred in the UK, Canada and the continent of Europe (with Germany and Switzerland notable exceptions). Many argue that the belief in the ability to exploit the Phillips Curve tradeoff was a key force leading to the Great Inflation from 1965 to 1983. Other factors such as political pressure (e.g., in the US to finance the Vietnam war and the Great Society), accommodating two oil price shocks, the consistent misreading of economic activity, and faulty analytics about what drives business cycle activity, also contributed to the Great Inflation (see Bordo and Orphanides 2013). The Great Inflation ended in the period 1979 to 1982 thanks to the pursuit of credible anti-inflation policies, especially by Paul Volcker in the US and Margaret Thatcher in the UK, with similar actions in other countries later in the decade. This helped cement the importance of central bank independence and facilitated the wave of legislative changes that gave the monetary authorities the authority to carry out their policies according to their assigned mandate. However, this strategy needed to be balanced with the requirement of democratic accountability which, simultaneously, created the pressure to promote greater transparency.

Moreover, independence never meant that the central banks were free to engage in a monetary policy strategy of their own choosing. Rather, the monetary authorities, at least in advanced economies, were given or negotiated a remit received from the political authorities. Within the limitations of the tasks set out in legislation they were free to choose the manner in which that remit was carried out. This is the principle

that came to be called instrument independence as distinct from goal independence. The latter is normally set by the government (see Debelle and Fischer 1994).[7]

These developments since the mid-1980s represented a sea change in the conduct of monetary policy as central banks had previously been proudly secretive. Indeed, central banks in the advanced world began a race to determine which one was most transparent or could provide the clearest forward guidance. This is the so-called "…long march toward greater transparency…" (Blinder et. al. 2008, pg. 911) that defines central banking since the early 1990s.[8]

The global financial crisis of 2007-2009 saw a reversal in all of these developments. Central banks were seen as less independent of government and more willing to provide fiscal support even if only indirectly. Some also saw some advantage in becoming more 'artful' and less forthcoming about their plans and policies. The days of the monetary authority standing by unless inflation and real economic activity showed signs of being excessively high or low quickly vanished. Central banks would do "whatever it takes" and intervene heavily and across a wide spectrum of economic activity.

Central bank governance has also evolved over time although, along this dimension, there are few indications today of any momentous reversals in the offing. This is surprising since the global financial crisis has revealed a number of flaws in the decision-making strategy adopted by some central banks and the reliability of their economic outlook.

[7] The one notable modern exception being the European Central Bank.
[8] This development is reflected in indicators of central bank transparency. See Siklos (2002, 2011, 2017), and Dincer and Eichengreen (2014).

Early in their history most central banks were dominated by a single decision-maker. While staff no doubt provide support to the Governor, central banking was seen as a top-down institution with extraordinary authority vested in the Governor. Even if Governors largely remain *primus inter pares* there is now recognition and perhaps even an expectation that decisions cannot be taken without the advice of a committee of experts whose accountability to the government varies. Moreover, it is now *de rigueur* to see central banks with technical and research support as a further indication of the professionalization of the central banking profession (e.g., see Adolph 2013). Paralleling this development has been the growth in the number of academics and economists as central bankers that have increasingly replaced the bankers and bureaucrats who originally ran most central banks. Moreover, in recent years, there is an impression that Central Bank Governors are once again playing a seemingly outsized role in public policy discussions. The media hangs on their every word. Meanwhile, political pressure on central banks is also on the rise. Surprisingly perhaps, there have been fewer indications of policy makers questioning whether there is sufficient diversity of opinions represented in policy making committees. Indeed, using the U.S. case as an example, the slightest indication of greater Fed dissent attracts the immediate attention of financial markets.[9] To the extent there exists dissent it is reflected in monetary policy committee members' economic outlook. A recent example, of course, is the so-called Fed 'dot plot'.[10]

[9] Thornton and Wheelock (2014) review the history of dissents inside the FOMC. These peaked under Volcker and declined under Greenspan only to rise under Bernanke and Yellen's chairmanship.
[10] These are found in the projections contained in the Monetary Policy Reports of the U.S. Federal Reserve. See https://www.federalreserve.gov/monetarypolicy/mpr_default.htm.

One area of central banking that has been left untouched by fads or fashion is the virtual elimination of a private sector ownership role in central banks. With a few notable exceptions (e.g., Switzerland) central banks were eventually nationalized and there is no hint that this phenomenon will ever be reversed. Indeed, whereas private ownership was part and parcel of the oldest central banks, after World War II, the central bank became an institution entirely within government.

At this juncture in monetary and economic history what has come to dominate the current debate is the policy strategy of central banking. Indeed, in order to understand where we might go from here there is a need to re-examine the evolution of monetary strategies since their creation in Sweden almost three and a half centuries ago.

From about the early 1990s until around 2007 monetary policy was increasingly viewed in narrow terms as concerned with inflation control. Prior to the most recent era, however, there was a never ending struggle between central banks and governments that were thought to behave in a manner captured by the famous time-inconsistency hypothesis of Kydland and Prescott (1977). The hypothesis suggests that central bank independence (or 'conservatism' in the language of Barro and Gordon (1983) and Rogoff (1985)) is a mechanism that can avoid inflation rising above what is deemed socially optimal by pushing back against the desire of the political authorities to exploit the Phillips curve trade-off. By implication, this implies that the central bank can protect or even enhance its reputation by committing itself to a policy that is successful at preventing the discretion that may originate from political pressure on the monetary authorities.

Finally, a successful monetary policy requires only a single instrument, an interest rate, to ensure low and stable inflation. Indeed, ever since central banks became a tool for macroeconomic stabilization, especially after World War II, until the late 1980s and early 1990s, the strategy that consisted of aiming for adequate economic growth while limiting inflation (captured in the famous Taylor Principle) came to dominate the consensus about how best to conduct monetary policy. Moreover, these developments took place in parallel with acceptance that fiscal discipline is essential to allow the central bank to meet its objective.

The foregoing sentiments were also given credence by central bankers. As Mervyn King, former Governor of the Bank of England, once said (King 1995): "Central banks are often accused of being obsessed with inflation. This is untrue. If they are obsessed with anything, it is with fiscal policy." Although this is arguably an exaggeration it does highlight the potential threat of fiscal dominance.

Events in recent years have not changed the consensus. Indeed, most governments and their central banks have not changed their numerical targets at all since the 2007-9 global financial crisis. An outside observer would be hard-pressed to conclude that monetary policy changed as a result of the momentous events of the past few years. Yet, the strategy of monetary policy has changed and many central banks now have to balance the need to maintain financial system stability defined as preventing imbalances, in addition to achieving an inflation objective. The resort to a multiplicity

of instruments to carry out a strategy that has yet to be made clear also suggests a regime shift in monetary policy.[11]

Equally important, the turmoil in global financial markets since 2007, followed by the admittedly slow return to a state that approaches pre-crisis conditions, led more central banks to invoke 'data dependence' as a guide to monetary policy. The problem is that, even in the heyday of the Great Moderation, when central banks were fond of saying that they looked at everything before setting the stance of monetary policy, post-crisis this was seen by some as an inability, if not unwillingness, to return to more rule-like behavior (e.g., see Siklos 2017).

Other than the breadth and scope of the interventions by central banks in recent years, there is some irony in that central banks are being encouraged, implicitly or explicitly, to adopt a strategy that defined the mandate of some of the oldest central banks, namely a concern about preventing financial instability together with allowances for the possibility of fiscal dominance. Finally, the continued resort to various forms of quantitative easing (QE) type policies in systemically important economies over an extended period of time also creates the possibility of a return of fiscal dominance through a back door.

Unlike our pre-crisis understanding of inflation, central bankers are not yet able to convince the public that their forays into financial market intervention are as effective as they have claimed or have consequences that they fully understand. Part of the problem is that so-called Unconventional Monetary Policies (UMP) are intended to

[11] We define a monetary policy strategy in terms of the goals of monetary policy. In contrast, a monetary policy regime is characterized by the instruments used to achieve the stated strategy.

deal with short-term difficulties in the financial system. Not surprisingly, much of the recent literature focuses on how QE affects asset prices. Demonstrating that UMP can help boost economic growth, return inflation to a normal level, or even convincing the public that output growth would have been even lower without it (a counterfactual) is much more difficult.

No wonder then, when faced with 'pushing on a string', the response of central banks is to 'push harder' but without a convincing reason to persist with such a strategy. A look back at the history of central banking, however, suggests that policy makers are attempting to define a new monetary policy strategy but one which has yet to be fully debated let alone well understood.

Central banks, it is sometimes forgotten, are creatures of sovereign states. As a result, while they are geared towards domestic objectives these are rarely removed from international concerns. Obviously, the prime symbol of the transmission of international shocks is via the exchange rate.

Other than flexible inflation targeting there have been three other monetary policy regimes that have, in one way or another, implicitly or explicitly taken a stand on the behavior of the exchange rate. Stated differently, declaring a policy regime aimed at some price stability objective, especially when this is combined with other goals (e.g., employment, another economic or political objective), should have implications for exchange rate behavior. Examples are the gold and the gold exchange standards, the Bretton Woods system of pegged but adjustable exchange rates, and the European Monetary Union which created a common currency by setting an irrevocable

exchange rate between sovereign nations. Moreover, the strategy has generally always been the same across all regimes, namely to achieve a form of price stability. Financial system stability was generally believed to be the collateral benefit from any strategy that aims to keep inflation low and stable. At the risk of over-simplification, policy makers have always sought, but did not always succeed, in defining a monetary policy regime that could rely on a minimum of policy instruments. One of the great appeals of flexible inflation targeting is that a single instrument is capable of meeting the strategic objectives of monetary policy. One only has to look at most central banks' depictions of the monetary policy transmission mechanism prior to the global financial crisis to get confirmation of this view.

Beyond these questions is the age-old role of exchange rates that has also re-emerged as a fallout from large swings in currency values as central banks follow non-traditional policies and deviate from the simple rules based policies that appeared to have worked so well during the Great Moderation (Bordo and Schenk 2016). Some central banks have also returned to using the older tools of exchange market intervention to short circuit the market's view of the currency's appropriate value.

This development is also a reflection of another perennial concern of policy makers, namely exchange rate stability. In contrast to the attempt to return to the pegged rates of the gold standard after World War I, the post Bretton Woods era has favored greater exchange rate flexibility. Nevertheless, one cannot entirely dismiss the possibility of a return to some attempt to moderate exchange rate movements especially if inflation targeting, with its reliance on a floating exchange rate, is

threatened. Since the latest global financial crisis there are signs, so far unsuccessful, that this movement toward formal exchange rate management could take place.[12]

What remains unclear is the form in which this might take place. A great deal of the difficulty is that the trade channel of exchange rate changes differs from the financial channel. In the former a depreciation improves the balance of trade but has negative effects on financial flows. Complicating matters is that these channels have a different impact depending on the sophistication of the financial system (e.g., see Kearns and Patel 2016).

Now is a propitious time to examine whether certain kinds of economies are more prone than others to adopting new strategies and to leave the past behind.[13] Moreover, it is also germane to ask whether certain types of events, such as a financial crisis, are likely to push an economy to a tipping point leading to a change in the monetary policy strategy in place.

Historically, large systemically important economies were at the forefront of creating central banks and vesting them with the authority and tools to influence economic outcomes. By the late 20th century, however, it was the small open economies that were seen as relatively more innovative in developing best practices in monetary

[12] Ilzetzki, Reinhart and Rogoff (2017), reprising an earlier study (Reinhart and Rogoff 2004), dispute the view held, for example, by the International Monetary Fund, that exchange rate regimes have typically become more flexible over the past couple of decades. Many inflation targeting economies are said to have adopted a variant of managed floating. One can, of course, quibble with their identification strategy. For example, Canadian officials would likely object to Canada's regime being labelled a managed float. Nevertheless their results remind us that policy makers scrutinize exchange rate movements as an indicator of exchange rate management.

[13] In what follows we focus on historical and economic reasons for the choice of regimes and not on the nexus between monetary thought and the adoption or rejection of particular forms of monetary policy. Interested readers should consult Laidler (2015), and references therein.

policy and coherent policy strategies. We provide some suggestive supporting evidence for this insight.

This paper also argues that, by the late 20th century, small open economies were more prone to adopting a new policy regime when the old one no longer served its purpose whereas large, less open, and systemically important economies were more reluctant to embrace new approaches to monetary policy.[14] Small open economies are more flexible [15] and as trade and financial globalization have progressed over time, especially after World War II, more aware of the importance of global shocks. In contrast, large and systemically important countries have tended to rely on a pre-conceived notion that they were more immune to global influences, that is, that their policies potentially influence the rest of the world but not the other way around. It has taken the aftermath of the global crisis of 2007-8 for even the Fed to begin publicly acknowledging that global conditions do matter. Assuming, as Milton Friedman once wrote, that in the aftermath of a crisis policy makers tend to be more receptive to the "ideas that are lying around"[16] there are at least two sets of results that can be informative about whether and what central banks learn from each other. First, the policy response and reforms in the aftermath of a financial crisis. Second, if the good ideas include the demonstration effect from the experience in other

[14] In our data set these economies are: Canada, Norway, Sweden, and Switzerland.
[15] And are, in words of Capie, Wood and Castañeda (2016), are perhaps more likely to be "high trust" societies.
[16] In the Preface to the 1982 edition (pg. xiv) of *Capitalism and Freedom* (2002) Milton Friedman argued: "Only a crisis—actual or perceived—produces real change. When that crisis occurs, the actions that are taken depend on the ideas that are lying around. That, I believe, is our basic function: to develop alternatives to existing policies, to keep them alive and available until the politically impossible becomes politically inevitable."

economies, then the extent to which global factors influence inflation in particular may well be to provide another indication of the likelihood of learning from others.

The combination of a flexible exchange rate regime, a concern for ensuring a form of price stability, and more effective prudential requirements rendered small open economies more nimble to policy shocks from various sources. Hence, innovations in the area of deciding when to reform an existing monetary policy regime may well originate in small open economies.[17]

A significant challenge in explaining the evolution of central banks across several economies lies in part with limitations on the scope and availability of data over a long span of time combined with what appear to be frequent breaks or interruptions in the conduct of monetary policy. Accordingly, this paper combines a narrative approach with some empirical evidence that is intended to support some of the claims being made. While the empirical evidence may not be definitive it does point in the direction of clear connections across economies in the policy regimes adopted over time. Our work is also assisted by the recent empirical macroeconomic literature that has led to the view that a few common factors can explain the bulk of the variance of macroeconomic data. If this is the case then there is considerable useful information in cross-country estimates of the drivers of inflation and economic growth.

As we shall see below, we can also potentially exploit correlations among cross sectional units to consider a series of counterfactuals. Several central banks have

[17] There are, of course, some exceptions such as the UK, an early adopter of many innovations in the conduct of monetary policy that persist to this day. Similarly, in other important cases, such as in Europe, politics overwhelms economics leaving the tension between the desire to have a common currency while relying on monetary policy to deliver economic outcomes its members aspire to, largely unresolved. See, for example, James (2012).

existed for a long time although, in historical terms, the institution is comparatively young. Hence, one way to ascertain their influence is to ask 'what if ' kinds of questions to better understand their economic impact as policy regimes and strategies have evolved over time.

One asks whether countries that did not have a central bank while others did would have ended up with better macroeconomic performance had they created a central bank earlier. Relying on panel data since at least 1870, or before, for at least 10 economies we can generate hypothetical estimates of inflation and real GDP growth under a counterfactual scenario such as the one just described. Until the 1990s, major changes in policy regimes were often adopted more or less simultaneously by several countries. However, regimes often ended as a result of examples from the smaller economies. It is, therefore, worth asking whether the data are suggestive of a learning mechanism whereby a change in the policy regime originates first from smaller, more open economies instead of from the dominant economies in the international monetary system.

3. Policy Regimes in Historical Perspective

Convenience dictates that exchange rate regimes should be sub-divided into the fixed or floating varieties. Of course, fixed exchange rates regimes come in different guises while floating rate regimes are ill defined unless an anchor for policy is chosen. In the case of fixed exchange rates we have seen the Gold Standard, through Bretton Woods, followed by the limited exchange rate systems that eventually gave birth to the European Exchange Rate Mechanism (ERM) and, finally, a monetary union of the kind

that resulted in the creation of the euro. Floating regimes have generally targeted either a monetary aggregate or, in recent decades, inflation.

Since central banks represent one of the most potent symbols of sovereignty their ability to respond to both domestic and foreign shocks is an appropriate way to think about policy regimes. Clearly, how the exchange rate regime is understood is one way to identify how the balance between these two shocks defines the regime in place.

All told it is fair to say that the world economy has seen five major monetary policy regimes adopted over the past two centuries.[18] They are: the Gold and Gold Exchange standards of pre-World War II. Then, shortly after the Second World War ended, the Bretton Woods system was put in place though it took several years to fully take effect. Like its pre-war counterpart the regime remained anchored to the notion that exchange rate fluctuations should be limited. For a policy regime that has been outlived by all the other major monetary arrangements, save one, it is surprising how the Bretton Woods arrangement continues to appeal to the imagination of some policy makers. Perhaps, as Dooley et. al. (2009) have argued, it is because the system survived in a different form after its presumed collapse in the early 1970s. Alternatively, as the global financial crisis reached its peak in 2008 and 2009, there were calls from many quarters for a 'new Bretton Woods', culminating with the London Summit of the G20 leaders.[19]

Once Bretton Woods ended, the search for an anchor of monetary policy led, in quick succession, to variants of the Bretton Woods system, chiefly in Europe. It also led to

[18] Six regimes if we add the creation of central banks. See below.

[19] The desire for a new Bretton Woods was, like the aim for a monetary union in Europe, more enthusiastically supported by politicians than academic economists.

the adoption of money growth targeting in a number of countries. The money growth targeting regime survived for less time than did Bretton Woods. In the case of Europe the volatile transition from the end of the Bretton Woods System and the pegged exchange rate systems of the 1970s and 1980s hastened the adoption of a common currency (the euro) and a common central bank (the ECB) among several sovereign states, a monetary regime that had never before in history been implemented in this manner. Yet, the drive to create a single currency in Europe was primarily driven by political motives. Hence, while politics eventually enabled the creation of the euro it also left the enterprise bereft of the necessary institutional structures and policy instruments necessary for its long-term survival which, as this is written, may be in doubt (e.g., see James 2012, Sinn 2014, Brunnermeier, James and Landau 2016). Nevertheless, this regime has so far still managed to outlive Bretton Woods.

While loose forms of exchange rate targeting persisted in various parts of the world it is the spread of inflation targeting that came to define the last two or three decades of monetary history. Indeed, on the eve of the global financial crisis, 10 advanced economies had adopted an explicit numerical inflation target (IT) as well as 23 emerging market economies. Four other economies (i.e., the US, the Eurozone, Switzerland, and Japan), although unwilling to acknowledge the IT label, do formally recognize the need to aim for some inflation objective and have made public a numerical value associated with some notion of price stability (e.g., see Siklos 2017).

Two other striking features about the foregoing brief history of policy regimes are worth noting. First, it is often the case that the transition from one type of regime to another, regardless of the type, has not always been a smooth one. The end of the Gold

Standard during the interwar era and the Great Inflation that spelled the end of Bretton Woods immediately come to mind. Second, whereas there was less of a tendency for different policy regimes to overlap each other before World War II, following Bretton Woods there is seemingly more overlap in the adoption date of policy regimes ranging from inflation targeting to the most binding form of a fixed exchange rate regime, namely the Eurozone single currency area. Nevertheless, with the exception of the UK, the adoption of IT is largely driven by small open economies while the larger, more systemically important economies have either resisted embracing the IT moniker or eschewed the label entirely. Table 2 provides a summary chronology of the principal monetary regimes since central banks examined in our sample were created.

If we focus on inflation performance only the Gold Standard always delivers the lowest mean inflation rate followed by inflation targeting in those countries where it was adopted. Note, however, that inflation volatility is relatively higher than in any of the other policy regimes considered. Where IT is not adopted the period since the euro enters into circulation provides the next best inflation outcome.[20] In contrast, Bretton Woods always delivers the highest rate of economic growth. No wonder then that some of the G20 leaders at the 2008 Washington summit summoned the memory of Bretton Woods (Winnett 2008). The Gold Standard comes in second place everywhere except for the UK, France and Norway. Similarly, the relatively brief era

[20] Except for France where ERM has a trivially lower average inflation rate (1.52% versus 1.54% during ERM).

of monetary targeting often performed worse than the other policy regimes other than for the UK.

Comparisons such as these are hazardous for several reasons. First, performance in a particular era reflect a delay in problems that only emerge in the next era. Second, economic growth performance cannot entirely be associated with the monetary policy regime in place. Structural factors, often slow moving, emerge in the aftermath of wars or technological developments that are independent of the monetary policy in place. Finally, Stock and Watson (2004) noted some time ago that inflation performance during the Great Moderation reflected a healthy dose of 'good luck' and not 'good policy'. The former was facilitated by relatively small shocks to the US economy. The same type of phenomenon may well have explained inflation performance elsewhere.

The recent financial crisis, however, has also reminded policy makers about another important distinction that has the potential of shifting the singular focus on the role of the exchange rate regime which has dominated the discourse about the influence of monetary policy regimes throughout history at least until 2008. The events of the past eight years have led to a rediscovery of the critical distinction between shocks that originate from the real and financial sectors of the economy. The interdependence referred to above, ostensibly guaranteed by a pure float, can be upended when financial flows enter the picture. In particular, the subsequent global impact of the financial shock that originated in the US in 2007 transcended how existing exchange rate regimes operated. Indeed, the highly synchronized downturn

in economic activity and inflation was felt around the world irrespective of how flexible exchange rate regimes were.[21]

Instead, it was a coherent policy strategy which included commitment to an inflation objective at its core, a resilient and effective financial regulatory regime, together with the flexibility and willingness to use the available fiscal space, that proved to be the defining characteristic of economies that suffered relatively less economically, especially during the worst moments of the global and subsequent Eurozone sovereign debt crises in 2008 to 2010. Another important factor in the success of these countries was the financial structure and regulatory oversight. Before the crisis, Canada, Australia and New Zealand had nationwide universal banks and one regulator in contrast to the U.S. Of course, these countries were not global financial centers unlike the UK which had a similar banking and regulatory structure (see Bordo, Redish, and Rockoff 2015). Finally, given the preference in some economies for a policy strategy that includes less than perfect exchange rate flexibility, a preference for anchoring expectations to an inflation objective proves relatively more important than the *de facto* exchange rate regime in place, especially in some emerging market economies. Indeed, IT regimes have been sufficiently successful at anchoring inflation expectations to the target that, years after the GFC, below target inflation rates are raising questions about whether central banks have become complacent leading to calls to raise the inflation target substantially (e.g., see Ball

[21] Rey (2015), for example, is another study that emphasizes the importance of a global financial cycle since the 1990s, that is, a reflection of the monetary policy of a dominant or 'centre country' (viz., the US). This has the implication of reducing the trilemma conditions for an independent monetary policy, where a floating exchange rate plays a critical role, to a dilemma. Hence, capital account management is necessary to preserve policy independence. Aizenman, Chinn and Ito (2016) conclude, however, that the trilemma is alive and well, at least in emerging market economies.

2014, and references therein). It seems that proponents of higher inflation want fewer opportunities to hit the ZLB which can create problems for central banks in search of still looser policies. But those who favor a tactic of raising inflation targets cannot provide a convincing argument that higher inflation will also improve aggregate economic performance. Estimating a threshold beyond which inflation produces a deterioration in economic growth has proved elusive (e.g., Bruno and Easterly 1998, Vaona 2012) Instead, the essence of their argument is that central banks must want to avoid the ZLB and negative interest rates as much as possible even though there is little evidence that these developments have proved difficult for central banks to implement

4. Methodological Approaches

The preceding section suggests that evaluating the impact of central banks throughout history is full of challenges requiring the interested observer to ask several 'what if' questions. Even under ideal circumstances engaging in counterfactuals is difficult. For example, we ask what aggregate economic activity would look like if an institution expected to intervene in the economy to meet a particular objective, or set of objectives, did not exist. However, as noted above, central banks are a pervasive feature of the economic landscape for a century or more. We have very few examples, or the necessary data, to evaluate what might happen if the monetary authority did not exist. Additionally, monetary history teaches us that it is difficult to neatly separate policy regimes from other events that are very likely to also have macroeconomic effects. To illustrate, it can be hazardous to contemplate what inflation and real economic growth might have been if a central bank had been

created earlier especially during an era when rules such as the Gold Standard were in place. Two reasons immediately come to mind. First, central banks under the Gold Standard were less interventionist than today's monetary authorities. Second, the Gold Standard is squarely focused on price level developments not inflation per se. Nevertheless, depending on the statistical properties of the price level one may still be able to explore central bank performance in terms of inflation.[22]

Nevertheless, there is considerable value in conducting counterfactual experiments if only to get an impression of some of the potential impacts of institutional changes such as the creation of a central bank. In part this is because rules are rarely followed exactly as intended. This is especially true when these institutions must also consider the international environment in which the rules are intended to be applied.

Counterfactuals, while useful, cannot entirely replace inference based on the observed behavior of time series. Accordingly, we also perform a set of econometric tests to help us understand not only when central bank policies may have changed but also the extent to which these changes are transmitted from one country to another over time.

4.1 *Breaks, Gaps and Their significance: Combining History and Econometrics*

From a practical perspective the choice of a monetary policy regime is likely the result of a shift in the behavior of one or more key economic performance indicators. Of course, a regime change may also create additional forces that may also produce

[22] "Under the Gold Standard the price level has a stochastic trend because real shocks to the demand and supply of gold caused changes in the money supply and, over the long-term, the price level." (Bordo and Schwartz 1999). The stochastic trend nature of price movements implies that the stationary component of prices can be expressed in first differences of the (log) of prices.

changes in one or more of these indicators. For example, one can imagine that the creation of a central bank, the abandonment of one exchange rate regime and the adoption of another or even an explicit commitment to achieving a form of price stability, at least statistically, is identified by a structural break. Given the particular importance of inflation in assessing central bank performance, an obvious choice then is to focus on the behavior of this variable. Output growth is another equally valid candidate for analysis. After all, an ostensible reason for inflation control is to create an environment for mitigating business cycle fluctuations, at least when interpreted through the prism of modern macroeconomic thought.

Whereas monetary policy was geared towards inflation control post-World War II, the Gold and Gold Exchange standards involved strategies that focus on achieving a form of price level stability by maintaining gold convertibility through the setting of the fixed nominal price of gold. In more modern parlance, the price of gold served as the instrument that translated into achieving price level stability**.**

There exist, of course, several statistical time series based tests for structural breaks. Since the countries in our data set may well have undergone more than one regime shift it is natural to consider first a test that allows for multiple structural breaks. The Bai and Perron (1998) test is likely the best known test under the circumstances and we also adopt it here. It has the advantage that it is model based as opposed to the standard univariate approaches to testing for breaks. Of course, if the model is mis-specified the advantage disappears.

All structural break tests, and many have been proposed, have their drawbacks (e.g., see Perron 2005). For example, Perron (1989) pointed out that the behavior of US

real GDP is best described as a trend stationary process with a structural break around the time of the Great Depression but that the result is partly dependent on the choice of the year of the break. As a result, unit root testing from structural break testing cannot be easily separated. Moreover, one must also consider the possibility that the break is akin to a one time shock or can occur gradually.[23]

A retrospective historical analysis may well have led to selecting a year that differs from the statistical testing. It is precisely differences between these two methodologies that require further analysis.[24] Moreover, as we shall see below, a narrative approach often leads to a range of years over which a break takes place as opposed to a single year. And when a gradual change is allowed the statistical procedure leaves little choice but to adopt a somewhat *ad hoc* function or model to capture such changes. History can provide more flexible timing for breaks but this does not mean that there is unanimity in pinpointing, for example, when financial crises take place and for how long.[25]

In one set of calculations, we assume that before the creation of the US Federal Reserve the Bank of England serves as the benchmark for global price stability. After 1913 the Federal Reserve is then assumed to serve as the standard sought by the

[23] An innovation (innovation outlier, or IO) model which assumes that the break occurs gradually, with the breaks following the same dynamic path as the innovations, while the additive model (or additive outlier, AO) model assumes the breaks occur immediately.

[24] There is occasionally the tendency to ignore history and rely instead on statistical testing alone. This ignores that the specification of the null and alternative hypotheses, not to mention the power of available test, invites caution in relying too heavily on this kind of strategy. Similarly, historical analyses are also subject to selectivity bias. Presenting both forms of evidence at least has the advantage of prompting the researcher to look for some explanation for any discrepancy between the timing adopted by historians and the one generated via econometric means

[25] An illustration is the Reinhart and Rogoff (2009) dating of various types of financial crises. Bordo and Meissner (2016) find fault with some of the banking and currency crises identified by Reinhart and Rogoff. In what follows we adopt the Bordo and Meissner (2016) chronology.

economies in our sample. The two are chosen because of the systemic importance of both economies. Clearly, other benchmarks are possible see below). A difficulty here is that, under the traditional Gold Standard and successive regimes tied to gold, the instrument of policy, as previously noted, translates into a regime geared toward the maintenance of price *level* stability. Once the Gold Standard ended in the middle of the twentieth century the objective of policy evolved into a focus on inflation performance. In what follows the discussion is in terms of inflation performance strictly for convenience. For the Gold Standard era we derive the estimates of interest in terms of the price level (or, rather, the log of the price level) and then take the rate of change to ensure comparability with the post-Gold Standard era.[26]

Define

$$d_{it} = \pi_{it} - \pi_t^B \tag{1}$$

where π is inflation and π^B is inflation in the benchmark economy. Each economy is indexed by *i* at time *t*. Notice that the benchmark economies are, by modern standards, large systemically important economies. If smaller, more open, economies adopt similar regimes over time and, as a result, deliver comparable inflation rates then d in equation (1) is expected to be stationary. If, however, stationarity is rejected then so is convergence of sorts between economy *i* and the benchmark economy. A possibility then is that adopting a new monetary regime is conditioned on the development, persistence, and size of any gap in inflation performance between

[26] For the Gold Standard (and related regimes) period we also present and provide cross-country comparisons in terms of the price level. Not all results are presented below.

economy *i* and the benchmark economy in question.[27] In other words, we treat equation (1) as serving as a proxy for the level of dissatisfaction with the existing policy strategy.[28] Dissatisfaction with the preferred or best performing existing international strategy may reflect a domestic failure to follow best practice in monetary policy. Alternatively, if the benchmark economy no longer serves as the lodestar for how to conduct monetary policy then the source of unhappiness with the current regime lies with the economy that is seen as the standard for others to follow. As note above, other benchmarks are contemplated. For example, if the 10 central banks in our study can, in fact, be treated as a global network of central banks that learn from each other then perhaps an international measure of inflation is a more suitable benchmark.[29] Unfortunately, no universally accepted measure of global inflation exists. Therefore, we construct three proxies. The simplest is an arithmetic average across the 10 economies in our data set. Next, we extract the first principal component in a factor model of inflation, again including data from all 10 countries in the sample.[30] Finally, many researchers extract a trend or equilibrium measure of a time series by applying the Hodrick-Prescott (H-P) filter. Hamilton (2017) not only reminds us of the drawbacks and distortions induced by this filter but recommends a

[27] A similar argument can be made in terms of another key economic indicator such as real GDP growth**.** Arguably, economic development is influenced by structural factors that are not easily quantified. Hence, for reasons already stated, we prefer to focus on inflation performance.

[28] For the benchmark economies the level of unhappiness with the existing regime would be its own historical experience for one or more key economic indicator or continued discrepancies vis-à-vis expectations for the particular economic indicator in question. This brings up the question of credibility in monetary policy. See Bordo and Siklos (2016) for an historical examination relying on a similar data set as the one used in the present study. The current study is more comparative in nature.

[29] Alternatively, the real price of gold is also a suitable benchmark.

[30] Again, in the Gold Standard era, we can examine these same relationships in terms of the (log) of the price level although the conclusions did not change**.**

simple new alternative. In what follows we implement Hamilton's replacement for the H-P filter to proxy for π_t^B in equation (1).

4.2 *Counterfactuals*

At the simplest level counterfactuals are an attempt to answer 'what if' kinds of questions. As a result, quantitative methods to obtain counterfactual results are varied. In what follows, we apply Hsiao et. al.'s (2012) method.

To illustrate their methodology consider the following four central banks. They are, in order of the dating of their creation (years in parenthesis; see Table 1): the Bank of Italy (1893), the Swiss National Bank (1907), the US Federal Reserve (1913), and the Bank of Canada (1934). Ideally, we would like some data when these institutions did not exist in order to determine what macroeconomic performance would have been like if a central bank had been created earlier. The treatment or intervention then refers to the year when a central bank is created.

Next, consider Figure 1. The plot shows when central banks were created relative to when these economies became nation or sovereign states in the modern sense of the word.[31] A positive bar means that the central bank came into existence before statehood or independence while a negative bar indicates how many years it took once statehood was achieved until the monetary authority to be created. The central banks that are identified by the vertical dashed lines are the subject of the empirical analysis. The choices are dictated by data availability and quality over a long time span. Details are left to the following section.

[31] The traditional definition relies on a date of independence or the introduction of a Constitution.

Almost half the central banks in our sample were in existence before statehood. As discussed above they were, at least for a time, banks of issue and their functions would evolve over time. However, statehood generally comes first followed by the creation of a central bank. Indeed, in many cases, the gap between the two events is small, a reflection of the almost symbiotic link between the concepts of sovereignty and central banking.

Figure 2 plots the number of central banks created since the Riksbank, the world's first central bank, opened its doors in 1668. It is seen that central banks are largely a creature of the 20th century. Indeed, the pace of central bank creation speeds up after the 1950s. Hence, central banks are comparatively young institutions. However, because so many central banks came into existence after World War II, when data availability increases dramatically, the experimental way of conducting a counterfactual experiment is simply not available or practical in the present context. Therefore, an alternative approach is required and this is where a long span of historical data is especially helpful.

Returning to the four central banks in our example, we have a substantial amount of data about how economies performed in several economies when monetary authorities did not exist in Italy, Switzerland, the US and Canada. While data availability is adequate statistical challenges remain, as we shall see.

The approach proposed and implemented by Hsiao et. al. (2012) exploits information in a cross-section of data. Hsiao et. al. (2012) ask what economic growth in Hong Kong would have been if sovereignty had not changed hands from the British to China in

July 1997.[32] The basic premise of the counterfactual is that there exist common factors that drive economic variables of interest whether or not there is some treatment or intervention. In the present context, once a central bank is created there is the presumption that an institution is created that has some discretion. Granted the scope of that discretion will be limited by the exchange rate regime in place, the remit given to the institution, its autonomy from government influence, to name three important factors. Similarly, there is not quite a comparable institutional mechanism that is able to fully take the place of the central bank.[33] Yet, economic performance, as summarized, say, by the price level, inflation and output growth performance, in two countries respectively with or without central banks will still respond to some common factors.[34]

Therefore, we can use information in the cross-section of inflation and real economic growth performance in countries that had a central bank to ask how these two variables would have behaved had a central bank been created in a country that did not have a monetary authority over the same period.

[32] They also ask what economic performance would have been if the 2003 economic partnership agreement with mainland China had not been signed.

[33] Before the creation of central banks there were, however, alternative institutional mechanisms that effectively played some of the role later assigned to a central bank (e.g., as the US Treasury did in the case of financial crises in the National banking era when it shifted deposits from the Independent Treasury to key commercial banks or the role of clearing houses in issuing emergency currency (Timberlake 1984. Gorton 1984). Also in the case of some dominant nationwide commercial banks in Australia, Canada, and New Zealand. In some cases, the government would also intervene from time to time in a manner reminiscent of what central banks would later do (e.g., as in the Finance Act of 1914 in Canada; see Siklos 2006).

[34] Productivity, demographics, geographical location, even historical events may link these economies even if they adopt different institutional frameworks. As we shall see, statistically speaking, the details of the common drivers of economic performance are less critical than the mere fact that some of these common factors are believed to exist.

More formally, suppose we observe a time series for country *i*, at time *t*, denoted y_{it}^N for the case where there is no central bank. The counterfactual assumes that there exist (common) factors that explain *y*. Hence, we can write

$$y_{it}^N = \alpha_i + \boldsymbol{\beta}_i^* \mathbf{F}_t + \varepsilon_{it}, i = 1,...,N; t = 1,...T \quad (2)$$

where $\boldsymbol{\beta}^*$ is a vector of coefficients that is constant over time but varies across the *i* cross-sections, F are the K common factors that vary over time, and ε is a residual that represents the random idiosyncratic component for *i*, such that $\mathrm{E}(\varepsilon_{\mathrm{it}}) = 0$. It is assumed, among other things, that the idiosyncratic components are uncorrelated across *i*. Therefore, $E(\boldsymbol{\varepsilon}_t \mathbf{F}_t^{'}) = 0$.[35]

Next, denote y_{it}^{CB} as the time series of interest when a central bank is in place. Therefore, the expression

$$\Delta_{it} = y_{it}^{CB} - y_{it}^N \quad (3)$$

is the treatment effect of *i* at time *t*. Since, in our example, we don't observe the right hand side variables simultaneously, the observed data can be thought as being expressed in the linear combination form

$$y_{it} = \mu_{it} y_{it}^{CB} + (1-\mu) y_{it}^N, \mu_{it} = \begin{cases} 1, & \text{if } i \text{ is under treatment at time } t \\ 0, & \text{otherwise} \end{cases} \quad (4)$$

Under the various assumptions made by Hsiao et. al. (2012) y_{1t}^N can be predicted from $\hat{y}_{1t}^N$ obtained from estimating (4). With *i*=1, and the remaining *i* assumed to be

[35] There are other assumptions that are less critical for the discussion that follows but should be borne in mind. See, however, Hsiao et. al. (2012, p. 707).

unaffected in the presence of intervention,[36] the foregoing expressions suggest that we can estimate what the price level, inflation or real GDP growth would have been in Italy, Switzerland, Canada, or the US, each of the *i*=1 in the above illustration, using data from the countries where central banks were already in existence. The only additional piece of information required is knowledge of $T^{\#}$, that is, the year when the central bank is created. From $T^{\#}$ until the data ends (i.e., T) $\mathbf{y}_t = \mathbf{y}_t^N, t = 1,...,T^{\#},T^{\#+1},...,T$. In other words, we observe a central bank in all economies examined. Hsiao et. al. (2012) also show that one can fit time series models to Δ_{1t} (e.g., AR type specifications) to determine the evolution of the treatment effect over time and in the long-run.

For the illustration considered so far the empirical strategy based on the counterfactuals proposed by Hisaio et. al. (2012) imply that, in the case of the US, we can use data from all available countries before $T^{\#}$ =1913, with the exception of Canada which did not have a central bank at the time. Similarly, in the case of the Swiss national bank, we can use all available data except for US and Canadian data since a monetary authority did not exist in these countries at $T^{\#}$=1907. And so on for other available cases, assuming we have sufficient data (see below).

One potential criticism is that if the size of the other economies used to generate the counterfactuals is too large or too small then estimates might be biased. This can be taken into consideration by adding a weight for the relative size of each economy in

[36] In the case of the Hsiao et. al. (2012) application, Hong Kong may well have been affected by the change in sovereignty but the comparator economies (e.g., neighbour economies with similar economic characteristics; see Hsiao et. al. (2012, p. 717-8) would not be similarly affected. In the present context, the creation of the US Fed may have affected US economic activity but it is less likely that these same variables would be impacted in the countries that already had central banks.

question. The difficulty is that if these weights change over time such an adjustment is ad hoc. We do not pursue this extension. Similarly, if location is thought to matter then, in principle, equation (2) could be expanded to include regional dummies (e.g., Europe vs North America).[37]

A more significant drawback perhaps is that for at least 6 economies in our data set (see the next section) we cannot ask what would have happened if a central bank existed because, with the exception of a few series, we have insufficient data.

Finally, we can use the Hsiao et. al. (2012) to determine what would have happened if, for example, targeting had not been adopted. Other counterfactuals can be imagined but the combination of data limitations and significant changes in economic structure in the economies considered here limit their usefulness. We briefly return to this issue later.

4.3 The Determinants of Inflation Differentials

The specification of equation (1) implies that, in a cross-section setting, there are likely economic and institutional determinants of inflation (or price level) differentials across countries (and time). In the case of institutional determinants our narratives suggest that a financial crisis, either of the global or banking varieties especially, are likely critical determinants of these differentials and, hence, might spur the adoption of a different monetary policy strategy. Other candidates include the

[37] Hsiao et. al. (2012) examine the statistical benefits of relying on the factor model approach to generating the counterfactual series (i.e., equation (2)) and find a significant deterioration relative to the simplest case of, say, relying only on growth rates in countries with no treatment to estimate what would have happened in the treatment economy (i.e., Hong Kong in their example). In the estimates presented below we report results using the simpler approach since, empirically at least, the performance of equation (2) was superior.

potential for fiscal dominance via the debt to GDP ratio.[38] We provide a variety of estimates of the following panel type regression written as:

$$d_{it}^{j} = \theta_i^j + \lambda_t^j + \mathbf{x}_{it}^{'}\boldsymbol{\beta}^j + \varepsilon_{it}^j \qquad (5)$$

where equation (5) is a standard fixed effects model (country and time effects, if necessary) with **x** capturing the economic and crisis determinants of *d*. The index *j* is added to recognize that a variety of benchmarks were considered.[39]

4.4 A Network of Central Banks?

Billio et. al. (2012) have proposed a measure of 'connectedness' based on principal components analysis and Granger-causality. If the performance of central banks, measured in terms of the price level (prior to World War II), inflation, or real economic growth, is more similar then this should be reflected in the number of orthogonal factors and their explanatory power. Define *N* as the total number of principal components in the 10 country data set used in this study. If central banks are highly interconnected then this should be reflected as a small number, *n*, of principal components that can explain most of the variation in the system of central banks considered.

Alternatively, causality testing provides an indication whether a particular time series *j* "Granger-causes" (G.C.) a time series *i* of past values of *j* contain information

[38] A World War or a major political conflict could be other candidate variables. These can sometimes represent harbingers of economic changes (e.g., following World War I the Gold Exchange standard was introduced; Bretton Woods can be traced as a fallout from World War II). Hence, it is difficult to identify these events as separate from other economic forces that produce regime changes.

[39] We specify (5) in terms of inflation for simplicity. In so doing we convert the price level data to inflation during the Gold Standard period even if some of the tests described above are evaluated in terms of the (log) level of prices. This complication does not affect the real economic growth specification.

that help predict *i.* The test can be carried out in a bivariate or multivariate (i.e., as in a vector autoregression) settings. For example, continuing with equation (1) which measures the inflation differential vis-à-vis a particular benchmark in the bivariate setting, a Granger-causality test between d_{it}^{j} and d_{kt}^{j} with $i \neq k$, would be carried out by estimating the following two regressions, namely

$$\begin{aligned} d_{it+1}^{j} &= a^{j} d_{it}^{j} + b_{ik}^{j} d_{kt}^{j} + e_{it+1}^{j} \\ d_{kt+1}^{j} &= a^{j} d_{kt}^{j} + b_{ki}^{j} d_{it}^{j} + e_{kt+1}^{j} \end{aligned} \qquad (6)$$

where a rejection of the null hypothesis that $b_{ik} \neq 0$ implies that *k* Granger-causes *i*. We can augment equation (6) with other determinants to allow for the possibility that there are additional factors, such as the type of exchange rate regime, or the incidence of financial crises, to give two examples that can influence the Granger-causality test which have no direct association with the notion that central banks learn from each other. Billio et. al. (2012) propose an indicator of connectedness they call the 'degree of Granger-causality' (DGC) defined as follows

$$DGC = \frac{1}{N(N-1)} \sum_{i=1}^{N} \sum_{k \neq i} (k \rightarrow i) \quad (7)$$

where $k \rightarrow i$ signifies that *k* G.C. *i*. A value of DGC that exceeds a certain threshold indicates a systemic relationship between the various measures of *d*.

4. Data and Empirical Evidence

4.1 Data

Annual data, originally collected for 10 economies until 2008 by Bordo and Siklos (2016), were updated where possible to 2015. The data used in their study represent the accumulation of data collected and disseminated over the years by many scholars,

including Reinhart and Rogoff (2009), Bordo and Landon Lane (2013), and Schularik and Taylor (2009), with additional historical data from some individual central banks (viz., Norway, Sweden, USA) who have made available historical data covering a long span of time.[40]

Other original sources that were used to construct the series used in Bordo and Siklos (2016) are found at the NBER (http://www.nber.org/data/). Global financial data, and Historical Financial Statistics of the Center for Financial Stability (http://www.centerforfinancialstability.org/hfs.php), are other data sources where some of the series used in this study can be found.

The 10 economies examined are: Canada, France, Germany, Italy, Japan, Norway, Sweden, Switzerland, the United Kingdom and the United States. An appendix provides the list of available time series and the samples over which they are available. Additional data were collected from various issues of the Central Bank Directory (Central Banking Publications), Siklos (2002, 2017). A file containing a list of original sources and the sources of updates to the Bordo and Sikos (2016) data is available.

4.2 Empirical Results

Figures 3 and 4 plot inflation rates, where sufficient data are available, around the time of regime changes identified by our historical narratives. Inflation five years before and after the creation of 8 of the 10 central banks in the data set is shown.

[40] Many of the links are provided in Bordo and Siklos (2016). Our data set also overlaps the recently published Jordà-Schularik and Taylor data set (JST; http://www.macrohistory.net/) which was also partially constructed based on some of the earlier work of, for example, Bordo and Jonung(1995)). One slight difference between their dataset and ours is the Canadian price level. We use data since 1910, not 1870, to maintain consistency in the measurement of the price level. JST have data since 1870.

Figure 3, for example, shows that it is unlikely that the prime motivating factor to create a central bank in Sweden or the UK was a desire to control inflation. Indeed, history clearly shows there were other factors at play. The same appears true for all the other cases shown with the exception of Norway where inflation becomes far less volatile after the Norges Bank opened for business in 1816. Indeed, the volatility in inflation is related to the fact that, in most instances, the Gold Standard was in place. Hence, the focus was on the behavior of the price level and not inflation.

The top portion of Figure 4 highlights the evolution of inflation in all 10 countries in our data set around the time of the break-down of Bretton Woods. Whereas inflation differentials were fairly small by the mid-1960s a divergence began to emerge as we approach the decade of the 1970s. The 'unanchoring' or drift in inflation that emerges following the end of Bretton Woods, underscored perhaps by the Smithsonian agreement of 1971, produced the great divergence in inflation rates exacerbated by the two oil price shocks of the 1970s.

The bottom portion of Figure 4 reveals that differences in inflation rates persisted for some time as countries sought, and then failed, to find a reliable anchor for monetary policy. By the early 1990s, however, several of the small open economies in our sample, and the UK, adopted explicit inflation targeting. Nevertheless, all central banks, in their own fashion, placed a much higher premium on inflation control. Hence, by the mid-1990s we began to see a return to much smaller inflation differentials. Indeed, the convergence in inflation rates would intensify throughout the second half of the decade of the 1990s and the first decade of the new millennium (not shown).

Tables 3 and 4 provide some summary statistics for some of the key series used in the descriptive and econometric analyses. It is immediately apparent that the choice of the benchmark has an impact on inflation and real GDP growth performance. It is generally the case, however, that small open economies in our data set (i.e., Canada and Sweden) perform relatively well regardless of the metric employed while a few others, notably Italy and France, consistently under-perform. Also note that inflation is not noticeably affected by the exclusion of financial crises but only when the UK and the US serve as the benchmark. Otherwise, there is a much more noticeable impact. In contrast, real GDP growth differentials are strongly affected by the exclusion of years when there is a GFC. Indeed, the asymmetry in inflation versus output growth performance is striking. This has some bearing on notions of how much central banks ought to concern themselves with real economic performance or the strength of any link between inflation and real growth.

We can obtain a few more insights about the data by looking at Figures 5 and 6. Figure 5 displays proxies for d_{it} as defined in equation (1). It is immediately clear that the choice of benchmarks impacts the time properties of the data. Nevertheless, there are some common features both pre and post-World War II.[41] For example, the Great Inflation of the 1970s is apparent across all proxies. Similarly, the great deflation of the early 1920s and the Great Depression also generally show up in all variants of d_{it} as does the rise in inflation immediately after World War II. Note that parts A and B of Figure 5 are, unless otherwise noted, cross-sectional averages.

[41] The sub-samples were partly chosen to facilitate visual comparisons across filters and across time.

Parts C and D of Figure 5 displays the behavior of deviations in the price level or a normalized indicator of the price level covering the Gold Standard period. Deviations from the equilibrium price level, as proxied by Hamilton's (2017) filter are stationary, as noted earlier (also see table 6). The contrast between the deviation form and the original (log) levels of the series are shown in part D, for comparison.

Figure 6 plots the deviations in domestic inflation from the global mean.[42] Although inflation is generally stationary the plots reveal sharp departures, often around the time of financial crises of the global variety (highlighted by the shaded areas in the figure. Note that, from this perspective, the GFC of 2008-9 pales in comparison with earlier GFCs. Volatility across the 10 economies also varies greatly. This may well have implications for understanding the dynamics of inflation from a cross-sectional standpoint (see below).

Next, we turn to some comparisons between the narrative and statistical approaches to dating crises. Tables 5 and 6 present a selection of results while Table 7 provides a general summary. Table 5 distinguishes between financial crises that have been deemed global in nature, according to Bordo and Landon Lane (2010), while the last two columns rely on the country-specific chronology from Bordo and Meissner (2016). In addition, the Table identifies the joint occurrence of banking and currency crises.

If crises are associated with a break in the time series properties of the data then Table 6 provides some indications of when these were most likely to occur. The manner in which the tests were applied is such that the first date shown represents

[42] That is, the arithmetic mean for all ten countries in the data set.

the most likely occurrence of a statistical break in the time series in question. The last date then represents the least likely timing of a break. Interestingly, the most recent GFC is often, though not always, one of the least likely sources of a break, at least in the time series property of inflation.[43] Similarly, the most prominent location of breaks in the data often take place before World War II. The rank of breaks post World War II is often fairly low. Of course, this is only indicative of the possibility that developments in central banking contributed to this outcome since other factors were also clearly at play (see below).

Table 7 provides some overall perspective on the importance of financial crises based on both the narrative and statistical approaches. The small open economies in the sample do comparatively well across the various indicators of crisis conditions, especially Norway and Switzerland (e.g., see column (3)). Although this result does not exclusively reflect the quality of monetary policy in these economies it is likely one of the factors at play in explaining the relatively small number of statistical breaks found in the behavior of inflation. Most of the breaks in the small open economies are observed before World War II.

The extent to which global financial crises, based on the narrative approach, dominate the landscape of crises in the individual countries sampled varies of course. GFCs are least frequent in Switzerland (2 of 7 crises identified) while half, or a slightly higher proportion of the total, accounts for crises in 4 of the 10 economies examined (US, Germany, Norway, and Sweden). There is also considerable variation in the fraction

[43] Not shown are results for output growth where the prominence of the 2008 GFC is higher relative to inflation.

of crises that exceed a year in duration. It is also notable that there are differences in the degree of agreement between the statistical and narrative dating of financial crises. It is somewhat reassuring that, other than perhaps Switzerland, the overlap between the quantitative and narrative interpretations of history is not small. Nevertheless, the results also suggest that both approaches are essential for a proper understanding of the determinants of financial crises and the potential role of the central bank to which we now turn.

Tables 8 through 10 present a selection of panel regressions that seek to quantify the importance of some determinants of inflation in the 10 economies in the sample. Although the results are, broadly speaking, robust across the various filters applied to the data, the most consistently reliable results, across various specifications and samples, were obtained when Hamilton's filter or global inflation were used as proxies to generate deviations from country-specific inflation rates.

Tables 8 and 9 differ only according to the proxy for financial crises. Bordo and Landon Lane's (2010) definition of GFCs is used as a determinant while, in Table 9, Bordo and Meissner's (2016) combined banking and currency crises serve as a proxy for the impact of crises on inflation.[44] Finally, Table 10 estimates the same relationship for the Gold Standard period only based on the dates provided in Table 2.

We focus on the common features found in these results and their implications. Financial crises, whether of the global or domestic variety, affect inflation

[44] Combining both types of crises seem to produce better results than separately including banking and currency crises.

performance negatively. However, the impact is quantitatively largest when the crisis is global. In contrast, crises are found to have a much smaller impact on deviations in inflation from a benchmark during the Gold Standard era. Output growth is also seen, on average, as raising inflation relative to any of the benchmarks considered, other than for the Gold Standard period. These results merely confirm that inflation and aggregate economic activity links are severed during the Gold Standard but are a feature of the full sample.

If fiscal dominance is proxied by the debt to GDP ratio then this too is a feature of central banking outside the Gold Standard era. Nevertheless, even if this variable is statistically significant it does not appear to be economically significant as it is dwarfed by the real and financial crises variables. Equally interesting is the finding that deviations in inflation from some benchmark are highly persistent in the Gold Standard era while there is much less persistence in the full sample estimates. Hence, once domestic inflation moves away from the benchmark, there is a relatively fast return to the benchmark. In other words, to the extent that this represents a global factor not captured by the benchmark it exerts less impact since the end of the Gold Standard. One way of thinking about the results is that there is potentially greater variation in inflation regimes after World War II ended relative to some global benchmark (e.g., the US).

Three other results are notable from Tables 8 through 10. First, the exchange rate variable does not exert any significant influence on inflation relative to the benchmark. This suggests that the benchmark captures the global component. Second, although oil price inflation raises inflation relative to the benchmark in all

regressions, the coefficient is economically small. Finally, once we omit fixed effects, the determinants combine to explain a relatively small fraction of the variation in inflation relative to some benchmark. Consistent with some of the other results there may be sufficient idiosyncracies in inflation performance that cannot be adequately captured in the panel framework. Alternatively, as Bernanke (2010) and Yellen (2015), among other central bankers, have pointed out we still have much to learn about what drives inflation dynamics.

Next, we turn to network effects in inflation performance. Table 11 and 12 evaluate the degree of connectedness in inflation and real output growth performance. There is clearly considerable variation in the degree of connectedness based on the principal components analysis. Indeed, the latest 'wave' of globalization is clearly seen in the data for the last two or three decades with brief spurts beginning in the 1950s and falling by the 1970s while the reduced importance of the first principal component in the first decades of the 20th century is also evident. In contrast, there is considerably more connectedness and persistently more so in inflation throughout history. Nevertheless, the strong connection in inflation performance is clearly a feature of the post-World War II era. There is no indication that inflation targeting per se has raised the degree of connectedness over the last two decades. However, as noted earlier, first Bretton Woods followed by a stronger commitment to lower inflation, together with more exchange rate flexibility, implies that the exchange rate regime as it is defined here plays a smaller role than we think in explaining inflation differentials.

The measure of connectedness based on G.C. tests (see Table 12) also suggests that central banks behave as if they are part of a related network, at least insofar as inflation differentials are concerned. Note that networks permit relationships to be indirect.[45] Hence, the existence of a network does not imply how integrated economies are, only that there are links, some stronger, some weaker, that tie the inflation fortunes of the economies in question.[46] Moreover, other than for d_{it}^{Global}, there is little empirical indication that this has changed markedly over almost century and a half of data used here.

Finally, we turn to some counterfactual experiments. These are shown in Figures 7 through 9. Figure 7 shows what inflation would have been like if the Swiss National Bank (middle), the US Federal Reserve (top), and the Bank of Canada (bottom) had been in existence before they were actually created[47]. Data limitations imply that we can only go back to 1870 for the SNB and Fed and 1913 for the BoC. The smallest impact from the late introduction of central banking is observed for Canada. The observed and counterfactual lines are almost on top of each other. It is worth noting, however, that thanks to the Finance Act of 1907, Canada arguably had a quasi-central bank before the Bank of Canada's creation (e.g., see Rich 1989).

[45] This is most readily seen by visualizing networks as a collection of nodes that are linked with varying degrees of strength. A typical application is the identification of bank networks. See, for example, Rönnqvist and Sarlin (2016).

[46] Indeed, the existence of network effects implies that economies need not be integrated for a shock to have systemic or global effects.

[47] Under the classical gold standard a central bank can only have a small impact on the price level except in the sense that a credible central bank could temporarily use its policy rate to affect domestic variables within the gold points which served as a target zone. See Bordo and Macdonald (2010).

In the case of Switzerland, had the SNB been created in 1870 instead of 1907 inflation would have been not much different, on average, but considerably less volatile. Finally, in the US case, it is difficult to see any impact on inflation and inflation volatility had the Fed been in place in 1870. It should be pointed out, as explained above, that the *raison d'être* of the Fed lies in the search for financial stability not inflation stability and the series of financial crises that hit the US throughout the period shown testifies to the real problem with the monetary regime in the US. Indeed, as shown in the next figure (Figure 8) which shows the counterfactuals for real GDP growth, the chief benefit of an earlier central bank in the US would have been observed through a substantial decline in the volatility of real GDP growth.[48] The reduction in real GDP volatility is plain to see in all three cases shown with the impact least dramatic for Canada, likely for the reason cited earlier.

Finally, we examine one more counterfactual, this time in the more recent era of central banking. While some central banks are accountable via a numerical inflation target (Canada, Norway, Sweden, the UK) others maintain they are equally accountable in achieving low and stable inflation (the remaining countries listed in Table 1) but not at the expense of an explicit recognition that real economic performance is also part of their objective function.[49] Figure 9 then considers the inflation and real economic growth consequences of inflation targeting (IT). We ask what inflation and growth would have been if Canada (1991), Sweden (1993), and the

[48] This result is also consistent with Miron's (1989) finding that the founders of the Fed did not believe their mission was to stabilize output. Instead, their role was to influence asset prices, as also reflected in the drop in the seasonal variation of interest rates (also, see Mankiw, Miron, and Weil (1994), and Mankiw and Miron 1991).

[49] Since Norway adopted inflation targeting only in 2001 we opted not to consider this case since this leaves us with relatively few (annual) observations.

UK (1992) had not adopted an IT strategy. Adoption years of IT are in parenthesis. The USA, Japan, and Switzerland did not adopt IT. Hence, these economies act as the controls used to estimate the treatment effect of IT. We define the treatment period as the period since Bretton Woods until IT is adopted.[50]

The left hand side of Figure 9 plots the observed and counterfactual estimates for inflation while the right hand set of plots display the outcomes for real GDP growth. It is immediately clear that inflation is almost always higher in the absence of an inflation target. Other than for Canada, differences between observed and counterfactual inflation rates actually exceed one or even two standard deviations away from the mean observed inflation rates. Hence, the improvement in inflation performance is considerable. Turning to real economic growth the evidence is more mixed with real economic growth lower under IT than in the counterfactual case. Once again the differences are larger for Sweden and the UK than for Canada. Note that, among the three IT economies, Canada has the reputation as having adhered most closely to its inflation target since the regime was introduced (e.g., see Siklos 2014).

Clearly, one can contemplate other counterfactuals but the methodology followed is not well suited to carry them out. For example, one might have asked about what might have happened if the gold standard had persisted beyond the 1930s, or if a central bank had not been created after World War II. Unfortunately, the available

[50] We considered other control periods with little impact on the conclusions. We also tried to include France, Germany, and Italy, as part of the control group and our conclusions are unchanged. It should be noted, however, that since these three economies adopted a common currency as well as transitional arrangements in the lead up to the introduction of the euro it was deemed preferable to exclude them from the control group.

data does not permit the creation of a sensible set of common factors where the treatment or intervention does not exist.

5. Conclusions

Central banks have evolved considerably over the past three centuries. Globally, the central bank is a comparatively young institution and its role as primary vehicle for economic stabilization is both unique and also of fairly recent vintage. Nevertheless, the history of monetary policy is also a turbulent one with several changes in policy strategies adopted over time. There has clearly been an evolution of sorts, again on a global scale, with a clear preference for some form of price stability even if many countries eschew adopting a formal numerical target.

Just when a consensus of sorts developed that convinced policy makers that best practice consisted in giving a central bank a clear mandate, narrowly focused on attaining some inflationary outcome that would promote stable economic growth, two major financial crises, beginning in 2007 until about 2012, that is, the so-called global financial crisis and the Eurozone sovereign debt crisis, led to some sober second thinking.

Although there are few indications that price stability is no longer a desirable objective central banks are being asked, or are adopting by default, to widen the scope of their mandate to include evincing a concern for financial stability. Historically, we have seen this. Indeed, long before some central banks were given a macroeconomic stability mandate, their task was for a time largely centered on the maintenance of financial stability. However, this took place at a time when little thought was given about whether the monetary authority should be autonomous

from government. As we have now come to accept central bank autonomy as useful, if not appropriate, it is less clear how this principle is squared with an expectation that financial stability and monetary stability are both tasks that a central bank ought to carry out. Moreover, for central banks in large economies or ones that have a systemic impact on the global economy, this development may further restrict their ability to improve how policy is conducted and to innovate. In the early days of central banking this was not the case partly because these countries were the first and also due to the greater frequency of financial crises necessitating change and adaptation to new circumstances.

In contrast, small open economies have long been buffeted by the complications of navigating the occasional conflict between domestic objectives and the impact of external shocks, regardless of the exchange rate regime in place. As a result, there is some evidence that there is more of a willingness to adopt different monetary policy strategies than in many, but not all, of the systematically important economies, at least based on observed choices made in recent decades. It remains to be seen whether this finding will extend to how the maintenance of financial system stability is managed.

The only thing that is certain is that we have not seen the last of attempts to improve how monetary policy is conducted nor in how central banks are governed. It is equally possible that just as the pendulum has swung back to the monetary authorities evincing a concern for financial stability the same forces will lead to a rewriting of the 'contract' between the central bank and the government. Whether this means a loss of autonomy or the development of a contingent contract between

the central bank and government remains to be seen. Clearly, crisis times require a different approach to policy than normal times.

Table 1
The Origins of Central Banks

Year	Country	Name	Motivation
1668	Sweden	Bank of the Estates of the Realm. Forerunner of the Riksbank	Finance war and the consequences of excessive inflation
1694	UK	Bank of England	Finance war, debt management, and banker to the government
1800	France	Banque de France	Manage public debt, issue notes, : note issue, improve state revenue (seigniorage)
1816	Norway	Bank of Norway	Economic crisis in neighboring Denmark prompts monetary reform (note issue, lending)
1876	Germany	Reichsbank. Forerunner of Bundesbank	Consolidation of previous note issuing authorities following unification, upholds Gold Standard, under government management
1882	Japan	Bank of Japan	Part of modernization of Meiji regime, reserves management, vehicle to promote industrialization
1893	Italy	Banca d'Italia	Consolidation of previous note issuing authorities following unification and a banking crisis
1907	Switzerland	Swiss National Bank	Centralization and standardization of note issue, banker for the government and custodian of reserves
1913	USA	Federal Reserve System	Creation of lender of last resort and other banking related functions
1934	Canada	Bank of Canada	Lender of last resort

Source: Adapted, updated, and expanded from Siklos (2002), Table 1.2. Several of the central banks in our sample have posted historical time series but they do not always include prices or real economic information (e.g., the Swiss National Bank's Historical time series: //www.snb.ch/en/iabout/stat/statrep/statpubdis/id/statpub_histz_arch#t3).

Table 2
Principal Monetary Regimes in Select Economies Since the Early 19th Century

Economy	Gold Standard	Bretton Woods	Monetary Targeting	Inflation Targeting	Exchange Rate targeting/ Monetary Union
Sweden	1873-1914 & 1922-1931	1959-1973		1993-	-
Inflation real GDP growth	-0.20 (3.75) 2.63 (5.70)	4.47 (1.98) 3.97 (1.55)		1.30 (1.24) 2.20 (2.65)	
United Kingdom	1821-1914 & 1925-1931	1959-1972	1976-1992	1992-	
Inflation real GDP growth	-0.38 (5.91) 0.94 (2.59)	4.26 (2.40) 2.49 (1.31)	7.79 (4.16) 1.82 (2.09)	2.65 (1.17) 1.72 (1.83)	
France	1878-1914 & 1926-1936	1959-1973			1993-1999 (MU)-2001
Inflation real GDP growth	-0.94 (8.44) 0.91 (4.09)	4.50 (1.49) 4.20 (1.02)			1.52 (0.61) 1.37 (1.42) 1.54 (0.83) 0.74 (1.43)
Norway	1875-1914 & 1928-1931	1959-1971		2001-	1971-2000
Inflation real GDP growth	-0.17 (3.63) 2.13 (2.70)	4.08 (3.03) 4.24 (1.34)		1.82 (0.90) 1.32 (1.41)	5.82 (3.28) 3.55 (1.64)
Germany	1871-1914 & 1924-1931	1959-1971	1975-1991		1993-1999 (MU)-2001
Inflation real GDP growth	0.70 (3.18) 2.75 (4.40)	2.54 (1.12) 4.67 (2.10)	3.23 (1.79) 2.62 (1.84)		1.89 (1.31) 1.51 (1.13) 1.64 (2.84) 1.04 (2.34)
Japan	1897-1917 & 1930-1931	1964-1972		2013 –	1973-2012§
Inflation real GDP growth	3.50 (8.93) 3.05 (6.56)	5.30 (1.16) 9.11 (3.40)			2.52 (4.35) 2.52 (2.66)
Italy	1884-1917 & 1927-1934	1959-1973			1993-1999 (MU)-2001
Inflation real GDP growth	0.83 (7.23) 2.57 (4.45)	3.50 (2.00) 5.44 (1.80)			3.26 (1.40) 1.42 (1.17) 1.95 (1.00) -0.08 (2.09)
Switzerland	1878-1914	1964-1971	1980-1999	2000* –	
Inflation real GDP growth	-0.57 (4.30) 2.66 (4.01)	3.72 (1.31) 4.07 (1.55)	2.75 (1.92) 1.70 (1.73)	0.52 (0.89) 1.82 (1.57)	
USA	1880-1917 & 1922-1933	1959-1971	1975-1991	2012** –	
Inflation real GDP growth	0.73 (4.29) 3.00 (7.17)	2.71 (1.74) 4.23 (2.11)	5.75 (3.07) 2.94 (2.49)		

Canada	1854-1914 & 1926-1929	1962-1970	1975-1981	1991-	
Inflation	0.47 (3.78)	2.89 (1.14)	9.13 (1.56)	1.90 (1.11)	
real GDP growth	4.08 (5.24)	5.36 (1.65)	3.41 (1.14)	2.41 (1.95)	

*Inflation forecast targeting; **Medium-term inflation objective;§

Sources: Siklos (2002), Bordo and Siklos (2016), and references therein. Annual data are used. See the text for additional details. The first set of figures gives mean inflation; the second gives real GDP growth for the samples listed. The last column occasionally provides two sets of figures because two separate regimes are considered.

Table 3 Summary Statistics – Inflation Adjusted for Benchmarks: UK&US, Global Inflation, Global Financial Crises

Country (1)	Benchmarks: I: UK &US (2)	Benchmark I excluding Financial Crises (3)	Benchmark II: Global inflation (4)	Global inflation excluding Global Financial Crises (5)	Benchmark II excluding Financial Crises (6)	Global inflation excluding Financial Crises (7)
Canada (CAN)	-0.11 (2.49)	-0.15 (2.37)	-1.10 (3.32)	-1.12 (0.34)	-0.22 (0.26)	-1.25 (0.34)
Switzerland (CHE)	-0.47 (4.36)	-0.57 (0.38)	-1.46 (3.64)	-1.55 (0.32)	-0.46 (0.38)	-1.45 (0.31)
Germany (DEU)	0.38 (4.56)	0.42 (0.40)	-0.67 (3.57)	-0.65 (0.32)	0.35 (0.41)	-0.67 (0.32)
France (FRA)	1.41 (7.37)	1.68 (0.71)	0.79 (5.91)	1.08 (0.56)	0.61 (0.77)	0.12 (0.61)
United Kingdom (GBR)	0.72 (4.36)	0.68 (0.38)	-0.24 (4.10)	-0.28 (0.36)	4.69 (1.37)	3.53 (1.21)
Italy (ITA)	4.20 (14.97)	4.13 (1.30)	3.22 (13.20)	3.15 (1.15)	1.30 (0.59)	0.50 (0.52)
Japan (JPN)	1.35 (5.94)	1.37 (5.85)	0.50 (5.19)	0.54 (0.50)	0.82 (0.47)	-0.21 (0.35)
Norway (NOR)	0.87 (5.38)	0.76 (0.47)	-0.09 (3.95)	-0.20 (0.34)	0.63 (0.45)	-0.34 (0.33)
Sweden (SWE)	0.70 (5.03)	0.74 (0.44)	-0.26 (3.78)	-0.22 (0.33)	0.25 (0.37)	-0.57 (0.36)
United States (USA)	0.18 (2.61)	0.20 (0.23)	-0.78 (3.48)	-0.75 (0.30)	0.08 (0.23)	-0.85 (0.31)

Note: Inflation is 100 times the log difference of the price level. Deviations from the US and UK benchmark and global inflation. A negative value implies below the benchmark. Standard deviations in parenthesis. Standard errors in columns (3) ,(5), (6), and (7). For the USA the level of inflation is given in column (2). Global inflation is defined in the text and in the notes to Figure 6. Global financial crises are the ones identified by Bordo and Landon lane (2010). Financial crises are as defined in Bordo and Meissner (2016).

Table 4
Selected Summary Statistics Output Growth Relative to Benchmarks: UK & US, and Global Mean

Country	Benchmark: UK & US			Global Mean		
	Full	Full –Adj.	Full ex crises	Full	Full – Adj.	Full ex crises
CAN	0.14 (4.03)	1.16 (4.37)	1.06 (4.49)	0.90 (4.10)	0.60 (3.72)	2.15 (4.02)
CHE	0.04 (6.29)	0.26 (4.88)	-0.21 (6.36)	-0.14 (4.47)	-0.34 (3.41)	-0.17 (4.57)
DEU	0.08 (7.34)	0.99 (5.69)	-0.21 (7.44)	-0.07 (6.61)	0.42 (4.32)	-0.13 (6.69)
FRA	-0.84 (8.53)	-0.31 (5.36)	-1.15 (8.73)	-0.98 (5.73)	-0.87 (3.85)	-1.06 (5.85)
GBR	-1.19 (3.96)	-1.23 (3.98)	-2.03 (4.39)	-1.33 (2.75)	-1.40 (2.53)	-1.35 (2.70)
ITA	-0.14 (7.26)	0.43 (4.82)	-0.52 (7.25)	-0.28 (4.63)	-0.14 (3.49)	-0.43 (4.59)
JPN	1.03 (7.49)	1.74 (5.38)	0.71 (7.42)	0.89 (5.60)	1.19 (4.11)	0.80 (5.550
NOR	0.22 (5.75)	0.65 (4.33)	-0.11 (5.59)	0.07 (3.21)	0.07 (2.72)	-0.03 (3.11)
SWE	0.18 (5.80)	0.47 (5.14)	-0.10 (5.78)	0.15 (4.39)	0.03 (4.25)	0.11 (4.41)
USA	*3.51 (5.62)*	*3.25 (5.19)*	*4.06 (5.23)*	0.79 (5.06)	0.43 (4.42)	1.09 (4.97)

Legend: CAN: Canada**, CHE:** Switzerland**, DEU:** Germany**, FRA:** France**, GBR:** United Kingdom**, ITA:** Italy**, JPN:** Japan**, NOR:** Norway**, SWE:** Sweden**, USA:** United States**.**
Note: The benchmark means that the UK serves as the benchmark until 1912; thereafter the benchmark is the US. For the US the first 3 columns are growth rates and not in deviation form. Hence, the values are in italics. Full means data since 1870, data permitting. See the appendix. Adj. means that the war years 1939-1946 are excluded as data are missing for some of the economies in the data set. Standard deviations in parenthesis. 100 times the first log difference in real GDP is output growth. See the text for the definition of the global mean. Crises are the global financial crises identified by Bordo and Landon Lane (2010).

Table 5 Dating Crises: Narrative Schemes

Country	Global Financial Crises	Alternative Chronologies	
		Banking Crises	Currency Crises
CAN	1890-1891 1907-1908 1913-1914 1920-1921 1931-1932 2007-2008	1923 2008	1891, 1893, 1908, 1914, 1921, 1929, 1931, 1950, 1962, 1981-1983, 1986
CHE	1890-1891 1907-1908 1913-1914 1920-1921 1931-1932 2007-2008	1931, 1933-1936, 2008	1914, 1939, 1971, 1977
DEU	1890-1891 1907-1908 1913-1914 1920-1921 1931-1932 2007-2008	1901-1902, **1931-1932**, 2008	1893-1894, 1907-1910, 1914, **1931-1932**, 1934, 1949
FRA	1890-1891 1907-1908 1913-1914 1920-1921 1931-1932 2007-2008	1882, **1888**, 1889, 1907-1910, 1994-1995, 2008	**1888**, 1914, 1923-1929, 1936-1937, 1948, 1957-1959, 1968, 1992-1993
GBR	1890-1891 1907-1908 1913-1914 1920-1921 1931-1932 2007-2008	1890-1893, **1974-1976**, 2007	1914, 1931-1932, 1947, 1949, 1961-1962, 1964-1967, **1974-1976**, 1992
ITA	1890-1891 1907-1908 1913-1914 1920-1921 1931-1932 2007-2008	1891-1892, **1893-1894**, **1907-1908**, 1914, 1921, 1930-1933, **1935-1936**, **1990-1995**, 2008	1893-1894, 1907-1908, 1935-1936, 1964-1969, 1976, 1981, **1990, 1992, 1995**
JPN	1890-1891 1907-1908 1913-1914 1920-1921	**1900-1901**, **1917**, 1927-1929, 1992-1997	**1900-1901**, 1904-1908, **1917**, 1921,

	1931-1932 2007-2008		1931-1934, 1979-1980
NOR	1890-1891 1907-1908 1913-1914 1920-1921 1931-1932 2007-2008	1921, 1931-1935, **1986-1993**	1914, 1931-1935, 1949, 1971-1972, **1986-1993**
SWE	1890-1891 1907-1908 1913-1914 1920-1921 1931-1932 2007-2008	1897-1899, 1907-1909, 1921-1922, **1931-1932**, **1991-1994**, 2008	1914, **1931-1933**, 1949, 1971-1972, **1991-1994**
USA	1890-1891 1907-1908 1913-1914 1920-1921 1931-1932 2007-2008	1884-1886, **1891-1893**, 1907-1908, 1914, **1930-1933**, 2007-2008	**1891-1893**, **1930-1933**, 1960-1961, 1971

Note: Dates for global financial crises are from Bordo and Landon-Lane (2010). Dates for the other crises are from Bordo and Meissner (2016). **Bold** numbers identify the simultaneous occurrence of banking and currency crises. The colors indicate the occurrence of a crisis under the regimes identified in Table 2. Yellow for the Gold Standard, gray for exchange rate targeting or a monetary union, bright green for monetary targeting, and turquoise for Bretton Woods.

Table 6 Unit Root and Break-Point Properties of Univariate Inflation Time Series

	Benchmark: UK & US		Global Mean Inflation		Hamilton filter		Factor Model	
Country	ADF	Breaks	ADF	Breaks	ADF	Breaks	ADF	Breaks
CAN	-9.62 *	*1919*, 1938, 1948, 1981,1987,	-6.54*	*1919*, 1942,1946,1951,1977, 1983, 1999	-5.51*	*1917*, 1931, 1980	-3.68*	1965, 1983, 1992, 1999
CHE	-5.37*	1918, 1937, 1945, 1951,1979, 1984, 1994	-9.05*	*1878*, 1916, 1974,1989, 1994	-7.81*	1911, 1916, 1921, 1981	-3.69*	1931, 1936, 1994, 2009
DEU	-1.01	1891, 1915, 1932, 1973, 1987, 1991, 1995	-6.92*	1932, 1915, 1893, 1946, 1974, 1991, 1995	-7.85*	1912, 1917, 1931, 1944, 1990	-4.49*	1930, 1951, 1984, 1989, 1995
FRA	-1.85	1904, 1927,1936, 1987, 1991, 2008	-6.00*	1908, 1927, 1936, 1954, 1986, 1994	-5.93*	1887, 1923, 1932, 1953, 1974, 1986, 1990	-1.37	1927, 1936, 1954, 1986, 2013
GBR	-3.73*	1917,1941,1948, 1991, 1975, 2006	-3.64*	1879, 1912, 1917, 1931, 1941,1952, 1968, 1981, 1986, 1991, 1995	-10.26*	1878, 1915, 1921, 1974, 1982, 2010	-3.36*	1925, 1935, 1949, 1991, 2013
ITA	-4.59*	1891,1915, 1948, 1974, 1987, 1996	-5.02*	1895, 1916, 1948, 1973, 1986, 1997	-5.10*	*1878*, 1912, 1917, 1949, 1974, 1986, 1990, 1997	-3.57*	1927, 1936, 1996, 2014
JPN	-1.52 (9)	1908, 1978,1983, 2012	-9.67*	1908, 1932, 1950,1977, 1989, 2013	-7.67*	1917, 1921, 1978, 1990, 1998	-8.78*	1930, 1932, 1982, 1999
NOR	-10.98*	1914, 1919, 1930, 1941, 1950, 1989, 2003, 2013	-9.21*	1876, 1912, 1921, 1930,1950, 1942, 1957, 1989, 1994, 2013	-10.03*	1878, 1915, 1921, 1987, 1991	-5.00*	1878, 1915, 1921, 1980, 1987, 1991, 2007
SWE	-6.83*	1914, 1919, 1930, 1941, 1992, 1996	-7.54*	1876, 1914, 1919, 1942,1950, 1992, 1996	-8.37*	1878, 1915, 1909, 1921, 1980, 1992, 1996	-4.56*	1931, 1934, 1950, 1992, 1996, 2013
USA	NA	*1879*, 1920, 1941, 1991, 1973, 1982, 2008	9.55*	*1878*, 1915,1987, 1994, 2008	-8.87*	*1879*, 1912, 1917, 1931, 1980, 1990, 2011	-4.03*	1966, 1982, 2008

Note: ADF refers to the Augmented Dickey-Fuller statistic. Perron (1989) test with only an intercept break, an additive outlier for the break, with the lagged dependent variable selected according to the Schwarz criterion, and a 10% trimmed estimate. The breaks are found sequentially starting with the full sample (usually 1870-2015, depending on data availability). In italics are estimates are breaks before the central bank in question was established. * signifies rejection of the unit root null at least at the 5% level. NA means not applicable. Note that estimation samples are affected by the filter used as well as data availability. This is especially the case for the factor model.

Table 7 The Anatomy of Financial Crises

Country	(1) Total number of crises	(2) Rank Order	(3) Number of Statistical Breaks crises (% pre WWII)	(4) Overlap of Narrative & Statistical (%)	(5) GFC as a share (%)	(6) Crises that exceed a year, consecutive (%)
CAN	13	3	3 (66.7)	23	46.1	7.7
CHE	7	10	4 (75)	14.3	28.6	46.7
DEU	9	8	5 (80)	40	55.6	55.6
FRA	15	2	8 (37.5)	77.8	26.7	55.6
GBR	11	4	6 (50)	72.7	36.4	70
ITA	18	1	8 (37.5)	27.8	33.3	62.5
JPN	10	6	5 (40)	30	30	72.7
NOR	8	9	6 (50)	87.5	50	14.3
SWE	11	4	7 (57.1)	36.4	54.5	54.5
USA	10	6	7 (57.1)	20	60	80

Note: see Table 4 for country name legends. The total number of financial crises is the sum of banking and currency crises according to the Bordo and Meissner (2016) chronology. The rank order is from largest to smallest number of financial crises. Column (3) is the number of statistical breaks relying on the application of the Perron (1989) break test. See Table 6 for details about the estimation strategy. Column (4) indicates the fraction of financial crises whose dates overlap with the ones obtained from a purely statistical analysis. Column (5) represents the fraction of financial crises that are global in nature according to the Bordo and Landon Lane (2010) chronology. Column (6) indicates the fraction of financial crises (see column (1)) with a duration of more than one consecutive year

Table 8 Panel Regression Estimates of the Determinants of Inflation Differentials

Dependent Variable: Deviation from Hamilton Filter				
Method: Pooled Least Squares				
Sample (adjusted): 1872 2013				
Included observations: 142 after adjustments				
Cross-sections included: 10				
Total pool (unbalanced) observations: 1111				
Convergence achieved after 13 iterations				
Variable	Coefficient	Std. Error	t-Statistic	Prob.
Constant	1.16	0.72	1.60	0.11
OIL price inflation	0.07	0.01	6.89	0.00
Exchange Rate change	0.03	0.02	1.42	0.16
Real GDP growth(-1)	0.29	0.05	5.70	0.00
Debt/GDP ratio(-1)	0.02	0.01	2.30	0.02
GFC	-2.31	1.12	-2.07	0.04
AR(1)	0.37	0.03	12.72	0.00
Fixed effects?	NO			
Time Fixed Effects?	NO			
R-squared	0.19	Mean dependent var		3.24
Adjusted R-squared	0.18	S.D. dependent var		9.99
Log likelihood	-4018.95			
F-statistic	41.82			
Prob(F-statistic)	0.00			

Note: See Table 5 for the dating of the GFC variable which is the Bordo and Landon Lane (2010) chronology. Sample reflects adjustment for data availability and the filter used. The absence of fixed effects follows the application of a redundant fixed effects test (F-based statistic; resu;ts available on request). The mean of the dependent variable is different from zero because the precise samples over which individual filtered estimates are computed can differ from the unbalanced sample used in estimation. This also explains that the total number of observations is not number of years times number of cross-sections.

Table 9 Panel Regression Estimates of the Determinants of Inflation Differentials

Cross-section fixed effects test equation:				
Dependent Variable: Deviation from Hamilton Filter				
Method: Panel Least Squares				
Sample (adjusted): 1872 2013				
Included observations: 142 after adjustments				
Cross-sections included: 10				
Total pool (unbalanced) observations: 1214				
Convergence achieved after 5 iterations				
Variable	Coefficient	Std. Error	t-Statistic	Prob.
Constant	1.08	0.71	1.53	0.13
OIL price inflation	0.06	0.01	6.89	0.00
Exchange Rate change	0.00	0.00	0.62	0.54
Real GDP growth (-1)	0.27	0.05	5.84	0.00
Debt/GDP ratio (-1)	0.03	0.01	2.63	0.01
Financial Crises	-1.60	0.62	-2.58	0.01
AR(1)	0.39	0.03	14.43	0.00
Fixed effects?	NO			
Time Fixed effects?	NO			
R-squared	0.19	Mean dependent var		3.09
Adjusted R-squared	0.18	S.D. dependent var		9.68
Log likelihood	-4352.66			
F-statistic	46.30			
Prob(F-statistic)	0.00			

Note: See notes to Table 8. The Bordo and Meissner (2016) chronology is used to measure financial crises by summing banking and currency crises (see Table 5). The absence of fixed effects follows the application of a redundant fixed effects test (F-based statistic; not shown).

Table 10 Panel Regression Estimates of the Determinants of Inflation Differentials: The Gold Standard Period

Dependent Variable: Deviation from Global Inflation				
Method: Pooled Least Squares				
Sample (adjusted): 1871 1917 1923 1931				
Included observations: 56 after adjustments				
Cross-sections included: 10				
Total pool (unbalanced) observations: 458				
Convergence achieved after 7 iterations				
Variable	Coefficient	Std. Error	t-Statistic	Prob.
Constant	0.42	0.23	1.86	0.06
Oil price inflation	-0.00	0.00	-2.74	0.01
Exchange rate change	0.00	0.00	1.47	0.14
Real GDP growth (-1)	-0.00	0.00	-0.11	0.91
Debt/GDP ratio (-1)	-0.00	0.00	-0.47	0.64
Financial Crises	-0.19	0.05	-3.94	0.00
AR(1)	0.83	0.03	28.08	0.00
Fixed Effects?	YES			
Time Fixed effects?	NO			
R-squared	0.96	Mean dependent var		0.09
Adjusted R-squared	0.96	S.D. dependent var		2.38
Log likelihood	-291.73			
F-statistic	766.47			
Prob(F-statistic)	0.00			

Note: See note to Table 8. Deviations are derived from the log level of the CPI series less the mean log levels globally (all 10 economies in the data set). See the text for more details. Sample is based on the dating of the Gold Standard in different countries. See Table 2.

Table 11 The First Principal Component: Inflation and Output Growth

Sample	# of principal components	Inflation	# of principal components	Output Growth
1911-1930	3	0.56	3	0.45
1916-1935	3	0.56	3	0.48
1921-1940	3	0.67	4	0.55
1926-1945	3	0.73	3	0.48
1931-1950	2	0.81	3	0.46
1936-1955	3	0.61	2	0.65
1941-1960	3	0.62	2	0.56
1946-1965	3	0.60	3	0.62
1951-1970	1	1.00	4	0.42
1956-1975	1	1.00	3	0.73
1961-1980	2	0.84	3	0.71
1966-1975	2	0.82	3	0.68
1971-1990	2	0.85	4	0.60
1976-1995	2	0.85	4	0.54
1981-2000	2	0.88	3	0.59
1986-2005	2	0.76	3	0.59
1991-2010	3	0.64	2	0.86
1996-2014	3	0.58	1	1.00
Other Samples				
1871-1914	1	0.39	4	0.31
1886-1913, 1925-1933	2	0.59	3	0.53

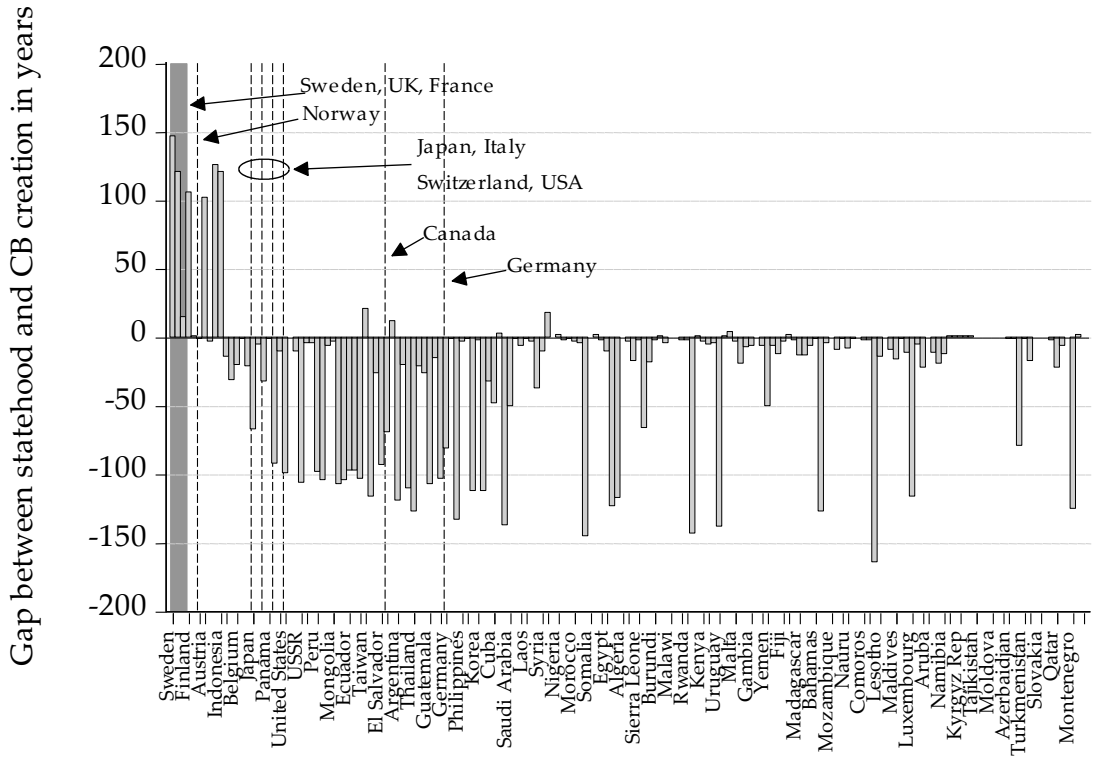
Note: See text for the details. The columns give the number of principal components estimated via maximum likelihood and the proportion of the total variation explained by the first principal component in a factor model for inflation or real GDP growth for the 10 countries in the data set (unbalanced panel).

Table 12 Degree of Granger Causality

Variable	Full Sample	1870-1925	1950-2015
INF	21%	23.3%	17.8%
HAM	15.6%	17.8%	21%
FACTOR	22.2%	NA	23.3%
GLOBAL	27.8%	14.4%	26.6%
DEVIATION FROM BENCHMARK	16.7%	15.6%	13.3%
Conditioned on GFC	17.8%	NA	NA
Conditioned on RR	16.7%	NA	NA

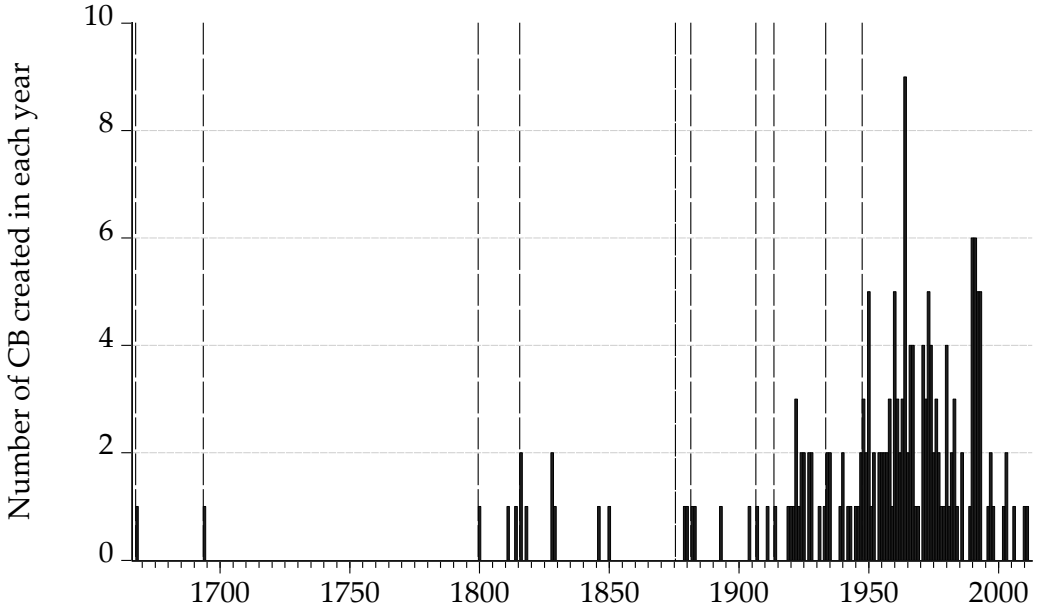
Note: See text for the definition and estimation details.

Figure 1 Years of Central Bank Formation and Statehood



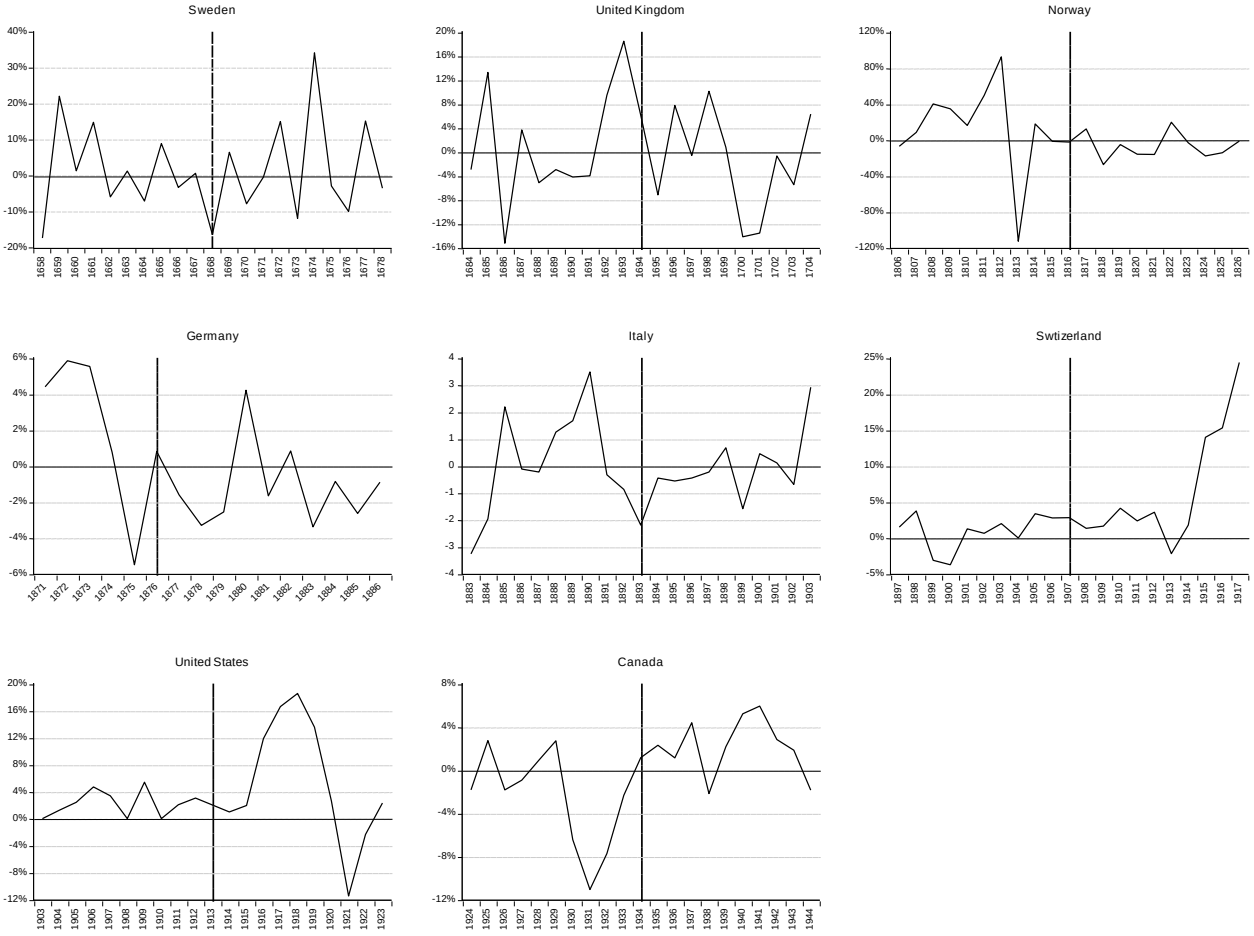
Note: vertical dashed lines indicate the central banks used in this study. The bars represent the difference between the year a central bank was established less the year of statehood or independence. Data are from *Central Bank Directory* 2014 (London, UK: Central Bank Publications) and the CIA World Factbook. The central banks explicitly labelled in the figure are the subject of the empirical and narrative analysis in the present study.

Figure 2 Number of Central Banks Established



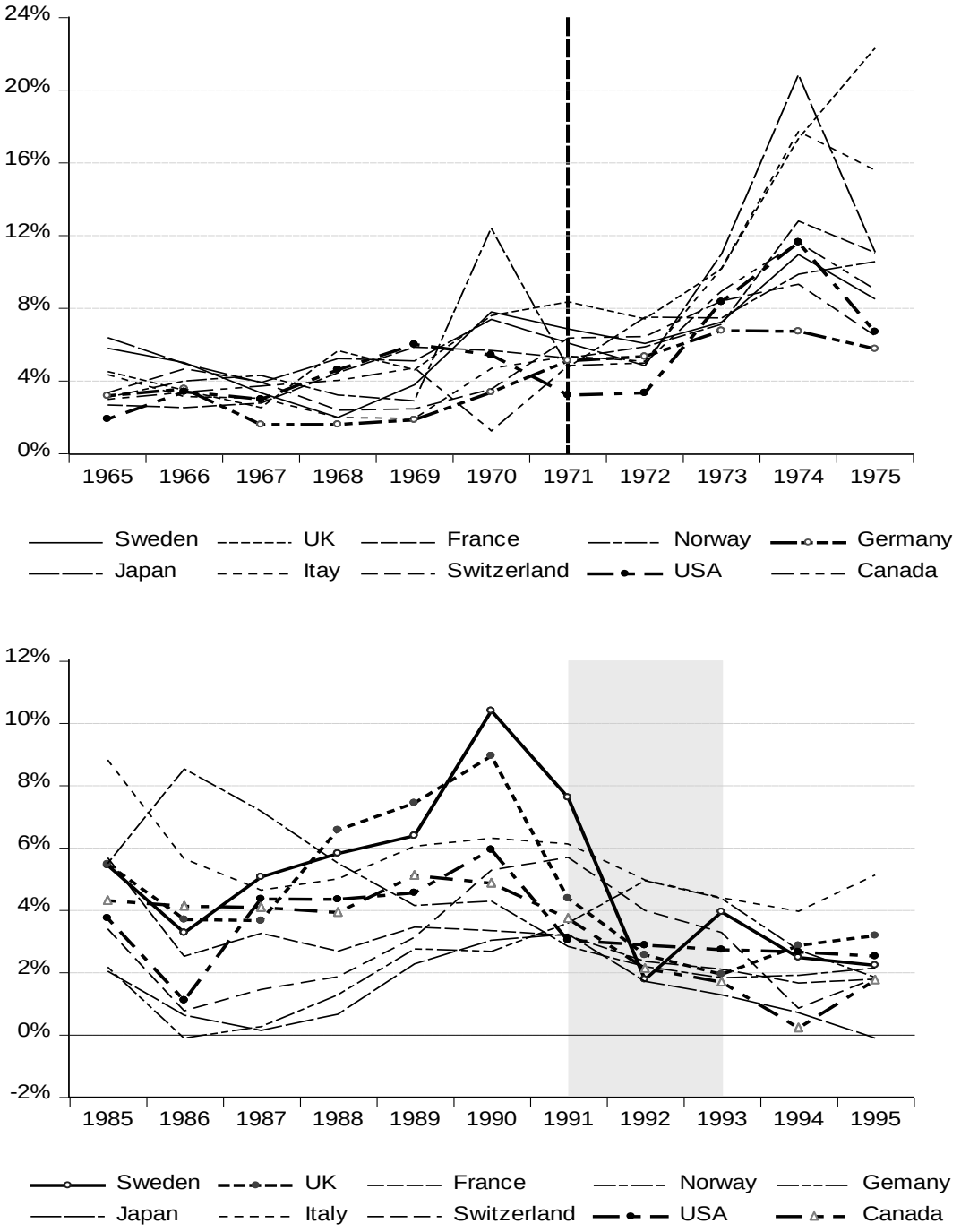
Note: See note to Figure 1.

Figure 3 Inflation Around the Time Central Banks Were Created



Note: Inflation is 100 times the first log difference in the CPI. The vertical dashed lines mark the year when the central banks shown were created.

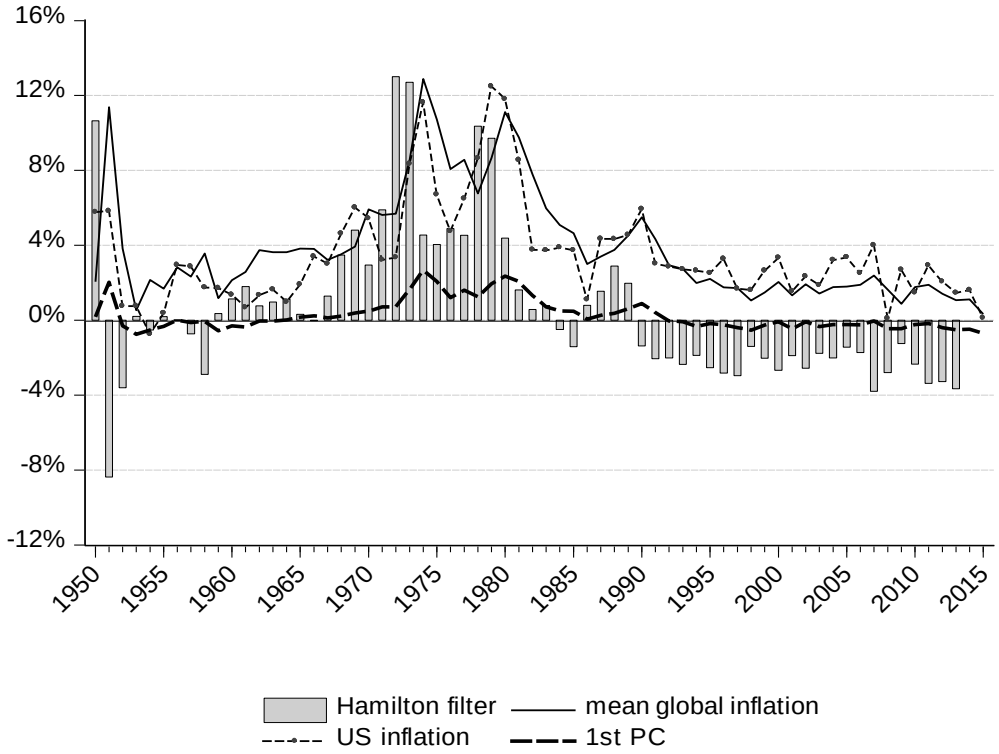
Figure 4 Inflation Around the Time of Change in Monetary Policy Strategy: Inflation Targeting and Bretton Woods



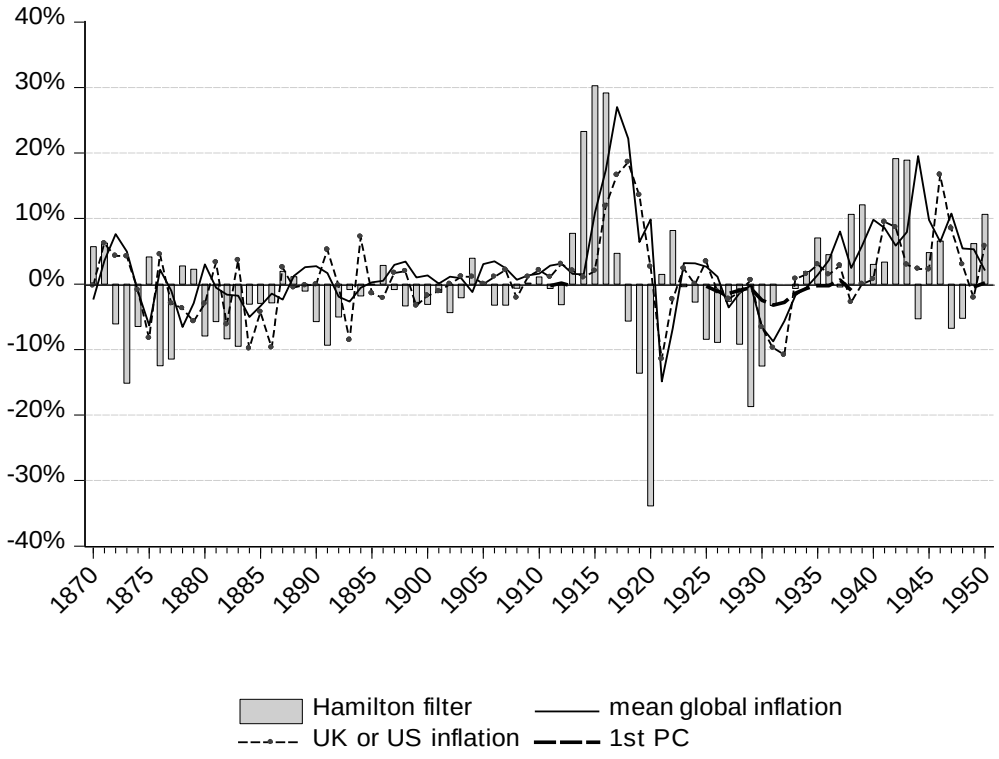
Note: the shaded area in the top figure highlight the years when Inflation Targeting (IT) was introduced in Canada, Sweden, the UK, and Norway. The vertical line in the bottom figure approximately dates the end of the Bretton Woods regime.

Figure 5 Varieties of Inflation Rate Differentials

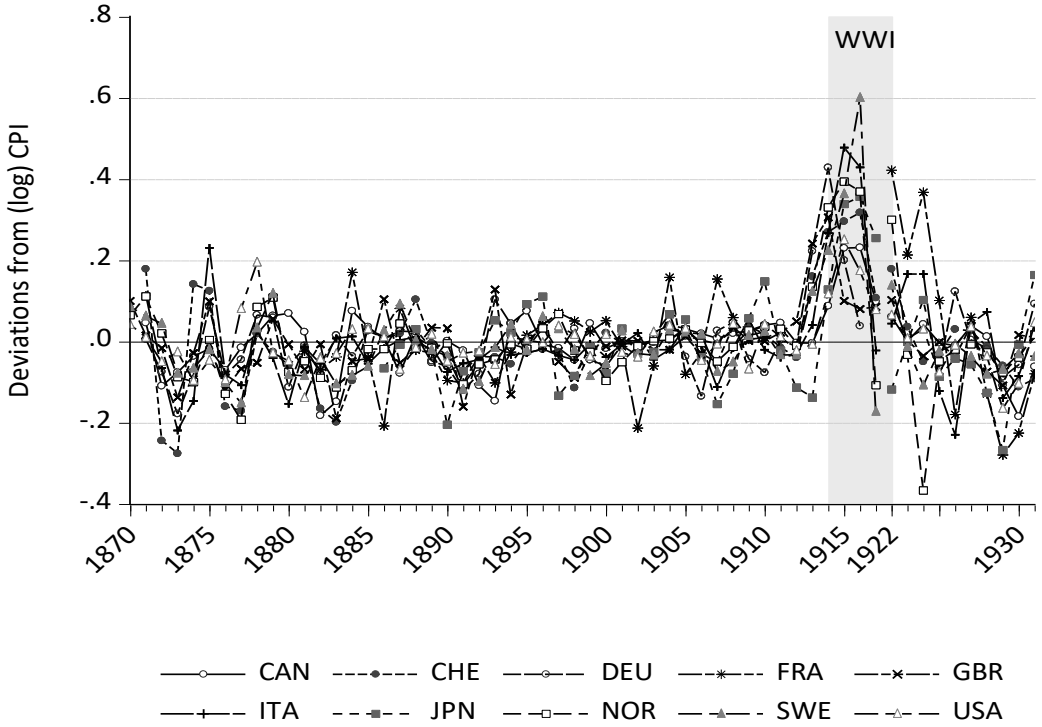
A. 1950-2015



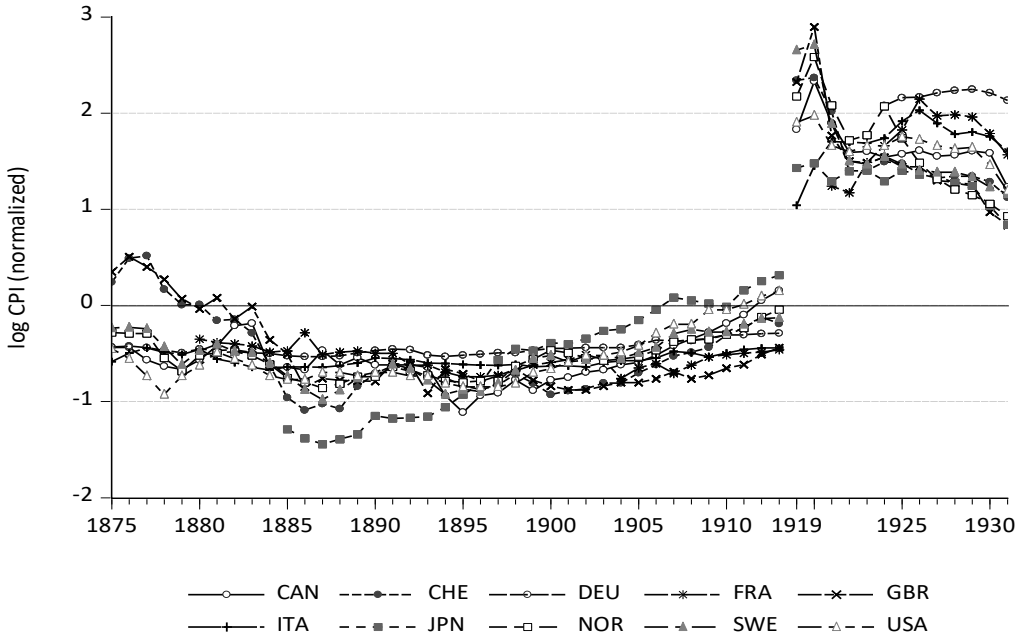
B. 1870-1949



C. The Gold Standard: Deviations from Equilibrium (log) Price Level

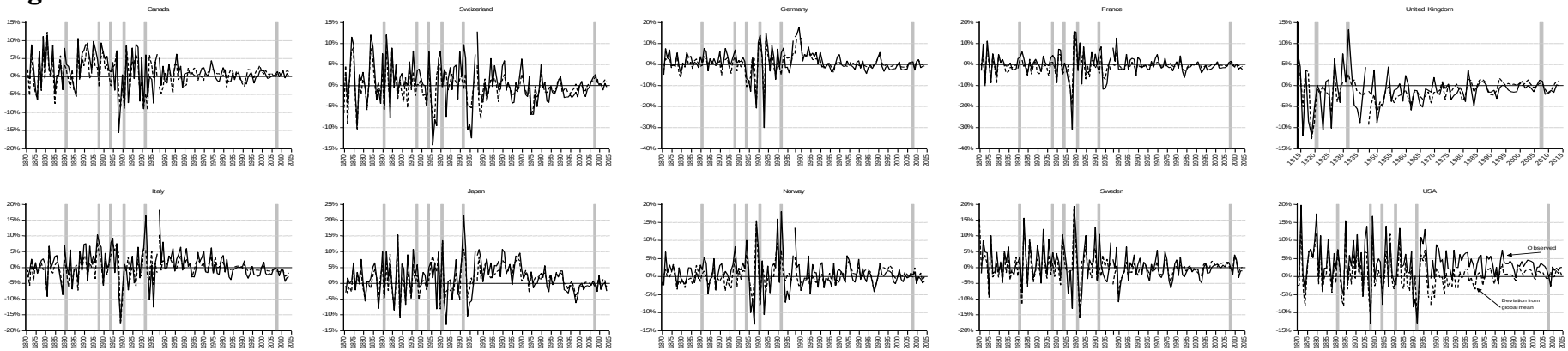


D. Gold Standard: (log level) Prices



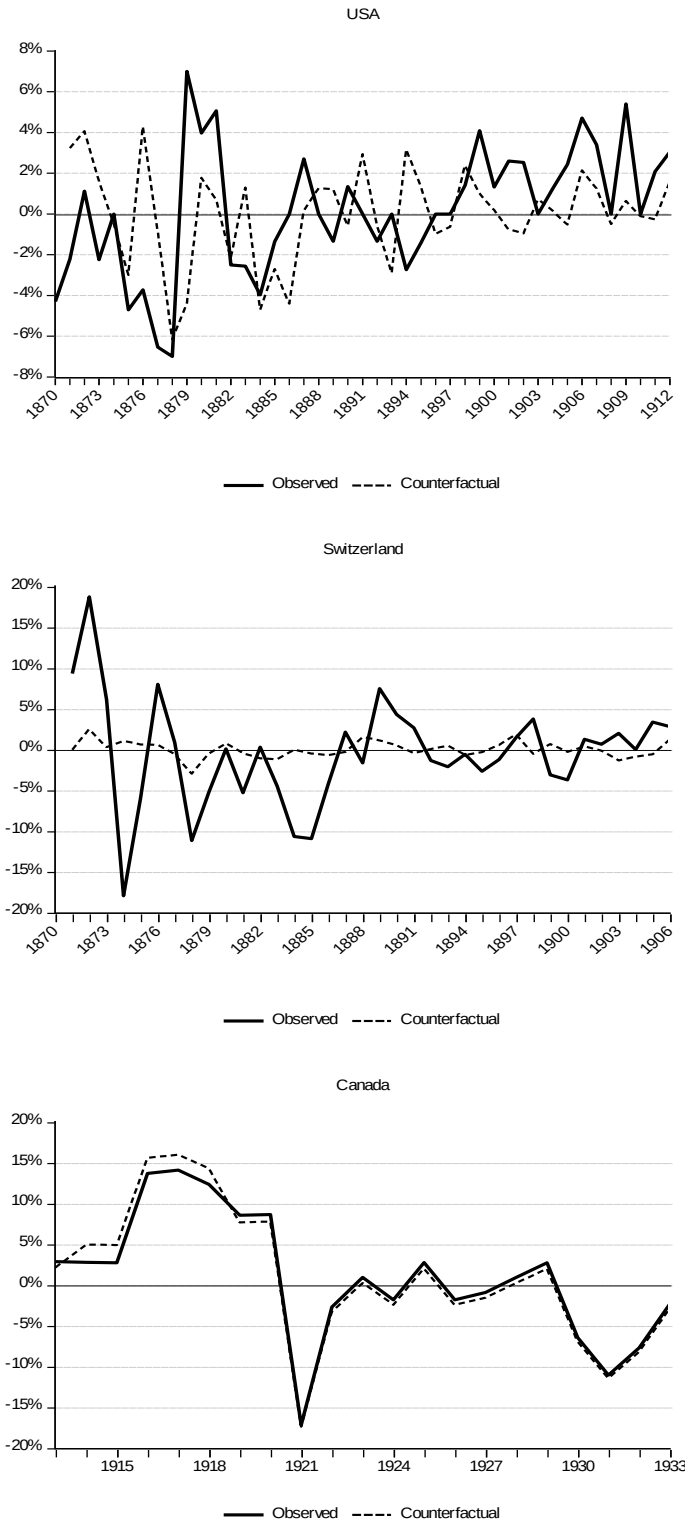
Note: See equation (1) for the definition and the text for estimation details. Part C shows the (log) price level less the Hamilton (2017) applied to the log of prices. Part D shows the (log) of prices normalized to 1 on 1885 in each country. See Table 4 for country name legends.

Figure 6 Observed Inflation Versus Deviations From Global Mean Inflation



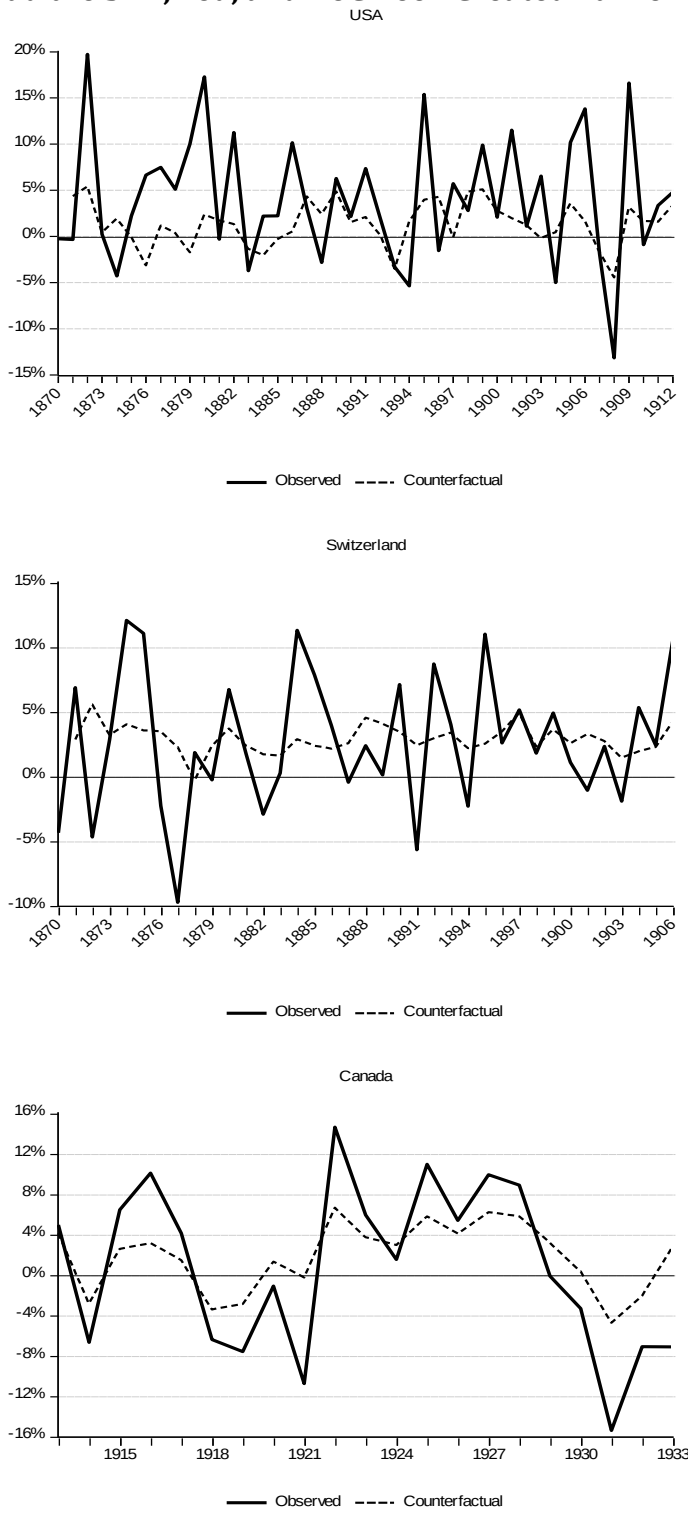
Note: Observed Inflation is 100 times the first log difference in the CPI. Global mean inflation is the overall arithmetic mean inflation rate in an unbalanced sample (1870-2015). The dashed line is d_{it} (see equation (1)). The shaded areas represent the years when there was a global financial crisis as defined in Bordo and Landon-Lane (2013).

Figure 7 Counterfactual Experiment:
Inflation Had the SNB, Fed, and BoC Been Created Earlier



Note: the top figure is for the US, the middle is Switzerland, and the bottom plot is for Canada. Details of the counterfactuals are in the text.

Figure 8 Counterfactual Experiments:
Real GDP Growth Had the SNB, Fed, and BoC Been Created Earlier



Note: See note to Figure 7.

Figure 9: Counterfactual Experiments: Inflation and Real Economic Growth With and Without Inflation Targeting

Note: See notes to Figures 7 and 8 and the text for a description.

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