

Uncertainty and Hyperinflation: European Inflation Dynamics after World War I

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ABSTRACT. Fiscal deficits, elevated debt-to-GDP ratios, and high inflation rates suggest hyperinflation could have potentially emerged in many European countries after World War I. We demonstrate that policy uncertainty was instrumental in pushing a subset of European countries into hyperinflation shortly after the end of the war. Germany, Austria, Poland, and Hungary (GAPH) suffered from pronounced levels of uncertainty caused by protracted political negotiations over reparations payments, the apportionment of the Austro-Hungarian debt, and border disputes. In contrast, other European countries exhibited lower levels of measured uncertainty between 1919 and 1925, allowing them more capacity with which to implement credible commitments to their fiscal and monetary policies. Impulse response functions from a small, reduced-form macroeconomic model suggest that increased uncertainty caused a rise in inflation contemporaneously and for a few months afterward in the GAPH countries, which contributed to their elevated inflation rates. For the other European countries in our sample, this effect was absent or much more limited. In line with recent literature, our results suggest that elevated economic uncertainty affected macroeconomic dynamics generally and inflation dynamics in particular during the interwar period.

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I. Introduction

Why do hyperinflations begin? In a mechanical sense, economists have known the answer to this question at least since the monetarist revolution: money is printed in response to unsustainable fiscal policy. But *ex ante*, how does one identify factors that trigger hyperinflation in one country but not another, when macroeconomic indicators look broadly similar across them? For example, as a consequence of World War I, many European economies abandoned their commitments to fixed exchange rates and ran up large public debts, predisposing them to high inflation, if not hyperinflation. Belgium, Britain, France, Holland, and Italy had debt-GDP ratios in excess of 100%, and each of these European countries saw its price level double since 1913; see Table 2. The table further shows that direct costs associated with the war were high for both Allied and Central Power countries: a grim fiscal and monetary situation prevailed throughout Europe after the Great War, and unfavorable macroeconomic preconditions applied just as much to the victors as they did to the vanquished.

In this paper, we examine inflation dynamics in Europe immediately after the end of World War I. In particular, we analyze how policy uncertainty influenced commitments to credible fiscal paths, and how pronounced uncertainty in a subset of European countries pushed them into hyperinflation shortly after the end of the war. Our contribution is to provide a new empirical methodology for analyzing how such policy uncertainty contributed to inflation dynamics and the incidence of hyperinflation in post-WWI Europe. Our approach is general in that we use a common modeling framework across the ten countries in our sample as well as specific as it is based on country-specific news.

In particular, our methodology constructs a measure of policy uncertainty using a new data set of daily exchange rates for ten European countries. From these high-frequency data, we construct country-specific measures of uncertainty based on monthly, realized volatility (RV). Although realized volatility measures were elevated across Europe after World War I, we show that they were particularly pronounced in Germany, Austria, Poland, and Hungary (GAPH) *prior* to their hyperinflations. For example, Germany's RV was several hundred times larger than that of Holland during 1922 and early 1923, prior to its hyperinflation. Using narratives collected from contemporary news sources and government publications, we show that the high degree of measured uncertainty in the GAPH countries was correlated

with weak fiscal capacity, protracted political negotiations over reparations payments, and unresolved disputes over borders and the apportionment of the Austro-Hungarian Imperial debt. By contrast, the European countries saw spikes in RV that are identified with policy uncertainty, but that were considerably smaller in magnitude. A detailed examination of news in European countries suggests high RV months are associated with events that contributed to policy uncertainty. GAPH appear to have experienced such events with greater frequency.

Our measure of uncertainty appears to capture the inability of policymakers in GAPH to formulate and commit to credible fiscal policies, and thus suggests a causal link between uncertainty and inflation dynamics – a point alluded to, but not formally tested, in Sargent (1982). To test for causality more formally, we embed our measure of uncertainty into a vector autoregression model that includes changes in inflation, industrial production, and notes outstanding at a monthly frequency. However, given the limited timespans of data available during the interwar period and particularly prior to the observed hyperinflations, we present results based on smoothed local projections (SLP) – a recent innovation by Barrichon and Brownlees (2017) – that permits inference on the effects of shocks even in relatively small samples. We then assess the effects of uncertainty on macroeconomic conditions prior to the start of hyperinflation for each GAPH country as well as for six other countries that did not tip into hyperinflation.

The SLP results show that increased uncertainty causes a contemporaneous rise in inflation and for a few months afterward in the GAPH countries that tipped into hyperinflation, thus supporting the narrative evidence. For Germany, our results suggest that a one standard deviation increase in our RV uncertainty measure leads to a contemporaneous increase in inflation of about 8% and another 3% in the subsequent month. Importantly, for the other European countries with lower RV measures, the effect of increased uncertainty on inflation is absent or near zero in magnitude. Our results for France show that a one standard deviation increase in uncertainty has no effect on its inflation rate. These findings demonstrate the utility of our methodology as it allows us to make comparisons between countries, such as Germany and France, which were, for example, on opposite sides of the reparations imbroglio as a payer and recipient, respectively. Our empirical results allow us to distinguish how greater uncertainty contributed to the hyperinflation in Germany. Further, it allows one to incorporate many country-specific narratives of the period, which detail how

uncertainty around such topics as reparations could contribute to driving inflation expectations further into a negative spiral (Webb 1986).

Our paper contributes to several strands of literature within economics and economic history. First, it complements the recent research literature initiated by Bloom (2009) that examines uncertainty and macroeconomic outcomes in the long term as well as fluctuations. Our research extends the work by Bloom et al. (2015) and others by focusing on uncertainty's effects on inflation, a macroeconomic outcome that has received comparatively less attention than investment and output.¹ Our conjecture that policy uncertainty is critical for understanding interwar European inflation dynamics also builds on research describing how the hyperinflations of the early 1920s resulted from unbalanced fiscal and monetary policy (Cagan 1956, Sargent 1982, and Dornbusch 1982). We build on earlier work that examined these hyperinflationary episodes, but focus on the period *prior to* the start of hyperinflation in order to better understand the role of measured uncertainty as a driver of inflation dynamics. We extend these earlier treatments by providing a quantitative modeling framework that can describe how the drivers of inflation differed between the countries that experienced hyperinflation and those that did not.

Our research also relates to the extensive literature on central bank independence. In particular, Bordo and Siklos (2015) show that central bank governance and effectiveness (i.e., fewer policy errors) play important roles in preventing a loss of credibility and control over inflation dynamics.² As we describe, polities were fractured as a result of World War I, destroying the old fiscal and monetary order that had existed under the classical gold standard. The efforts of all nations to reorganize and establish new operating norms for their economies was reflected in higher levels of measured uncertainty, although to varying degrees. The successes and failures of these efforts are tracked by our RV measures and are shown to affect inflation dynamics in the GAPH countries.

Finally, our analysis relates to recent studies on fiscal policy shocks. One strand seeks to quantify how uncertainty around the timing, magnitude, and composition of fiscal policies fundamentally influence medium-term macroeconomic projections and thus policy actions designed in reaction to a given perceived economic situation (Paredes et al., 2015). Another shows that unexpected changes in fiscal volatility shocks had a sizable adverse effect on U.S.

¹ For example, Leduc and Liu (2016) found that for post-war U.S. data, an increase in uncertainty leads to an increase in unemployment and a decline in inflation.

² See also Bordo and Siklos (2014) and Bordo and MacDonald (2002).

economic activity in the late twentieth century (Fernández-Villaverde et al., 2015). The interwar period provides a clear parallel to the important avenues of how fiscal policy uncertainty influences the broader macroeconomy as examined in these papers. Finally, work by Boanchi and Melosi (2017) shows that policy uncertainty linked to fiscal policy contributed to inflation dynamics during the Great Recession in the U.S. In many parts of Europe, uncertainty over reparation payments, border disputes, and legacy debt obligations conspired with limited tax bases and political events to weaken policymakers' abilities to provide direction over the future path of tax and spending policies that might have helped to stabilize inflation rates in the GAPH countries.

II. Policy Uncertainty in Europe after World War I

World War I has been described as a watershed moment in European economic history. The war destroyed property and killed both soldiers and civilians; it also left a legacy of fractured states grappling with high unemployment, industrial dislocation, and debt. Old imperial powers were dissolved; new nation states were formed; ethnic groups were involuntarily separated across new borders; and armed conflicts and border disputes continued even after treaties were drawn. Existing trade flows were disrupted and then reorganized, often in patterns that did not resemble the old ones. As a result, policymakers across the continent struggled to find their footing, often attempting to replicate institutions of the past, such as the gold standard, even though fundamental political and economic change had occurred.

Table 1 shows the fiscal burden that resulted from the war. Debt-to-GDP ratios (for countries that existed pre- and post-WWI) rose significantly, suggesting that, in the absence of rapid economic growth, new taxes and controls on spending would be necessary in the 1920s to return to prewar ratios. As much of the spending of the war had been monetized, prices rose considerably, as shown in the last column of Table 1.³ Given these damaging statistics about the postwar economic environment, it is not obvious *ex ante* which countries in Europe might subsequently experience hyperinflation. For example, in addition to the

³ Sargent (1982), Eichengreen (1995), Ferguson (1999).

situation shown in the table, France ran budget deficits and financed them through money creation and increased national debt in the early 1920s.⁴

The historical record suggests that being on the winning or losing side of a war is insufficient for determining which countries subsequently experienced hyperinflation. The Central Powers of Bulgaria and Turkey, the successor state to the Ottoman Empire, experienced very substantial increases in prices between 1914-25 (more than 3000%), but prices never increased by more than double in any given year. Czechoslovakia – a newly formed state carved out of a losing Central Power– saw its prices rise by roughly 1600% between 1914 and 1921, but prices stabilized thereafter (Sargent, 1982).⁵ On the other hand, Russia, part of the Entente, did experience hyperinflation.

How then does one identify the likelihood of a particular country experiencing hyperinflation given macroeconomic indicators at war's end that look broadly similar across Europe? We hypothesize that pronounced macroeconomic policy uncertainty in particular European countries was an important driver. Our focus on uncertainty follows a recent strand of the literature, beginning with Bloom (2009), which shows how uncertainty can influence macroeconomic outcomes.

Several unresolved political issues cast a pall over all of postwar Europe and proved counterproductive for generating credible fiscal policy. The most widely known of these was the intractable debate over reparations payments. As laid out in the Treaty of Versailles, the Allies paradoxically acknowledged that Germany lacked the resources to pay, but also insisted on payment:

“The Allied and Associated Governments recognize that the resources of Germany are not adequate... to make complete reparation for all such loss and damage. The Allied and Associated Governments, however, require, and Germany undertakes, that she will make compensation for all damage done to the civilian population of the Allied and Associated Powers.” (Articles 231-2, Treaty of Versailles)

The individual treaties struck with other belligerents – namely, the Treaties of Saint-Germain-en-Laye (1919) and of Trianon (1920) that established Austria and Hungary, respectively, as independent states – similarly specified that reparations were to be paid.

⁴ Fraser and Taylor (1990).

⁵ Similarly, Japan, Italy, and Germany, all losers in World War II, did not subsequently experience hyperinflation.

Notably, these treaties did not specify the total amount or number of years payments would have to be made. Instead of providing precise terms for payment of damages, a political entity, known as the Reparations Commission (RC), was charged with working out the details. The RC met repeatedly after the treaties were concluded – in San Remo (April 1920), Bath, Hyde, Spa (July 1920), and Brussels – but the gap between what the Allies sought and what Germany and others were willing to pay remained large. In January 1921, France demanded 226 billion gold marks (or \$53 million); Germany's counter proposal was just 50 billion gold marks.⁶ Meanwhile, the U.S. Congress failed to ratify the Versailles treaty and was thus reduced to "observer status" as the negotiations dragged on. On May 5, 1921, four days after the deadline initially imposed on the RC for reaching an agreement and nearly two years after the treaty was signed, a deal was finally struck with Germany whereby it would pay 123 billion gold marks.

Reparations began taking their toll on the young Weimar Republic even before a final agreement was reached.⁷ The Versailles Treaty had specified that 20 billion gold marks (\$4.76 billion U.S.) would be paid immediately to provision occupying armies and for a variety of deliveries including ships, securities, natural resources (e.g., coal and timber), livestock, and agricultural products. Between 1920 and 1922, Germany ran a budget deficit, and reparation payments replaced armaments as the single biggest item in the budget – absorbing 48% of it between April 1920 and March 1923 (Young, 1925). The final agreement proved very costly from a political standpoint. Adolf Hitler denounced the London payments schedule and began to attract large crowds that were unhappy with the treaty's terms. Walter Rathenau – founder of the German Democratic party, foreign minister of the republic, and advocate of fulfilling Germany's obligations as specified in the treaty – was assassinated on June 24, 1922 by right-wing extremists. In this same year, the RC declared Germany to be in default for its failure to deliver a shipment of timber.

The issues were similar in Hungary and Austria. The amount of Austrian reparations was not fixed in the Treaty of Saint Germain. The country's constitutional courts made the claim that since the country was new as of 1918 and was therefore not obligated to pay obligations that arose out of the war, but the signing of the international treaty suggested this

⁶ Boemke (1998, p.410).

⁷ The constitution creating it was signed on August 11, 1919.

legal argument would not satisfy foreign expectations.⁸ The new state nevertheless went bankrupt before payments could begin.

Hungary's amount was not fixed in the Treaty of Trianon, but was set in 1924 at 200 million gold crowns. In the meantime, budget gridlock ensued. By 1920, the minister of finance, Lorant Hegedus, drafted a financial program that reduced budget expenditures, sought tax reform, and strove for deflation, but the program was met with opposition because of disagreement over Hungary's payments to the allies. As Sargent (1982) noted, "[t]his circumstance alone created serious obstacles in terms of achieving a stable value for Hungary's currency and other debts, since the unclear reparations obligations made uncertain the nature of the resources to back those debts." The budget situation was further complicated by the fact that the Succession states to Hungary were supposed to compensate it for the *biencedes* (Hungary's former property), but this amount was never fixed, and the issue remained unsettled through the 1920s.⁹

The victors of World War I also faced fiscal uncertainty as a result of the failure to resolve the reparations question (Young, 1925, p.8). Physical damage from the war was concentrated in northeastern France and Belgium, and reconstruction of the war-ravaged areas required revenue. Allied soldiers who were fortunate enough to return from the battlefield at best faced diminished employment opportunities (overcapacity in steel, coal, and agricultural production), and at worst, destroyed communities. Adding to these domestic problems were the international debts that Great Britain and France had accumulated during the war. Private creditors in lending countries, such as the U.S., had no incentive to forgive the debts, which only intensified pressure to seek fiscal solutions by demanding large reparation sums from the former Central Powers.

Uncertainty over borders was a second important issue that hindered clarity in fiscal policy decision-making in post-WWI Europe, making it difficult to forecast expenditures (e.g., securing and policing borders) and derive revenues from disputed areas. Border disputes also led to continued high military expenditures in many European countries even after the war ended, adding significantly to treasury obligations and budget deficits (Young, 1925, p.8), and creating uncertain fiscal obligations so long as disputes remained unresolved. The German Republic accepted its new western borders, but still faced uncertainty in this direction given that France and Belgium were using the threat of invasion as a "stick" in

⁸ Dumbery, 2007, p.102.

⁹ It was canceled in 1930.

negotiations over reparations payments. Germany's fears were eventually realized in 1923 with their joint occupation of the Ruhr. To the east, Germany failed to fully accept the borders demarcating the newly-formed states of Poland and Czechoslovakia. Territorial uncertainty was exacerbated by France's attempt to impose a *cordon sanitaire* to hem in the "diseased nation" of Germany through its mutual assistance alliances with these two new nations.

Austria suffered immediate financial troubles as a result of having no natural borders defined by ethnicity or production, and the dismembering of the Austro-Hungarian empire led to serious economic dislocation as new boundaries dissected railroad lines (regardless of their system) as well as production (e.g., separation of iron ore coal mines from steel mills and the spindling of cotton and the looms and finishing plants).¹⁰ Border disputes also created uncertainty for Poland. The region of Upper Silesia was only forcibly removed from Germany and incorporated into Poland in June 1922 by the League of Nations after a plebiscite mandated by the Versailles Treaty failed. In order to secure its borders, the Polish government committed large sums to, accounting for 53% of the budget deficit and one third of the nation's budget in the early 1920s.¹¹ The Polish government was also engaged in ongoing military engagements with Soviet Russia from 1919 to 1921.

Finally, uncertainty over fiscal and monetary policy resulted from unresolved issues regarding the formation of new states out of the former Austro-Hungarian Empire - namely, Austria, Hungary, Czechoslovakia, Poland, and the Kingdom of Slovenes, Croats and Serbs. The successor states to the Austro-Hungarian Empire struggled with diminished or non-existent state capacity. Hungary was reduced to 33% of its former size, left with few raw materials for inputs into industrial production, a reduction in the internal market size, and no access to the sea, diminishing its capacity for international trade.¹² Upon dissolution, political chaos ensued. Bela Kun's communist regime and the Romanian occupation of Budapest (August-November 1919) delayed state formation and the ability to collect revenue. Further, the assignment of the existing debt of the Austrian Monarchy needed to be settled. Interest payments were suspended in 1919, and it was not until the Innsbruck Protocol of 1925 was signed that the existing unsecured debt was formally apportioned as follows: 41.7% to

¹⁰ Prochnik (1922).

¹¹ Durand (1922).

¹² Jonas (2016).

Czechoslovakia; 36.8% to Austria; 13.7% to Poland; 4.1% to Italy; 2% to Yugoslavia; and 1.6% to Romania.

III. Estimating Uncertainty

As Obstfeld and Rogoff (1983) show, since households take into account the future inflation when determining how much money to hold today, multiple equilibria for the path of inflation can arise. Inflation could simply depend on the growth rate of money over the growth rate of output, as in a monetarist model, or it could depend on other factors, including the intertemporal government budget constraint, as emphasized in models of the fiscal theory of price level. For example, Woodford (1995) examines how a government's decision on how to finance its budget is crucial to the path of the inflation rate. Further, news that causes agents to believe that expected primary surpluses will be smaller in the future can result in unanticipated inflation in the present – even before it shows up in a country's budget balance (Davig and Leeper, 2011). Our approach to understanding how uncertainty translates into inflation dynamics allows for the possibility that both fiscal and monetary news may influence the path of inflation today and in the future, regardless of whether the price-level path veers away from the path of the money stock as would be the case in a “pure” fiscal theory of the price level model (McCallum and Nelson, 2005).¹³

As we have discussed, in Europe, unresolved political issues and weak state capacity contributed to uncertainty over borders, the size of debts and other fiscal obligations as well as an inability to generate revenues to support them. However, because fiscal policy uncertainty appears pervasive, our empirical strategy for testing its influence on inflation dynamics needs to permit one to consider the possibility that hyperinflation could have occurred in any European country. Thus, we thus develop country-specific measures of uncertainty so that we can make within-country comparisons (to assess whether uncertainty is a driver of inflation and of experiencing hyperinflation) and cross-country comparisons (to determine whether countries that experienced hyperinflation had more pronounced measures of uncertainty relative to that which existed in other parts of Europe).

¹³ Sargent (1982) argues “that the European inter-war hyperinflations grew out of persistently active fiscal policies that forced monetary authorities to adjust the money stock passively to meet higher average levels of government deficits,” as pointed out in Leeper (2005), but like the latter, we also allow for the possibility that shocks to real debt can generate current or future money creation.

To do so, we follow the methodology introduced in Bloom (2009) and then extended by subsequent researchers, which measures uncertainty and examines the properties of these measures on their own and in relation to the macroeconomy. In particular, we use the volatility of financial market variables as a measure of economic uncertainty, whereas Bloom (2009) created an uncertainty index based on the volatility of daily U.S. stock returns. Baker and Bloom (2013) show that bond-yield, exchange-rate, and GDP-forecast volatility are additional suitable proxies for uncertainty. Similar proxies, such as the option-based VIX index of stock market volatility, have been used as uncertainty measures in more recent papers. For example, Baker et al. (2016) find a high correlation between the VIX index and alternative uncertainty indexes. Gilchrist et al. (2014) measure uncertainty using variations in corporate bond spreads and find that such uncertainty has a strong effect on business investment.¹⁴ Other measures have been created; for example, Bloom et al. (2015) construct a measure of U.S. economic policy uncertainty (EPU) based on newspaper coverage frequency. They found that their EPU measure influences aggregate investment, consumption, and employment. Jurado et al. (2015) generate an uncertainty index from the residual of factor-based macroeconomic model and show that their measure suggests fewer periods of elevated uncertainty as compared to those indicated by financial market data.

Based on our desire to maximize country coverage in the 1920s and to use a well-established measure of uncertainty, we hand collected daily exchange-rate data from various issues of the *Commercial and Financial Chronicle* from the years 1919 to 1925.¹⁵ From this data set, we compute the monthly realized volatility (RV) based on the daily logged first difference of the countries' foreign exchange spot prices in the New York trading market. Exchange rates are a particularly useful asset price for measuring uncertainty since they capture both real-time economic and political “news” specific to a particular country as well as information about a country's price dynamics during periods of economic instability.¹⁶ Such RV measures have been shown to be reasonable and consistent proxies for the true, but unobservable, variance in financial time series; as per Andersen et al. (2003).

¹⁴ As noted by Gilchrist et al. (2014), there is no single objective measure of economic uncertainty used in the literature so we focus on one measure that has been used previously in the literature and one where we can be certain that war-time events did not disturb its functioning so that it provides clear signals on “news.”

¹⁵ Cite Peel paper on use of the CFC for German hyperinflation. Also cite Baillie and Bollerslev papers using weekly data.

¹⁶ In his description of interwar hyperinflations, Sargent (1982) provides examples of purchases of foreign assets and capital controls, which suggest how important exchange rates were to the economic environment of the time. For further discussion of the German hyperinflation and exchange rates, see Frankel (1977, 1980), Salemi (1980), and Webb (1986).

These FX-based RV series should be comparable measures of uncertainty since they are based on exchange-rate trading in New York, whose institutional features were not affected by events in Europe.¹⁷ Previous research on our sample period supports the notion that foreign-exchange markets were well functioned: for example, Frankel (1977) provides empirical evidence that the exchange market for German Reichsmark operating in London was efficient.¹⁸ As such, our RV measures of uncertainty accurately reflect how economic and political news affected the countries' state of affairs and is not polluted by distortions due to country-specific marketplace characteristics.

The RV calculation is straightforward. For a given month, we calculate the average of the squared daily, demeaned log first differences of an exchange rate as a consistent estimate of the true, but unobservable, variance of monthly changes in the exchange rate; that is,

$$(1) \text{RV}_{kt} = \frac{1}{N_t - 1} \sum_{i=1}^{N_t-1} (\Delta x_{ki+1} - \mu_{kt})^2,$$

where k is a country index; N_t is the number of trading days in month t ; Δx_{ki+1} is the change in the logged foreign currency exchange rate for country k from day i to $i+1$ in month t ; and μ_{kt} is the average value of these changes in month t . Because these are measures of scale deviations, we can readily compare them in relative terms, to describe the series themselves and provide insight into their cross-sectional and time-series behavior. As shown in Table 2 for annual averages, the RV measure shows a reasonable degree of cross-sectional and time-series variation. Notably, the GAPH countries have generally higher RV values and exhibit upswings leading into the observed hyperinflation periods, with these characteristics of the measure especially pronounced for Germany in 1923. The average RV values for the non-hyperinflation countries are clearly lower, although they do exhibit some interesting spikes.

This variation can be examined in greater detail in time series plots of individual country RVs. Our graphical analysis presents all the RV measures relative to the value for Holland in its inaugural month of July 1919.¹⁹ Figure 1 presents the relative RV measures for Holland and Britain, which exhibit the lowest RV measures. Holland's RV measure in

¹⁷ Cite Webb (1986) on London trading and data in Einzig book. We could cite the Vollrath and Voth paper on connected firms to Schaaf having higher returns in Germany in the Weimar period as a reason not to use stock market data, for example.

¹⁸ See also the follow-up discussion in a comment by Salemi (1980) and a response by Frankel (1980).

¹⁹ Holland was selected as the base country since it was neutral during the war and has exchange rate data for the entire sample period.

January 1920 is much higher relative to its normalizing observation in July 1919. As we discuss in greater detail in the next sub-section, changes in month-to-month volatility can be triggered by “news” of various types. For example, Holland’s RV measure spikes to 3.0 in January 1920, which can likely be attributed to the Holland’s decision to join the League of Nations and its refusal to hand over Kaiser Wilhelm as a war criminal under the Treaty of Versailles. After the peak in early 1920, the Dutch RV series declines steadily and reaches a low of 0.1 by the end of the sample in December 1925. The UK measure follows a similar pattern, although it exhibits much more volatility in early 1920. These patterns suggest that uncertainty in the Dutch and UK economies and political environments, while relatively elevated shortly after the end of the war with the November 1918 armistice, declined steadily over the sample period.

Figure 2 shows the RV measures for three other European countries that, ex post, did not experience hyperinflation. Belgium, France, and Italy exhibit much higher peaks and are more volatile relative to the Dutch and UK benchmarks, reaching levels that are ten to twenty times larger than the Dutch benchmark value of July 1919. In fact, the Belgian series (in red) was about forty times the benchmark on two occasions. This degree of variation in the uncertainty measures speaks to the wide variation in post-war economic conditions and fiscal policy making environments across Europe. For example, France felt justified in running large budget deficits, believing Germany would eventually pay reparations for the reconstruction of territories destroyed or damaged during WWI. The French finance minister Poincare more or less proclaimed this in his famous quip “*le Boche paiera tout,*” or roughly, the Germans will pay for everything. And, in order to enforce their claim to reparations and secure borders shared with Germany, France maintained significantly higher budget shares of military spending into the early 1920s. Note that the RV measures for France and Belgium spike to nearly ten before and during the occupation of Germany’s Ruhr Valley in January 1923.

Figures 3 and 4 show the RV dynamics for the GAPH countries that eventually experienced hyperinflation. Figure 3 depicts the RV measure for Germany, which experienced the most dramatic hyperinflation of the countries in our sample. The magnitude of the economic uncertainty reflected in the series is immense, nearly 4,500 times larger than the Dutch benchmark in October 1923, after the hyperinflationary dynamics had started and the new Rentenmark was being introduced to replace the paper mark. The series declines to

near zero in early 1924 due to a decline in trading in the currency.²⁰ Figure 4 also depicts the German RV series, but truncates the series at 250 times the Dutch benchmark in order to allow comparison with the other three hyperinflation countries in our sample. While less volatile than the German RV measure, these series exhibit much higher values than observed for the non-hyperinflationary countries; i.e., their RV values are commonly fifty to 100 times the Dutch benchmark. The elevated levels suggest that the movements of these countries' exchange rates were larger and more affected by the arrival of news, suggesting that this news contained more information on the current and future success of these countries' policy decisions.

IV. Is Realized Volatility Associated with Fiscal Policy “News”?

We now examine whether the RV measure of uncertainty is associated with country-specific “news”, such as political developments, that could influence a country's economic outcomes. Table 4 lists the ten months with the largest realized RV prior to the start of hyperinflation and the five months with the largest realized RV for non-hyperinflationary countries. Using historical newspapers, secondary sources, and archival collections of the League of Nations, we coded news for our sample period and record this in the table for these months. As described in Section IIA, we focus on events and governmental actions that would directly or indirectly influence fiscal policy decision making such as territorial disputes, reparations, and political and social unrest. Panel A guides our detailed discussion that follows focus on the hyperinflationary countries; Panel B provides the information for non-hyperinflationary countries.

IVA. Austria

The Treaty of Saint Germain was signed in September 1919 and established the first Austrian republic.²¹ As noted above, the treaty reduced the size of Austria, handing over former parts of the empire to existing and newly-formed states; obligated Austria to pay reparations while not specifying the amount or payment schedule; and prohibited Austria from re-uniting with either Germany or Hungary. The new Austrian republic struggled to

²⁰ According to the foreign exchange tables in the *Commercial and Financial Chronicle*, New York quotation of the Reichsmark continued through October 1924 when Rentenmark trading began to be reported.

²¹ New York trading in the Austrian currency began in July 1919, as reported in the *CFC*.

formulate a stable government, first relying on the temporary government of the Social Democrat Karl Renner and then inviting the former emperor to return to create a constitution. On December 25, 1919, Karl IV was crowned Archduke of Austria, but food and raw material shortages continued into the winter. Allies exerted pressure on Austria to disarm; it was refusing to do so given the uncertainty of its borders. In terms of our uncertainty measure, the RV value rose steadily and reached an unnormalized high of 121.7 in January 1920, when news reports cited that Vienna had run out of coal and was shutting down its electric tram system.

The fledgling government was unable to formulate a budget plan in 1920; each successive draft of the budget (the 4th of the year in May) showed a growing deficit. Protests erupted over a proposed tax on capital erupt in May (RV value rose to 141.3). By January 1921, the government declared itself insolvent and turned its finances over to the Reparations Commission (RV value of 109.5). In the first half of 1921, Austria sought a loan to stabilize its financial situation, pledging revenues from customs, state railway, and salt and tobacco monopolies, an idea the League of Nations eventually endorsed in July. However, the loan could only be offered if other countries were willing to remove their liens on the Austrian assets that were pledged as part of the reparations agreement, which they refused to do. In August 1922, Lloyd George stated that the Allied governments were unable to extend further financial assistance to Austria unless guarantees of reconstruction were made by the League of Nations. The RV measure reached its maximum value of 160.72 in that month, and trading in the currency ended in October 1922 when the League of Nations assumed control.

Two border crises boiled over in 1920. Tyrol and Salzburg held plebiscites in May, voting to breakaway and join Germany, provoking strong responses from Italy and France (and thus complicating Austria's ability to get them to release liens). Hungary seized Burgenland in September 1920, a region promised to Austria in the Treaty of St. Germain. Armed struggle continued through December 1921, when a plebiscite organized with Italian diplomatic assistance placed most of the region within Austria.

IVB. Germany

As seen in Figure 3, the RV series for Germany is quite elevated, reflecting the frequency and magnitude of political and economic crises that roiled that country in the wake of World War I. Problems arose immediately following Germany's decision to accept the

terms of the Versailles Treaty in January 1920. On March 13, a general strike was called in Berlin to protest Germany's decision to accept the terms of Versailles and pay reparations. On that same day, monarchists staged the Kapp Putsch and drove Gustav Bauer's republican government from the nation's capital, forcing it to flee to Stuttgart. A day later, amidst the chaos in the capital, communists seized the demilitarized regions of the Ruhr, initially in response to the Kapp Putsch, but also with designs to gain control of the republic. Roughly 300 policemen were killed. Both uprisings were quashed by the end of the month, but not without considerable bloodshed, especially in the Ruhr, and the toppling of the Bauer government, who resigned on March 27th. Meanwhile, operating under the new constitution of August 1919, the government redirected control of state finances away from local and regional governments by passing a law that prohibited these jurisdictions from imposing any taxes that were similar in origin to those of the federal government. After making only one payment agreed to under the London Ultimatum of May 1921 (which guaranteed payments of 132 billion gold marks), the new Wirth government requested a moratorium on reparations payments in December. In that same month, Germany's efforts to secure a private bank loan to help finance its expenditures were rebuffed.

At the start of August 1922, French Prime Minister Raymond Poincare demanded payment of reparations or threatened "coercive measures," presumably occupation of the Ruhr. Germany asked for a delay after foreign minister Rathenau's assassination by extremists, and defaulted on its scheduled payment. The Reparations Commission then agreed to a six-month moratorium on payments, in part because the politically-delicate transfer of Upper Silesia to Poland was taking place simultaneously. By October, Wirth had requested a full moratorium on debt payments, but the French position had hardened. It refused to pay its Allied war debts until it received reparations from Germany. The German moratorium request was not met and Wirth was forced to resign in November. At the same time, capital flight was worsening, and Germany responded by imposing exchanged controls. A second London conference aimed at resolving the reparations impasse ended in December 1922 with no new agreement; Repko warned Germany it was in default over its failure to deliver timber to France, and Wirth's secret negotiations with Poincare to sign a non-aggression pact failed.

When Germany missed its reparations-related delivery of coal in January 1923, Repko declared the country in technical default. In response, Belgium and France invaded the

Ruhr with more than 60,000 troops. Germany responded by ordering government employees to disobey the occupying French. German banks closed in Dusseldorf in response to occupation, and a broad strike in the mines led to the French arrest of the German heads of these operations. Toward the end of the month and into the next, France tightened its control over the Ruhr, and barred exports from the region to non-occupied Germany. The Ruhr dispute continued throughout the spring, with the German government financing “passive resistance” to French occupation, further straining its budget. Since the fall of 1922, extremists, including Hitler and the National Socialists, drew large crowds at speeches and acts of protest. In June 1923, France and Belgium called for an end of German passive resistance in the Ruhr as a quid pro quo for a new reparations conference; they occupied Dortmund, leaving only one railway line out of the Ruhr.

IVC. Hungary

Even after the new republic of Hungary managed to stabilize its borders with Czechoslovakia and Romania and signed a peace treaty in June of 1920, the country remained fragile. In the second half of the year, Prime Minister Teleki had to form two consecutive governments to maintain power, put down wayward military units in the country’s capital, and get a reluctant National Assembly to ratify the Treaty of Trianon, which it finally did in November. Rumors of a coup by former emperor Charles IV threatened the government’s existence in early 1921 as did a continuing territorial dispute with Austria over the Burgenland region. The coup by Charles IV finally materialized in March, but without military support, he was forced to retreat to western Hungary.

By September, the border dispute with Austria heightened when Hungary sent troops into the region to protect its access to railway lines; Allies then warned Hungary to withdraw. Finance minister Lorant Hegedus resigned in September 1921 as the budget situation worsened. Political instability continued to plague the young republic in the second half of the year, with Charles IV attempting another coup and the National Assembly responding to his attempt by passing a the Dethronement Act of the House of Habsburg in November. In December, the city of Sopron, a German-speaking area within Burgenland, holds a plebiscite, voting to remain with Hungary despite Austria’s treaty-based territorial claim.

At the end of 1921, the country appointed yet another minister of finance (Tibor Kallay); the government continued to operate under a provisional budget since it had failed to

pass a budget bill for the fiscal year. In January 1922, the budget crisis worsened: the government announced a deficit double its previous estimate, and used the provisional budget to authorize the payment of both the capital and interest on the public debt using bond finance. Hungary continued with aggression toward the newly-formed central European states, prompting Czechoslovakia, Romania and the Kingdom of Serbs, Croats and Slovene (Yugoslavia) to form the Little Entente -- a series of treaties negotiated in 1922 and finalized in August, which recognized each other's independence and promised mutual defense against Hungary. In September, with the budget and capital flight worsening, Hungary implemented foreign exchange controls and requested admittance to the League of Nations in the hopes of obtaining a loan to stabilize the economic situation.

IVD. Poland

Facing five territorial disputes (two with Czechoslovakia, and one each with Germany, Lithuania, and Russia) Poland's postwar existence was uncertain. Its RV measure often changed in response to events associated with these disputes. After its surrender, Germany withdrew its armies from the Eastern front, leaving a power vacuum that was quickly filled by the Russians and Poles, both of whom laid claim to the area spanning parts of present-day Latvia and the area in present-day Ukraine between Kieve and Lviv. The territorial dispute escalated into warfare, with both countries claiming historical precedent to these areas. While each side in the conflict had seen some success in their offensives in the first half of 1920, Russia was forced to sue for peace in November and negotiations began the following month; however, labor strikes arose in Polish occupied parts of former Russian territory. At the same time, Polish relations with Lithuania rapidly deteriorated when general Zeligowski set up a permanent occupation force in Vilna over strong objections from Lithuania. An attempt by Belgium to settle the dispute between Lithuania and Poland failed in December.

Facing budget pressures from these disputes, Treasury Minister Grabsky resigned. Negotiations with Russia dragged on into early 1921, and food and clothing shortages worsened in the big cities of Poland. Multiple uprisings among the Polish population in Upper Silesia occurred in 1921, with hostilities spiking in August; the Supreme Council of the Allies thus ordered a cessation to fighting as they worked to resolve this territorial

dispute. The budget minister of Poland requested strict supervision of all expenditures by the Diet, including military spending, as fiscal position of the country eroded further.

The League of Nations resolved the German border dispute over Silesia in October 1921, with Poland receiving most of the industrial areas but about one-third of the contested land; however, it made no headway on Poland's dispute with Lithuania. In February 1923, the League relented and simply divided the neutral zone -- setting a demarcation line as the official border, but one which Lithuania refused to recognize: the dispute thus remained unresolved during our sample period.

In June 1923, the Sikorski government was overthrown, and a new Cabinet led by Witos of the Piast (Peasant) party took charge. He kept Grabski on as minister of treasury, who intended to introduce currency reform (zloty), balance the budget, and lower inflation. However, Witos then decided not to support these reforms, and Grabsky resigned in protest the following month. Witos and Linde, his new finance minister, attempted to secure a foreign loan of \$100 million loan from Hallgarten & Co. and a \$150 million loan from J.P. Morgan to finance budget deficits, but both attempts failed. Poland was given official notice of the creation of USSR in that same month.

V. Estimating the Role of Uncertainty on Macroeconomic Outcomes in the 1920s

V.1. Methodology

The preceding sections suggest that Europe found itself in a highly uncertain environment for formulating policy after World War I, and that policy uncertainty (as measured by our measure of realized volatility in exchange rates) was particularly pronounced in countries that ultimately experienced hyperinflations. A detailed examination of individual countries further suggests that RV months are associated with events or news that could influence the course and direction of fiscal policy. We now consider whether the RV measure provides insight into inflation dynamics.

Given the historical setting, we seek to analyze inflation dynamics, but to our knowledge, there is no model directly linking macroeconomic uncertainty with inflation dynamics. However, a wide variety of statistics have shown that uncertainty around specific policy elements have influenced macroeconomic outcomes. As shown in Table 5, there are

several constraints that define our sample period and coverage. First, we are limited by when data – whether monthly macroeconomic data or the exchange rate data used to calculate the RV measures – become available for the ten European countries in the sample. For example, the earliest month for which we have sufficient data to conduct our multivariate analysis is July 1919, when the daily exchange rate series are first reported for the UK, Holland, and Italy. Another constraint concerns the availability of monthly inflation figures. These mainly become available in the early 1920s for the GAPH countries as well as for Belgium, Czechoslovakia, and Holland. Our sample period extends up through April 1925 when monthly data on notes in circulation ends for most of the non-hyperinflation countries, although a few end late in 1924. The endpoints for the non-hyperinflation countries are mainly determined by when data on bank notes in circulation end. The last column of Table 5 lists the number of observations available for each country and highlights the econometric challenge we face with this small sample.

In terms of measuring the relationship between uncertainty and inflation, a crucial modeling assumption is deciding on when hyperinflation began for the countries that experienced it. Our intuition is that when a country crosses over into a state of hyperinflation, the stability of the macroeconomic relationships that we would hope to capture with a model break down sufficiently as to prevent reasonable inference and quite likely provide spurious inference. Because there is no standard definition of hyperinflation, we use the simple rule of a 100% change in monthly prices (i.e., a doubling of the level of prices) within a month to define the onset of hyperinflation within a country. As shown in the top panel of Table 5, this defines the end date of our sample for two of the GAPH countries. In Germany, our sample ends in June 1923, with a monthly inflation rate of about 86% since the monthly inflation rate in July 1923 reached 136%.²² Similarly, Poland's hyperinflation started in October 1923, when monthly inflation reached 132%; thus, our end date for Poland is September 1923, when the monthly inflation rate was 32%.

The start of hyperinflation for Austria and Hungary are defined somewhat differently. For the Austrian sample, the monthly inflation rate reaches a maximum of only 83% in August 1922. In the following month, the League of Nations extended the country a

²² The hyperinflation reached a peak of a monthly inflation rate of 569% in October 1923 before the reichsmark was decommissioned and replaced in December 1923; see Webb (1986). Salemi (1980) chose the same endpoint of June 1923 for his study based on judgement; i.e., he stated that “a regression attempting to explain [German inflation] between February 1921 and August 1923 might do well by explaining [German inflation] for only the last few months.”

significant loan and assumed control of certain monetary functions. As this represented a regime shift and effectively ended trading in the kronen (i.e., no reported price fluctuations in New York trading), our RV measure of uncertainty could not be calculated beyond September 1922. For Hungary, monthly inflation rates were certainly elevated, reaching 68% in July 1923 and 52% in February 1924, but never exceeded 100%. However, commentators – such as Sargent (1982) – describe Hungary as experiencing hyperinflation by noting that, for example, its price index increased by a factor of 263 between January 1922 and April 1924. Accordingly, we also use regime change to mark the sample's endpoint at June 1924, when the Hungarian National Bank was formed and the krone effectively stopped trading before the forint was introduced in August 1924.

Before describing our econometric approach, Table 6 presents simple summary statistics on the correlations between the monthly changes in countries' inflation rates (denoted as $\Delta\pi_{k,t}$) with lagged values of the changes in their RV values; i.e., $\rho(\Delta\pi_{kt}, \Delta RV_{kt-j}), j \in [0, 6]$. These correlations provide a simple view into how changes in uncertainty influence future changes in inflation. The top panel presents the correlations for the GAPH hyperinflation countries. The first point to notice is that, with the exception of Poland, there is a fairly large contemporaneous correlation between changes in GAPH inflation and uncertainty, ranging from 0.25 to 0.38; i.e., inflation and uncertainty tended to move together in these countries. While the degree of statistical significance will be a consistent concern in our analysis due to the relatively short sample periods available, we observe that these values are positive, relatively large, and statistically significant at the 15% level. The second point to notice is that the one-lag correlations remain positive and significant for all GAPH countries except Austria, whose second-lag correlation fits this pattern. These correlation patterns provide intuitive support for the hypothesis that economic uncertainty is an important driver of inflation in countries experiencing hyperinflation and that these effects do not appear to be long-lived.

The bottom panel of Table 6 presents these correlations for the other countries in the sample and suggests a qualitatively different result. Britain, Czechoslovakia, and France show barely any correlation at any lag between these two variables. The contemporaneous correlations for Belgium, Holland, and Italy are similar to those of the GAPH countries in magnitude and significance, but their subsequent lagged correlations oscillate in a pattern that likely negates the initial contemporaneous correlations. Overall, these correlation patterns

provide preliminary support for the hypothesis that uncertainty, as reflected in our RV measures, was not likely pronounced enough to induce hyperinflation.²³

To estimate more fully the effects that uncertainty had on the economic dynamics of European economies after World War I, and inflation in particular, we use a standard vector autoregression (VAR) model. In particular, for each country in our set, we introduce our RV series into a small VAR model that includes changes in inflation, industrial production, and notes (or money) in circulation at a monthly frequency. The latter variable has been highlighted as a way of gauging fiscal policy regimes.²⁴ As government expenditures fluctuated due to volatile tax revenues, reparations negotiations, and military actions, different countries were, to varying degrees, financing deficits through the issuance of debt obligations or by monetizing them; see Sargent (1982) and Webb (1986). The latter is clearly a precursor to rising inflation and loss of currency value. Thus, the growth of notes in circulation, particularly for the GAPH countries, is an important variable in our empirical framework.²⁵ We place the RV series as the first variable in the model, such that uncertainty does not respond to macroeconomic shocks in the current period, while the other series can change based on an uncertainty shock; see Leduc and Liu (2015) for further discussion. Our macroeconomic series are collected from contemporary sources as described in the Appendix.

While VAR models and their estimated impulse response functions (IRFs) are standard tools for assessing macroeconomic dynamics, they are subject to certain general challenges as well as some specific challenges. As summarized in recent work by Barnichon and Brownlees (2017), VARs are known to provide meaningful dynamic structure and shock identification to the system of variables under analysis, which translates into efficient parameter estimation and generation of multipliers of interest, such as impulse response functions. We place the RV series as the first variable in the model, such that uncertainty does not respond to macroeconomic shocks in the impact period, while the other series can change based on an uncertainty shock.²⁶ Impulse response functions provide the empirical

²³ Please note that Granger-causality testing of the bivariate relationship between the countries' uncertainty and inflation series are available upon request.

²⁴ See, in particular, Frankel (1980), Sargent (1982), and Webb (1986).

²⁵ Our macroeconomic series are constructed from various relevant historical references; see the Appendix for details.

²⁶ See the discussion of this ordering in Leduc and Liu (2015).

regularities that substantiate theoretical models of the economy and are therefore a natural empirical objective.

However, inference drawn from VARs is highly dependent on the chosen model specification and is not robust to model misspecification. In response to this shortcoming, Jòrda (2005) proposed computing IRFs based on local projections (LP), which are a sequence of predictive regressions of a variable of interest on a structural shock over different horizons. Using the LP approach, an IRF over the period from T to $T+j$, one would run J regressions with the same explanatory variables and a dependent variable whose time index increments from T to $T+j$. The IRF is then simply the sequence of regression coefficients on the structural shock parameter; the same logic holds for the estimated confidence bands. This technique is much more robust to possible misspecification, and does not suffer from the curse of parameter dimensionality inherent to VARs. These properties are of particular value in our study, which has limited sample size and thus requires as much estimation parsimony as possible.

The LP methodology nevertheless still requires a large number of estimated parameters and has been found to be excessively noisy under certain circumstances (Ramey, 2016). Barnichon and Brownlees (2017) propose an estimator that improves on both of these considerations by imposing the restriction that an IRF be a smooth function across the horizon of interest. This restriction, as well as the shrinkage estimation technique employed, reduces the number of estimated parameters, and provides clearer inference between variables across the horizon of interest. Again, given our limited sample of between 20 and 66 monthly observations, the smooth local projection (SLP) estimator provides overwhelming benefits in terms of parameter estimation, IRF generation, and meaningful inference. The SLP regressions we estimate are:

$$(2) \Delta\pi_{kt+j} = \alpha_k + \beta_1\Delta RV_{kt} + \beta_2\Delta RV_{kt-1} + \beta_3\Delta\pi_{kt-1} + \beta_4\Delta IP_{kt-1} + \beta_5\Delta Notes_{kt-1} + \varepsilon_{kt+j}, j \in [0, 6].$$

where Δ represents the log first difference of the series.

Figures 5 and 6 present our SLP-generated IRFs and their 95% confidence intervals for the GAPH and the non-hyperinflationary countries, respectively, for the effect of a unit (or one-standard deviation) increase in the RV uncertainty measure on the monthly inflation

rate.²⁷ The IRFs for the GAPH countries exhibit a common downward trend from above zero at the beginning of the projection horizon to below zero by the sixth month. This general pattern supports the hypothesis that an increase in uncertainty corresponds to an increase in inflation in the contemporaneous month and the month immediately following, although the effect declines to zero by the third month and either remains there or reverses in subsequent months. Importantly, the SLP-generated confidence bands show that these positive relationships are statistically significant across all four hyperinflation countries for the contemporaneous month and the first month of the projection. Thus, our empirical results support the view that increases in uncertainty lead to an immediate, if relatively short-lived, increase in inflation.

Turning to the individual GAPH countries, we observe this pattern very clearly for Germany in Panel A, where the SLP-implied responses of inflation changes to RV changes are positive for the contemporaneous and first projection months. The magnitude of these responses is summarized in Table 7. As shown in the first row of Panel A, for the contemporaneous month, the standard deviation of log changes in the monthly German RV measure is 1.21, which is equivalent to an increase of 235% in value. The model-implied response of the monthly log growth rate of inflation is 0.076, which is an increase of 0.29 standard deviations or equivalently of 7.9%. For the first month of the projection horizon, as shown in the first row of Panel B, the one-standard-deviation increase in the RV measure in month t leads to an increase in the inflation rate in month $t+1$ of 0.03 standard deviations, which corresponds to an increase of 3.3% in value.

The SLP impulse response functions for Poland, Hungary, and Austria exhibit similar patterns of positive and significant responses early in the projection horizon, declining to near-zero by about the third month. For example, the estimated contemporaneous response for Austria of 0.116 translates a one-standard-deviation move in log monthly RV growth of 1.32 (or a percentage increase of 273%) into an increase in the log monthly inflation rate of 0.16, which is an increase of 0.65 standard deviations or equivalently of 17% in value. The corresponding increases for one standard deviation moves in the log RV measures for Poland and Hungary are monthly inflation increases of about 8% 15% in value, respectively. These notable effects suggest that measured uncertainty played an important role in determining inflation and macroeconomic dynamics in these countries during the interwar period.

²⁷ Please note that the IRFs generated via the VAR and local projection methods are presented in Appendix 2.

In contrast, Figure 6 shows the more limited role that uncertainty seems to have played in the inflation dynamics of the other European countries in our sample. The first observation is that the IRFs are closer to flat or oscillating slightly near zero. In fact, with few exceptions, these estimated responses are not significantly different from zero at the 10% significance level. A second observation is the notably smaller magnitude of these estimated responses, ranging between -0.01 and +0.01 at the contemporaneous and one-month horizons. As shown in the last column of the bottom panels of Table 7, the marginal effects of an increase of one standard deviation change in a country's log RV measure on the inflation rate are quite small for the non-hyperinflation countries. The effects are under a 1% change in absolute value, with two minor exceptions. In summary, the results for the non-hyperinflation countries suggest that the role of uncertainty in the observed inflation dynamics is not significant and is in contrast to the results for the hyperinflation countries.

VI. Conclusions and Implications

The physical and political destruction wrought by the First World War traumatized Europe and had economic reverberations long after the official peace treaties were signed. Both the victors and the vanquished faced massive costs of reconstruction, uncertainty regarding political borders and tax revenues, and extended negotiations over war reparations. The many factors and developments that influenced the affected countries created an environment of heightened uncertainty that deeply affected economic expectations and outcomes.

In this paper, we extend the recent literature on measuring uncertainty and examining its quantitative effect on the macroeconomy into the interwar period. Using a new, hand-collected database of daily foreign exchange rates from this period, we create realized volatility (RV) measures of uncertainty for ten European countries, four of which – Germany, Austria, Poland, and Hungary (GAPH)– experienced hyperinflations. Relatively high degrees of uncertainty were observed earlier in our sample period, starting in mid-1919, but especially so for the GAPH countries.

We then place these RV measures into a small, reduced-form macroeconomic modeling framework, and our empirical results show that uncertainty was a key driver of the inflation dynamics for GAPH, but not for the other European countries. This result not only quantifies the narrative descriptions of the interwar hyperinflation episodes, but also provides

clearer insights into the effects of specific developments during the period. For example, while particular details of reparation negotiation affected, say, both France (as a receiver) and Germany (as a payer), the heightened degree of uncertainty in Germany meant that renegotiation surprises had a greater effect on them and likely drove expectations further into a negative spiral, as detailed in Webb (1986).

Several recent studies – such as Jurado et al. (2015) – have set about answering the question of how important time-varying uncertainty is to macroeconomic fluctuations. Our results show that even in a period of heightened uncertainty, such as the interwar period, higher relative levels of uncertainty are significant drivers of inflation dynamics in countries that subsequently experienced hyperinflation. However, lower relative levels of uncertainty in other European countries do not seem to influence their inflation dynamics. These joint conclusions align well with the finding by Danielsson et al. (2016) – that periods of unusually high and low uncertainty are more meaningful indicators of financial stability (i.e., banking crises in their work) than just the level of uncertainty itself.

Overall, our analysis suggests that the heightened uncertainty of the interwar period in Europe most affected the countries whose governmental structures were weakened by the war, which is a parallel to the work of Cole and Kehoe (1996, 2000) on self-fulfilling debt crises. Their work shows that financial crises that may threaten a country's ability to repay its debt may quickly become self-fulfilling. The parallel to fiscal policy and inflation expectations is clear, and our results suggest that higher levels of uncertainty directly contribute to these expectations. As noted by Webb (1986), Germany's continuation of government deficits during 1920 through 1922 suggests that people believed that the debt could be repaid. However, as our empirical results suggest, Germany's relatively high and increasing measure of uncertainty contributed to increasing inflation, which tipped into hyperinflation, and decreasing trust in the government's ability to repay its obligations. In contrast, France's lower and relatively more stable degree of measured uncertainty suggests that there were many fewer concerns regarding its ability to maintain its fiscal balance.

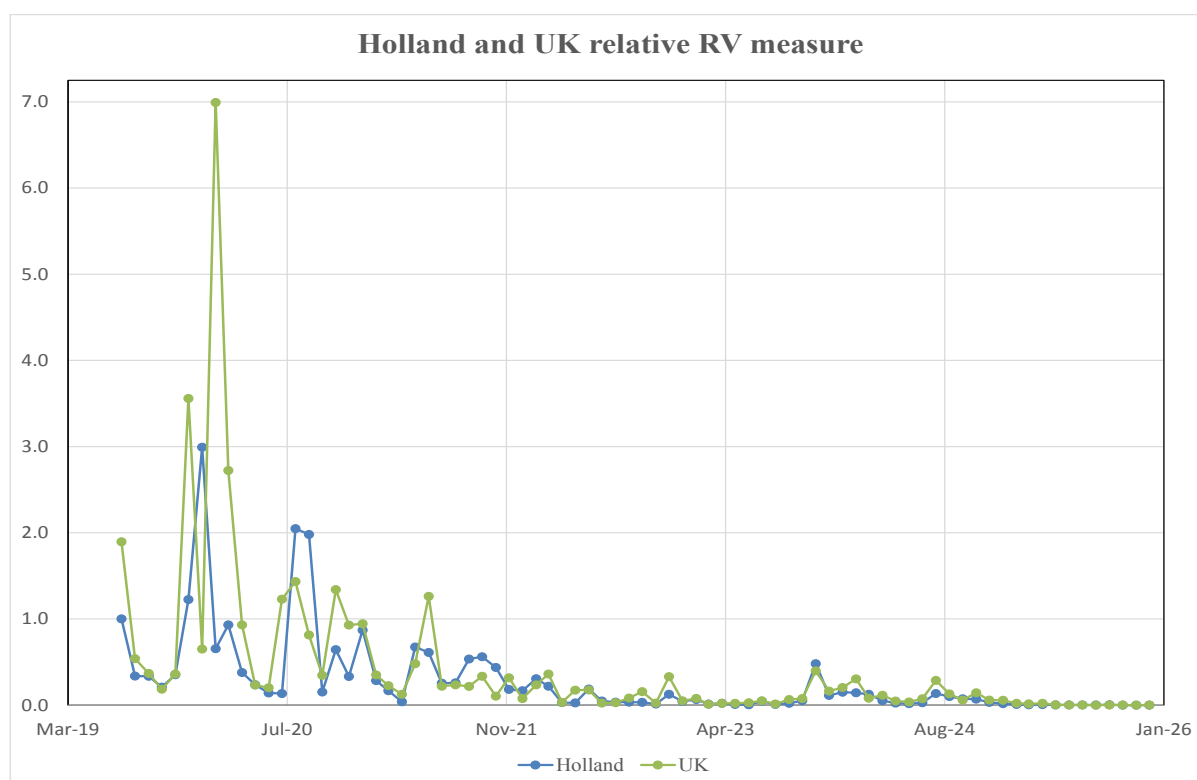
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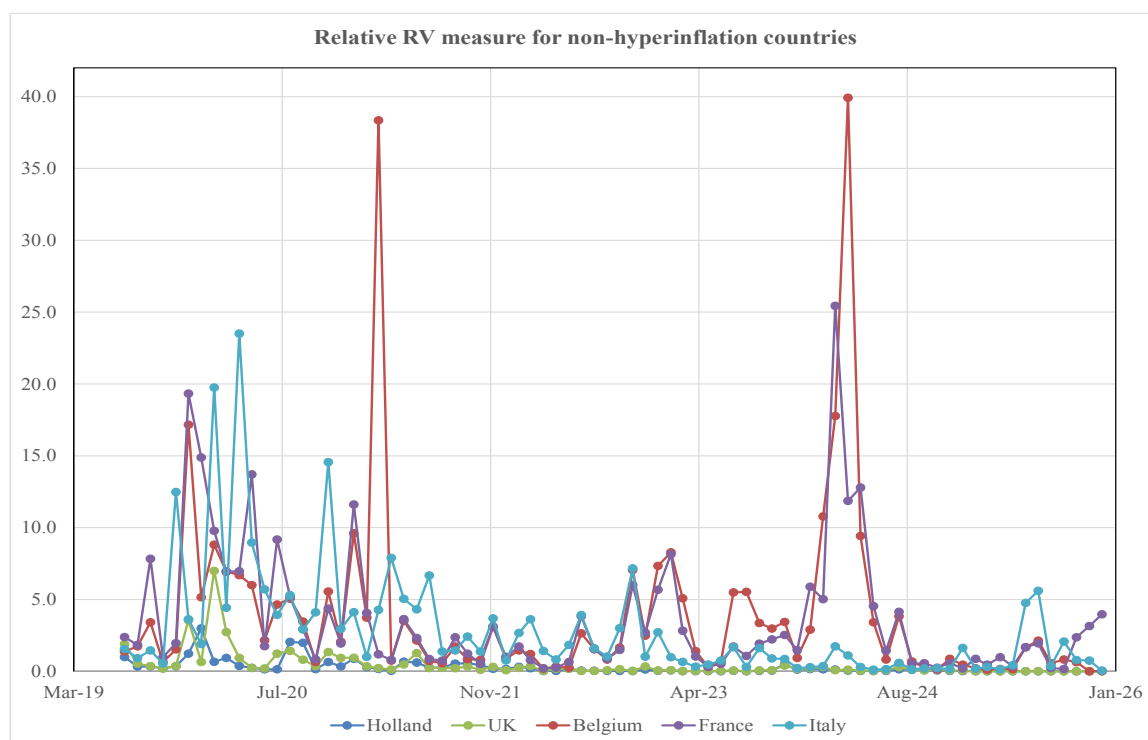
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Figure 1. Realized volatility for Holland and UK relative RV measures



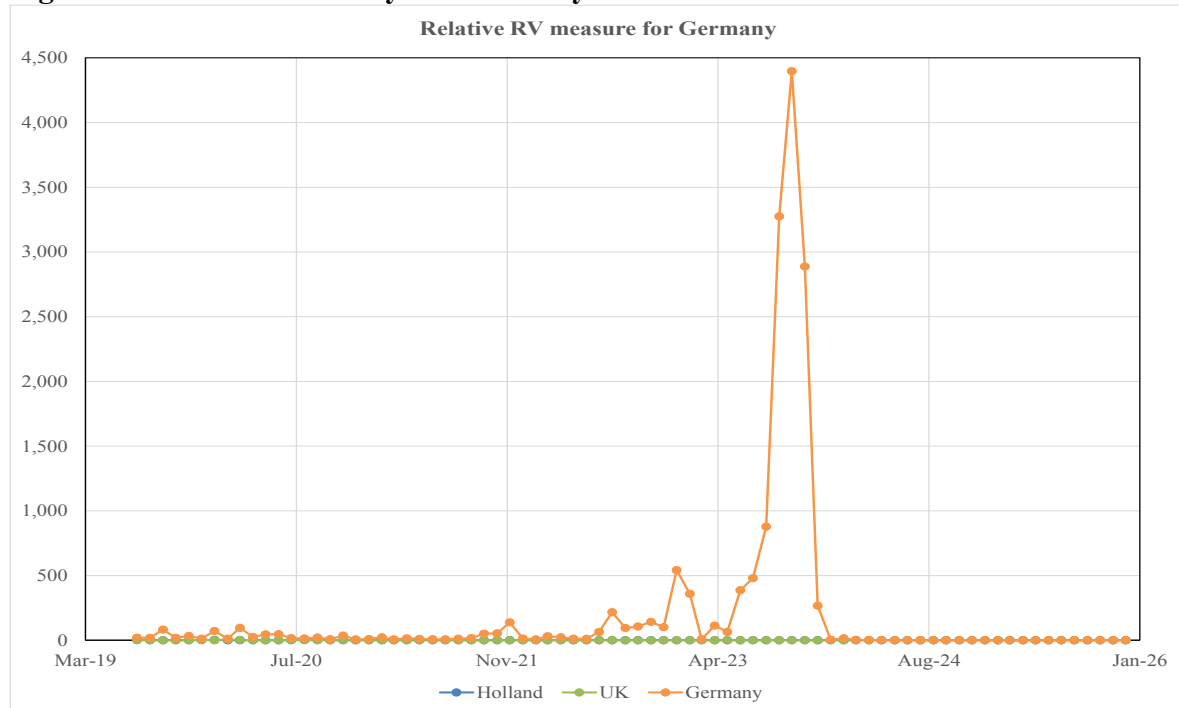
Note: Values are relative to the RV measure for Holland in July 1919.

Figure 2. Realized volatility for the non-hyperinflationary European countries



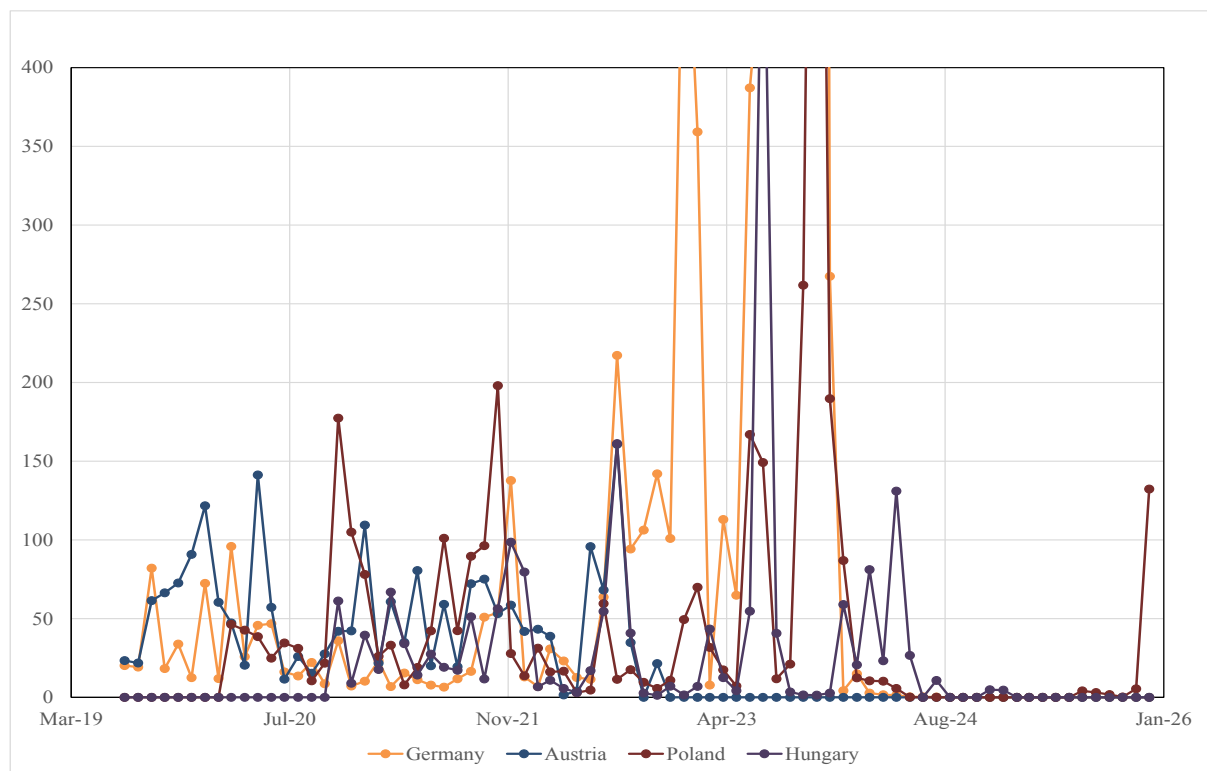
Note: Values for all countries are expressed relative to the RV measure for Holland in July 1919.

Figure 3. Realized Volatility for Germany



Note: Values for Germany are expressed relative to the RV measure for Holland in July 1919.

Figure 4. Realized Volatility for Germany, Austria, Poland, and Hungary



Note: Values for all countries are expressed relative to the RV measure for Holland in July 1919.

Figure 5. Impulse response functions of a one standard deviation change in ΔRV_{kt} on $\Delta \pi_{kt+j}$ for the GAPH countries based on the smooth local projections regression methodology

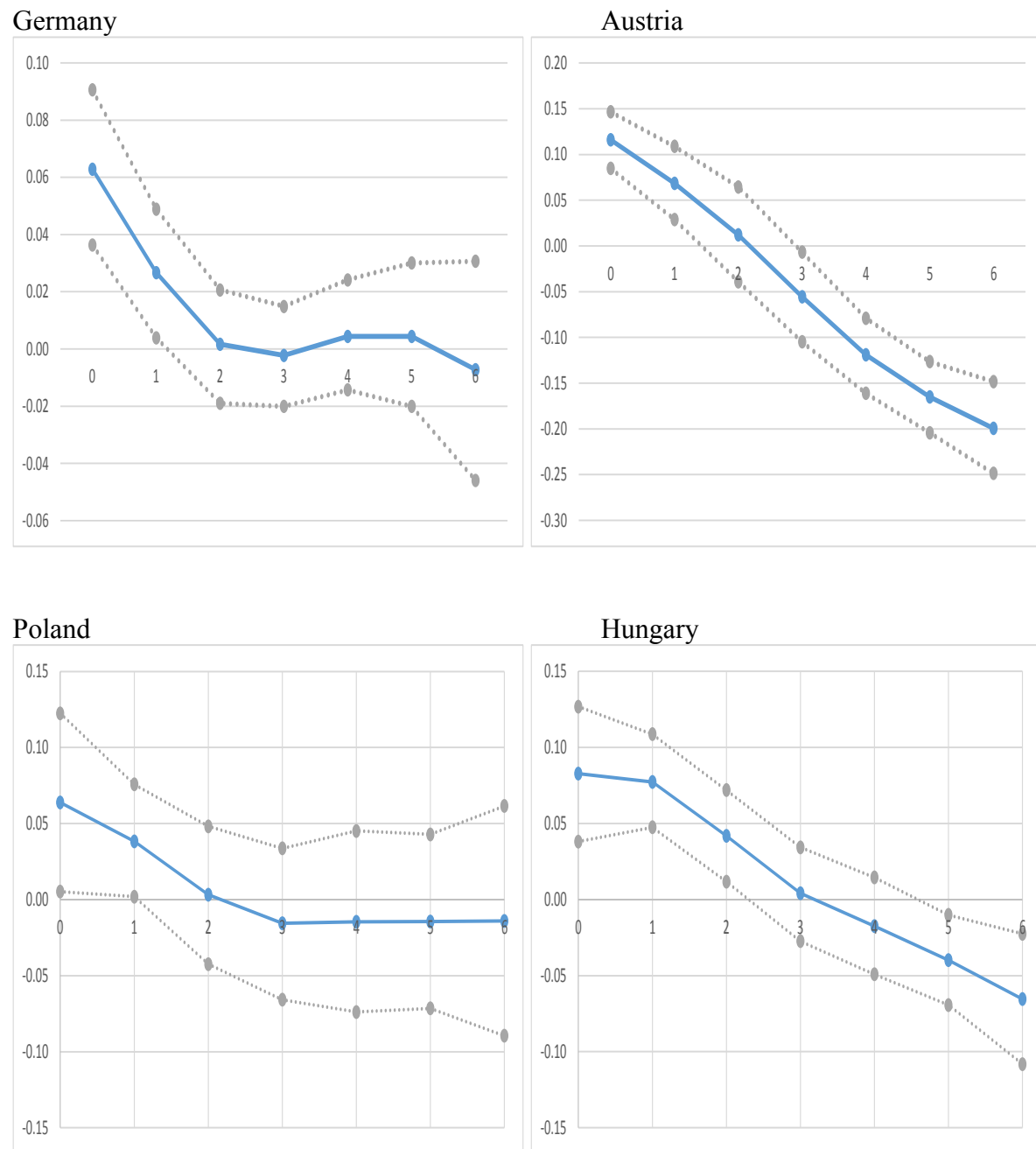
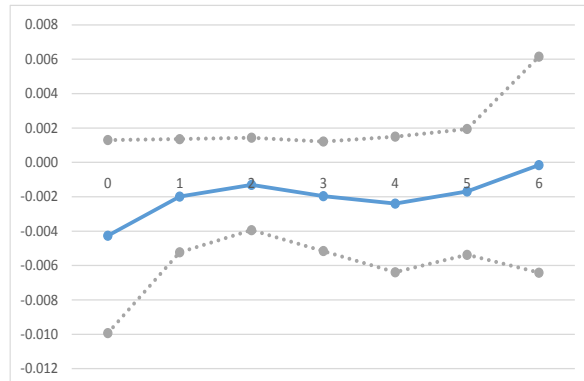
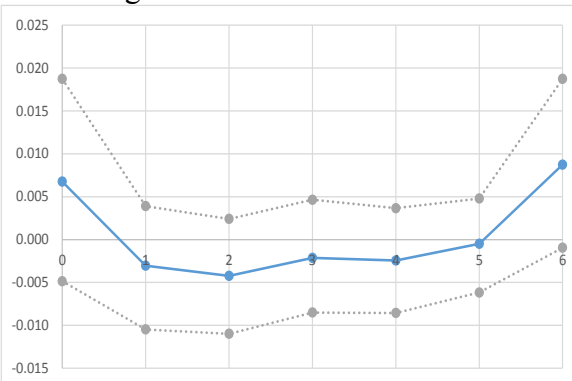


Figure 6. Impulse response functions of a one standard deviation change in ΔRV_{kt} on $\Delta \pi_{kt+j}$ for the non-hyperinflation countries based on the smooth local projections regression methodology

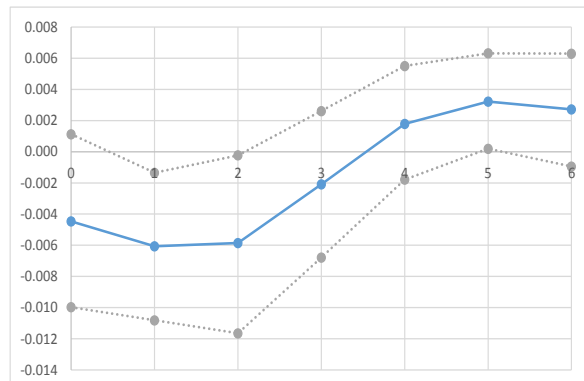
Britain



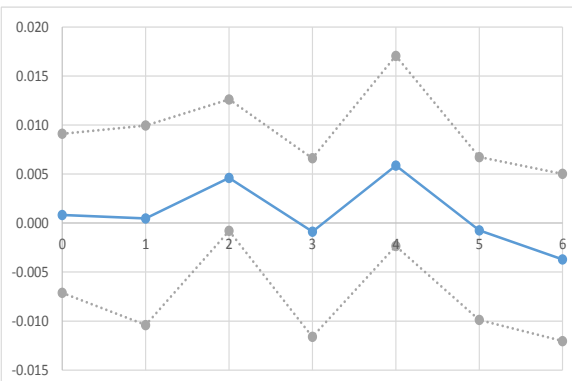
Belgium



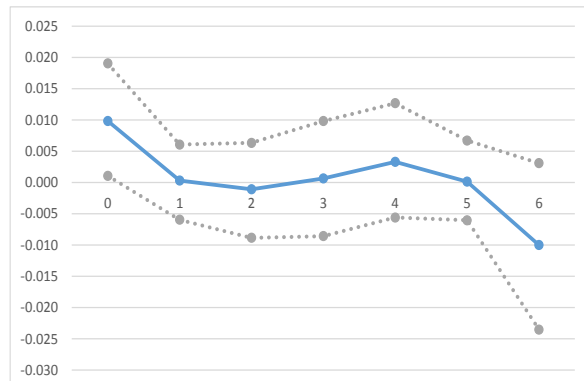
Czechoslovakia



France



Holland



Italy

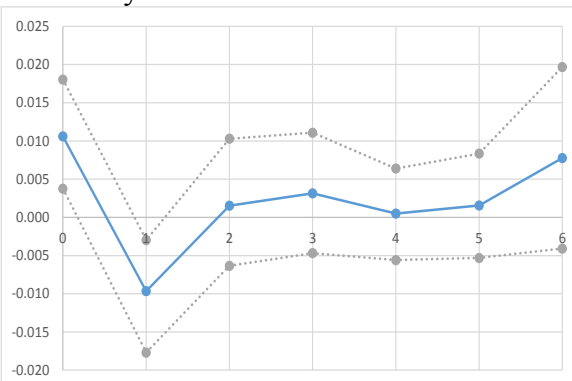


Table 1. Macroeconomic summary ratios

	Debt-to-GDP ratio		Annual inflation
	1913	1920	(1914-1918)
Austria	63.3%		13.5%
Belgium	49.5%	102.7%	25.2%
Czechoslovakia			
France	66.3%	185.5%	30.0%
Germany	42.1%		17.9%
Holland	61.6%	59.6%	33.1%
Hungary	--		53.7%
Italy	69.2%	142.3%	36.3%
UK	25.8%	130.7%	20.6%
Poland	--		66.4%

Note: The debt-to-GDP ratios are from Reinhart and Rogoff (2008). Hungary and Poland were not distinct countries in 1913. The annual inflation rates are calculated by the authors based on data from *Statistisches Handbuch der Weltwirtschaft*.

Table 2. Average annual values of uncertainty measures based on monthly foreign exchange realized volatility (RV) measures

Average annual RV (relative to Holland, July 1919)

	<u>Austria</u>	<u>Germany</u>	<u>Hungary</u>	<u>Poland</u>	<u>Belgium</u>	<u>Britian</u>	<u>Czech.</u>	<u>France</u>	<u>Holland</u>	<u>Italy</u>
1919	56.07	31.00	---	---	4.31	1.15	---	5.72	0.58	3.43
1920	51.07	33.51	35.07	53.26	4.77	1.49	29.27	6.53	0.89	8.17
1921	55.42	29.35	37.80	63.46	5.49	0.40	8.44	2.70	0.41	3.64
1922	46.41	65.54	32.53	16.65	1.71	0.14	7.86	1.76	0.10	2.40
1923	---	1,217.26	59.78	162.98	3.73	0.08	0.34	2.46	0.07	0.96
1924	---	2.35	29.77	10.50	7.57	0.13	0.29	6.08	0.08	0.45
1925	---	---	0.38	12.24	0.58	0.01	0.00	1.36	0.00	1.42

Table 3. Cost of World War I

	Gross cost (\$m)	Advances to allies (\$m)	Net cost (\$m)	Net cost per capita (\$)
Great Britain	44,029	8,695	35,334	766
Rest of British Empire	4,494		4,494	13
France	25,813	1,547	24,266	613
Russia	22,594		22,594	135
Italy	12,314		12,314	343
United States	32,080	9,455	22,625	229
Other Allies	3,964		3,964	127
<i>Total Allies</i>	145,288	19,697	125,591	
Germany	40,150	2,375	37,775	557
Austria-Hungary	20,623		20,623	352
Turkey and Bulgaria	2,245		2,245	85
<i>Total Central Powers</i>	63,018	2,375	60,643	
<i>Total</i>	208,306	22,072	186,234	

Sources: Cost data from Bogart (1920: 267); Population data from Urlanis (1971: 209).

Source: Broadberry and Harrison (2005).

Table 4. Months with the highest country RV values

Panel A. Top 20 RV values for the GAPH countries

<u>Germany</u>		
<u>Month</u>	<u>Rank</u>	
September-19	18	Constitution of August 1919 gave control over taxation to federal authorities
January-20	19	Versailles Treaty comes into force.
March-20	16	Kapp Putsch. The Ruhr Uprising by Communists.
December-21	12	Wirth requests a moratorium on payments only 6 months after making the first installment under the London Ultimatum
August-22	10	The Allied Reparations Commission unanimously decided to grant Germany a six-month moratorium on reparations payments
September-22	17	The Reichsbank in Germany was closed by police following a bank run by employers looking to meet overdue payrolls
October-22	14	Chancellor Wirth submitted a question for cabinet council discussion asking whether Germany should declare bankruptcy.
November-22	11	Wirth's complete moratorium efforts failed, and he is forced to resign on Nov. 14th
December-22	15	New German proposal of a 5 year moratorium on reparations payments
January-23	5	France occupies the Ruhr to ensure payment of war reparations in kind.
February-23	8	Striking railway workers in the Ruhr began returning to their jobs as German resistance faltered
April-23	13	Wilhelm Cuno's government was spending more than seven times the amount it received as revenue.
June-23	7	Germany asks for a new reparations conference
July-23	6	France notified Britain that it would not accept an international conference to discuss the German reparations problem.
August-23	4	Dr. Wilhelm Cuno (No party affiliation) Leaves office
September-23	2	The German government declares a state of emergency under Article 48 of the German Weimar Constitution.
October-23	1	cabinet of German Chancellor Gustav Stresemann resigned in response to the Social Democrats joining the Communists in the
November-23	3	Gustav Stresemann resigns as German Chancellor after a vote of no confidence from members of the government.
December-23	9	A new Cabinet is formed under Dr. Wilhelm Marx
<u>Austria</u>		
<u>Month</u>	<u>Rank</u>	
9/1/1919	13	The Treaty of Saint-Germain-en-Laye was signed
10/1/1919	12	The treaty was ratified by parliament
11/1/1919	9	Emperor Karl returns to Vienna. He has been asked to lead a constitutional committee
12/1/1919	6	Ferdinand Hanusch, the Minister of Labor, introduces the Eight-Hour Act in order to limit the work day
1/1/1920	3	Vienna runs out of Coal, shutting down electric tramcars
2/1/1920	15	
3/1/1920	20	Hungary formally reverts to kingdom, but with throne vacant
5/1/1920	2	200,000 person street march and protest against a proposed tax on capital occurred on May 11
6/1/1920	18	The government of State Chancellor Karl Renner ends
1/1/1921	4	Austrian government declares itself insolvent
3/1/1921	14	Reparations Commission holds conference with Austria on budget situation and financial relief
5/1/1921	7	Threat of secession crisis in May and June at several Austrian provinces
7/1/1921	16	League of Nations recommended a loan, authorized if liens removed.
9/1/1921	10	Regular Hungarian troops have reoccupied Burgenland
10/1/1921	8	Bauer introduces the Social Democratic Financial Plan, which would increase taxes and decrease government
11/1/1921	19	Finance minister announces budget with deficit 3 times larger than estimated in July
12/1/1921	17	Plebiscite to determine fate of Burgenland. Austria gets most of it
6/1/1922	5	Finance Minister Dr. Guertler is forced to retire after protest against the new customs tariff
7/1/1922	11	
8/1/1922	1	Allied Powers ask for intervention of League of Nations as Austria had exhausted all foreign borrowing possible

Poland

Month	Rank	
March-20	18	the currencies and the administration of Poland were unified
April-20	19	Poland began its main offensive, Operation Kiev.
November-20	5	Soviets sued for peace and the war ended with ceasefire
December-20	9	Belgian diplomats try to resolve the Lithuanian-Polish dispute on behalf of the League
January-21	14	Newspaper reports: Poland in desperate state for want of food and clothing
March-21		Constitution of the Republic of Poland
July-21	10	Third Polish Uprising against Upper Silesia joining the Weimar Republic
August-21	20	
September-21	12	
October-21	11	
November-21	3	League of Nations divided Silesia, with Poland receiving most of the industrial areas
July-22	16	Germany and Poland concluded bilateral treaty concerning upper Silesia
December-22		Presidential election; took 5 ballots to get Narutowicz elected; assassinated 5 days later
January-23	17	Lithuania seized the Klaipėda Region; League view as adequate compensation for losses
February-23	15	Formal transfer of the region to Lithuania
June-23	6	Sikorski is overthrown, and a new Cabinet led by Mr. Witos of the Piast (Peasant) party t
July-23	7	Witos tries to secure \$100 million loan from Hallgarten & Co. but fails
October-23	2	Witos government resigns/collapses on Sept.12
November-23	1	Decision to use foreign exchange reserve to arrest the exchange depreciation
December-23	4	Poland complies with League and turns Jaworzyna over to the Czechs.
January-24	13	Prime Minister asks to use remaining foreign currency reserves to support the currency
December-25	8	

Hungary

Date	Rank	
11/1/1920	8	National Assembly reluctantly ratified the Treaty of Trianon
1/1/1921	17	Hungary requests help for mediation of border conflict (western) with Austria
3/1/1921	7	Charles I, the former king, first coup attempt began on 26 March 1921.
4/1/1921	18	Prime Minister Teleki is forced to resign after the failed coup.
6/1/1921	19	establishes a government-run note institution with limitations on note issue and prohibitions c
9/1/1921	13	Border dispute heightens with Austria
11/1/1921	10	Charles I second coup attempt
12/1/1921	4	Plebiscite to determine fate of Burgenland. Austria gets most of it
1/1/1922	6	Prime Minister Kallay announces budget deficit nearly double what was estimated
7/1/1922	12	
8/1/1922	2	Cabinet met in an extraordinary session today to consider the Austrian problem
9/1/1922	15	Admitted to League of Nations; necessary step for obtaining loans.
3/1/1923	14	Representatives from Hungary visit the Bank of England for financial help
6/1/1923	11	Presentation to the Reparations Commission on Hungary's inability to pay
7/1/1923	1	Negotiations for loan from League of Nations in progress
8/1/1923	16	League is reviewing Hungary's financial situation.
1/1/1924	9	Hungary to ratify terms of a League loan.
3/1/1924	5	Final negotiations of League loan, including borders and reparations schedule.
5/1/1924	3	
6/1/1924	20	

Panel B. Top 5 RV values for other countries

Belgium

<u>Month</u>	<u>Rank</u>	
Dec-19	4	neutrality revoked; Belgium credit extended
Mar-21	2	sending troops to Ruhr
Feb-24	5	Feb. 29 = Cabinet resigns due to trade and exchange rate
Mar-24	3	Mar. 19 = ending budget calculations based on German reparations
Apr-24	1	April 6 = rumors of foreign loan to stabilize the currency

Britain

<u>Month</u>	<u>Rank</u>	
Jul-19	4	Negotiations with coal miners; concerns on FX rate and humanitarian aid to Europe
Dec-19	2	The Cunliffe Committee recommends an early return to an effective gold standard
Feb-20	1	
Mar-20	3	The Egyptian legislative assembly passed a resolution demanding independence
Aug-20	5	

Czechoslovakia

<u>Month</u>	<u>Rank</u>	
3/1/1920	2	Masaryk presidency
5/1/1920	4	
11/1/1920	1	Cabinet set to resign, rumored Polish invasion
5/1/1921	3	coal cut off due to fighting in Upper Silesia, Salzburg votes to join Germany
7/1/1922	5	

France

<u>Month</u>	<u>Rank</u>	
Dec-19	2	military council remains in place after Treaty lapse
Jan-20	3	French and Belgium military and economic alliance deepens
May-20	4	strike negotiations; rebuilding efforts
Mar-24	1	some form of "bear interest" trade in the franc
May-24	5	French communists to fight Dawes plan

Holland

<u>Month</u>	<u>Rank</u>	
Jul-19	5	Dutch ships being returned
Dec-19	4	objections objections regarding Entente administration of the Rhine
Jan-20	1	refuses to extradite Kaiser Wilhelm to the Allies
Aug-20	2	
Sep-20	3	

Italy

<u>Month</u>	<u>Rank</u>	
Nov-19	4	Nitti elected Prime Minister
Feb-20	2	Nitti suggests not accepting Fiume seaport in Croatia
Apr-20	1	new taxes enacted and civil service strike
May-20	5	Prime Minister Nitti resigns, but remains in government forming cabinets
Nov-20	3	Fiume independence agreed upon, but its leader still moves troops

Table 5. Model estimation samples

Country	Start date	Reason	End date	Reason	# months
Austria	1921-Jan	Monthly CPI starts	1922-Sep	Month before League of Nations loan and control	21
Germany	1920-Apr	Monthly WPI starts	1923-Jun	Month before defined hyperinflation	39
Hungary	1922-Nov	Monthly WPI starts	1924-Jun	New central bank commences operations; realized volatility near	20
Poland	1920-Sep	Monthly WPI starts	1923-Sep	Month before defined hyperinflation	37
Britain	1919-July	Monthly RV starts	1924-Dec	Monthly notes data ends	66
Belgium	1921-Jan	Monthly WPI starts	1925-Apr	Monthly notes data ends	52
Czech.	1921-Feb	Monthly WPI starts	1925-Apr	Monthly notes data ends	51
France	1919-Jul	Monthly RV starts	1924-Dec	Monthly notes data ends	66
Holland	1920-Jan	Monthly WPI starts	1925-Apr	Monthly notes data ends	64
Italy	1919-Jul	Monthly RV starts	1924-Nov	Monthly notes data ends	66

Table 6. Correlations of inflation changes with lagged changes in realized volatility

$$\rho(\Delta\pi_{kt}, \Delta RV_{kt-j})$$

Country	Lag value j						
	0	1	2	3	4	5	6
Austria	0.27*	0.11	0.23*	0.26	-0.36*	-0.22	-0.17
	0.2	0.22	0.22	0.22	0.27	0.26	0.26
Germany	0.38*	0.24*	0.01	-0.08	0.15	0.17*	0.13
	0.14	0.15	0.16	0.17	0.17	0.17	0.17
Hungary	0.25*	0.51*	0.09	-0.16	0.04	-0.21	-0.27
	0.21	0.17	0.23	0.25	0.25	0.27	0.29
Poland	0.06	0.25*	0.09	-0.07	-0.08	-0.20*	0
	0.16	0.16	0.17	0.17	0.18	0.18	0.18
Britain	-0.06	0.03	0.06	-0.04	-0.08	-0.03	0.02
	0.12	0.13	0.13	0.13	0.13	0.13	0.13
Belgium	0.20*	-0.23*	-0.05	0.11	-0.03	-0.18*	0.22*
	0.13	0.15	0.14	0.14	0.14	0.15	0.14
Czech.	-0.01	-0.09	-0.27*	-0.02	0.07	0.07	0.04
	0.14	0.14	0.15	0.14	0.15	0.15	0.15
France	0.07	0.01	0.13	-0.06	0.15*	-0.02	-0.08
	0.12	0.12	0.12	0.13	0.13	0.13	0.13
Holland	0.23*	-0.22*	0.21*	-0.25*	0.21*	0.07	-0.22*
	0.12	0.13	0.12	0.14	0.12	0.13	0.14
Italy	0.23*	-0.31*	0.18*	-0.09	-0.01	0.03	0.13
	0.12	0.14	0.12	0.13	0.13	0.13	0.13

Note: The asterisk denotes statistical significance at the 10% level.

Table 7. SLP sensitivity results**Panel A. Contemporaneous month (i.e., $j = 0$)**

Country	RV std.dev	RV increase	Contemporaneous effect		Inflation increase	
	(ln delta)	(%)	Coefficient	Effect (ln delta)	# inflation std	(%)
Germany	1.21	235.4	0.063	0.076	0.29	7.9
Austria	1.32	272.7	0.116	0.158	0.68	17.1
Hungary	1.72	455.8	0.080	0.142	0.78	15.3
Poland	1.21	235.4	0.064	0.077	0.37	8.0
Britain	1.17	223.4	-0.004	-0.005	-0.16	-0.5
Belgium	1.25	248.6	0.007	0.008	0.13	0.9
Czech.	1.88	556.5	-0.004	-0.008	-0.21	-0.8
France	1.07	190.8	0.001	0.001	0.02	0.0
Holland	1.15	214.7	0.010	0.011	0.12	1.1
Italy	1.01	174.6	0.011	0.011	0.17	1.1

Panel B. One-month into the projection horizon (i.e., $j = 1$)

Country	RV std.dev (ln delta)	RV increase (%)	One-month effect			Inflation increase (%)
			Coefficient	Effect (ln delta)	# inflation std	
Germany	1.21	235.4	0.027	0.008	0.03	3.3
Austria	1.32	272.7	0.068	0.090	0.39	9.7
Hungary	1.72	455.8	0.077	0.142	0.78	15.3
Poland	1.21	235.4	0.038	0.046	0.22	4.7
Britain	1.17	223.4	-0.002	-0.002	0.00	0.0
Belgium	1.25	248.6	-0.003	-0.004	-0.06	-0.4
Czech.	1.88	556.5	-0.006	-0.011	-0.29	-1.1
France	1.07	190.8	0.000	0.000	0.01	0.0
Holland	1.15	214.7	0.000	0.000	0.00	0.0
Italy	1.01	174.6	-0.010	-0.010	-0.16	-1.0