Online Appendix 3 to "The Borchardt hypothesis: a cliometric reassessment of Germany's debt and crisis during 1930-32"

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Abstract

Online Appendix 3 reports the calibration of parameters. It also demonstrates the model features by reporting the responses of selected variables to a negative export demand shock.

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Online Appendix 3

Model features

Figure $A1$ demonstrates the model features by plotting how selected variables respond to a negative export demand shock.[1] The left panel of Figure $A1$ plots the responses of output, labor, CPI index, and consumption, contrasting the case of a fixed exchange rate with a flexible exchange rate.[2] Figure $A1$ shows that output, labor, and consumption are quickly stabilized under a flexible exchange rate, while under a fixed exchange rate the impacts on output, labor, and consumption are larger and it takes a longer time to return to the steady state. The market clearing condition implies that without exchange rate flexibility as a buffer that absorbs part of the shock, output must fall concurrently with the fall in export demand, thereby dramatically reducing demand for labor and capital inputs. As a result, a fixed exchange rate leads to a far sharper decline in output, labor, and capital on impact than under a flexible exchange rate. The figure is consistent with the conventional argument that when facing a negative external shock, a flexible exchange rate performs better than a fixed exchange rate regime.

The right panel of Figure $A1$ plots the response of real exchange rate, capital, net worth, and risk premium. Here, several differences in the transmission mechanism between fixed and flexible exchange rates stand out. First, the need to restore equilibrium make the real exchange rate depreciate under both fixed and flexible exchange rates, but the amount is larger under a flexible exchange rate. Since the exchange rate is fixed, the real exchange rate adjustment under a fixed exchange rate is achieved by internal deflation (decline in producer price), as somewhat exemplified by the much larger decline in the CPI index. This adjustment is slow due to producer price rigidity. In contrast, the adjustment in the real exchange rate under a flexible exchange rate is facilitated by depreciation of the nominal exchange rate. With a constant producer price (by construction) and an increase in the price of imported goods due to currency depreciation, the CPI index under a flexible exchange rate actually increases.

[1] The parameter values on which Figure $A1$ is based are given in Table $A2$ of the paper.
[2] All the variables are expressed log-deviation from their steady states.

Second, net worth increases under a fixed exchange rate, while it decreases under a flexible exchange rate. This is because entrepreneurs' net worth is the sum of firm profits and rent on capital (both in domestic currency), minus the foreign debt repayment (in foreign currency). There are thus two counteracting forces that determine the net worth as noted below.

(a) Real depreciation increases the real burden of the existing foreign debt repayment and therefore reduces the net worth, or the so-called balance sheet effects. Following a negative export demand shock, the real exchange rate depreciates under both fixed and flexible exchange rates. However, real exchange rate depreciation is much larger under a flexible than under a fixed exchange rate, making the net worth to decline much larger under a flexible than under a fixed exchange rate.

(b) The entrepreneur receives firms' profits plus rent on capital, which is equal to output minus wage expenditures. A decline in wage expenditures (real wages multiplied by labor employment) increases entrepreneur net worth. Under a flexible exchange rate, the decline in wage expenditures is roughly balanced by the decline in output. However, under a fixed exchange rate, due to the dramatic fall in real wages and labor input on impact, the decline in wage expenditures is even larger than the decline in output, making the net worth increase.

For a fixed exchange rate, the increase in net worth due to factor (b) is larger than the decrease in net worth due to factor (a), and hence net worth rises. Due to the decline in foreign borrowing and a falling risk premium, net worth continues to increase in the subsequent periods. For a flexible exchange rate, factor (a) dominates factor (b), and net worth falls. If we assume that firms' profits are not accrued to the entrepreneur, then net worth would decline under both fixed and flexible exchange rates. However, the baseline that the decline in net worth is larger under a flexible than under a fixed exchange rate remains unchanged.

The third difference is that under a fixed exchange rate, capital rebounds much faster than under a flexible exchange rate. To explain the rapid recovery of capital under a fixed exchange rate, note that net worth increases under a fixed exchange rates. The increase in net worth reduces the risk premium and hence the cost of capital, thereby raising the demand for capital input. As the balance sheet effects become stronger, this model feature can eventually reverse the relative performance of fixed and flexible exchange rates.

Calibration of parameters

Table $A2$ reports the values assigned to the models' parameters, most of which we calibrate using data on Germany's interwar years. The choice of parameter values otherwise follows Céspedes, Chang, and Velasco (2003, 2004, 2005), whose values are calibrated to emerging markets. We take this approach, because Germany's situation in the 1920s (as a capital importer that incurred high levels of foreign debt) is argued to have been similar to emerging markets that suffer from the "original sin" problem (Eichengreen and Hausmann 2005).[3] Robustness checks of parameter values will be made in Online Appendix 4, especially for parameters calibrated by limited data and for parameters that are crucial for our results.[4]

[INSERT **Table** $A2$ about Here]

The capital share α in the production of domestic goods is taken from the historical capital shares database constructed by Bengtsson and Waldenström's (2018). We use the average capital share in GDP for Germany in 1925-29, which is equal to 0.36. We set the steady-state world real interest rate ρ to 4 percent. The country risk premium's

[3] Original sin refers to the inability of a country to borrow abroad in its own currency. As mentioned above, only about 5.3 percent of total German foreign debt was denominated in Germany's domestic currency as of 1931. For developing countries in the 1990s, on average only about 4 percent to 7 percent of the international securities (adjusted for hedging currency exposures through swaps) they issued were in domestic currencies (Hausmann and Panizza 2003, Table 1).

[4] The German foreign debt consisted of both public and private debt. In terms of flow, corporate (private) borrowing between 1925 and 1929 accounted for 78 percent of all the capital flows Germany received; in 1930, government (public) loans constituted nearly 80 percent of total borrowing (Ho and Yeh 2019). In terms of stock, calculations based on data provided by Papadia and Schioppa (2020) show that the share of private (respectively public) debt among total foreign debt was about 42 percent (respectively 58 percent) for the year 1931. Even though the model stipulates that balance sheet effects stem from the private sector, the same effects exist also with respect to the public sector; the reason is that both sectors respond similarly to a deteriorating balance sheet: the real debt burden both of corporations and of government increases, reducing their access to credit and raising the risk premium that they must pay to secure credit.

sensitivity μ to the ratio of foreign debt to net worth indicates the extent of capital market imperfections; empirical data are used to estimate the parameter μ. In the model, the risk premium is increasing in the ratio of foreign debt to net worth:

$$1+\eta_{t+1} = \left(\frac{Q_t I_t}{P_t N_t}\right)^{\mu} = \left(1+\frac{S_t D_{t+1}}{P_t N_t}\right)^{\mu}, \tag{1}$$

where η_{t+1} denotes the risk premium, I_t is capital whose price is Q_t, $P_t N_t$ is entrepreneurs' net worth in nominal terms, S_t is the nominal exchange rate, and D_{t+1} is the amount of debt borrowed abroad.

We compute the risk premium as the difference between the German and U.S. long-term interest rates, whose values are taken from the Jordà–Schularick–Taylor (2017) Macrofinancial History database. For $S_t D_{t+1}$, we use the amount of commercial debt, taken from Papadia and Schioppa (2020); and the net worth of German firms, $P_t N_t$, is approximated by the aggregate market value of firms listed on the Berlin Stock Exchange (per Statistisches Reichsamt 1939).[5] The values of μ so obtained for the years 1928, 1929, and 1930 are (respectively) 0.0325, 0.0334, and 0.0268.[6] We therefore set $\mu = 0.03$.

Our calibration for the elasticity χ of world demand for domestic goods follows Madsen (2001), who uses panel data from 17 countries over the period 1922–1939 and obtains a value of 0.37 for the short-run price elasticity of exports.[7] That value is smaller than the one reported by Artus and Knight (1984), who take data from 12 industrial countries for the period 1963–1982 and obtain an average price elasticity for the foreign demand for exports of about 0.65.[8] The discount rate β is set at 0.99, which corresponds to an annualized equilibrium real interest rate of 4 percent.

[5] In calibrating μ, we include only commercial (private) debt in the numerator in order to make the numerator (debt) and the denominator (net worth) have the same coverage. Our method does not eliminate all mismatches between the numerator and the denominator, but is the best that we can do under the current data constraint.

[6] Parameter μ is computed as $\mu = \ln\left(1+\eta_{t+1}\right)/\ln\left(1+S_t D_{t+1}/P_t N_t\right)$.

[7] The 17 countries are Australia, Belgium, Canada, Denmark, Finland, France, Germany, Ireland, Italy, Japan, the Netherlands, New Zealand, Norway, Sweden, Switzerland, the United Kingdom, and the United States. To the best of our knowledge, elasticities estimated from data on the interwar period are rare. Horner (1952) reports both UK and U.S. demand elasticities in the case of wool as well as U.S. demand elasticity for both wheat and butter. These estimates range from 0.24 to 0.54.

[8] The 12 countries are Austria, Belgium, Canada, Denmark, France, Italy, Japan, the Netherlands, Norway, Sweden, Switzerland, and the United States.

Parameter γ is the proportion of consumption spent on domestic goods. A proportion of $(1-\gamma)$ is spent on foreign goods. We use one minus the ratio of imports to consumption to approximate γ, employing the data provided by Ritschl and Spoerer (1997). The value of γ thus obtained is 0.73 for the period 1930-1932, which is greater than the value of 0.60 adopted by Céspedes, Chang, and Velasco (2003, 2004, 2005).

Ritschl (2003) finds that the estimated money demand function for interwar Germany exhibits what he refers to as pathological behavior. The estimated coefficients are either too low or have the wrong sign. Post–World War II estimates of the elasticity of money demand for Germany range from 0.94 (Beyer 1998) to 1.3847 (Bahmani-Oskooee and Bohl 2000). We set the elasticity, ε^{-1}, to 1.5735, which is Ritschl's (2003) estimate for Germany from 1925 to 1929, even though that estimate is statistically insignificant. The value we adopt is in line with the estimate given by Daniele, Foresti and Napolitano (2017) for Italy from 1861 to 2011.[9] Both the elasticity of substitution among different labor types, σ, and the elasticity of labor supply, υ, are set at 2. Both values are standard calibrations.

We explore the literature to find plausible wage and price rigidity parameters for Germany in 1930. As far as we know, there is no study that gives an estimate of the degree of price rigidity, θ_p, for the interwar period.[10] For the pre-1914 period, Eggertsson (2008) adopts a value of 0.67 for the United States. Using Bayesian estimation, Fagan, Lothian, and McNelis (2013) report a value of 0.616 for the United States, and Chen and Ward (2019) obtain values of 0.53, 0.50, and 0.41 for (respectively) the United Kingdom, Sweden, and Belgium.

Several studies offer Bayesian estimates for Germany's price rigidity in the more recent period, and the values obtained are similar: 0.67 (Kollmann et al. 2015), 0.65 (Hristov 2016), and 0.6206 (Drygalla, Holtemöller, and Kiesel 2020). These values are close to the

[9] Daniele, Foresti, and Napolitano (2017) find that the income elasticities of money demand for M1 and M2 are 1.4744 and 1.4494, respectively.

[10] Payne and Uren (2014) choose an annual value of 0.25 for interwar Australia; however, their calibration of that parameter is based on works by Nakamura and Steinsson (2008) and Carvalho and Dam (2010), who are concerned with more recent price rigidity.

U.S. price rigidity parameter and are much smaller than that for the eurozone.[11]

The aforementioned studies indicate that price levels were more flexible prior to 1914 than today. As a proxy for the interwar period, we use the average of (a) price rigidity from estimates for the pre-1914 period and (b) estimates made in modern times. Thus, we have $\theta_p = 0.6076$, which implies that prices of domestic goods are adjusted (on average) every 2.55 quarters.[12]

It is more difficult to set the degree of nominal wage rigidity, θ_w, for interwar Germany. We are not aware of any estimate for pre-1914 or interwar wage rigidity. Estimates for modern-day Germany range from 0.3 to 0.5 and are smaller than estimates of price rigidity.[13] However, these estimates are inadequate for interwar Germany, because—according to research on the Great Depression—nominal wage rigidity rendered real wages countercyclical and was a major channel through which monetary contraction affected the real economy (O'Brien 1989; Rose 2010).

Eichengreen and Hatton (1988) find that the ratio of Germany's nominal hourly earnings to the cost-of-living index remained fairly stable throughout 1929–1938, which suggests that wages and prices might have had comparable degrees of rigidity. In their econometric study of Germany's interwar unemployment, Dimsdale, Horsewood, and van Riel (2006) offer strong evidence of nominal wage inertia. A price decline had a positive effect on the real wage and thus contributed to a rising real wage. This dynamic implies a higher degree of rigidity in money wages than in prices, whereby the former respond with a lag to changes in the latter. The bottom line is that, for interwar Germany, nominal wages were at least as rigid as prices. Hence, we set the degree of wage rigidity θ_w equal to 0.75, which is greater than the degree of price rigidity and close to the estimates of today's wage rigidity in the United States and the eurozone.[14] Note that setting $\theta_w > \theta_p$

[11] For the United States, Del Negro et al. (2017) use estimates from Nakamura and Steinsson (2008) to select a value of 0.75. Smets and Wouters (2007) apply Bayesian estimation and obtain a value of 0.65. For the eurozone, Smets and Wouters (2003) obtain a value of 0.908, whereas De Walque and Wouters (2008) get a value of 0.930. Both studies employ Bayesian estimation.

[12] We exclude Belgium from this calculation owing to the relatively small size of its economy.

[13] Estimates of the degree of wage rigidity given by Kollmann et al. (2015), Hristov (2016), and Drygalla, Holtemöller, and Kiesel (2020) are 0.5, 0.49, and 0.3204, respectively.

[14] The values for wage rigidity that scholars have employed for the United States and the eurozone are 0.73 (Smets and Wouters 2007, for the U.S.), 0.75 (Del Negro et al. 2017, for the U.S.), and 0.737 (Smets and Wouters 2003, for the eurozone).

gives more weight to the wage deflation channel. Exchange rate depreciation, which boosts domestic inflation, benefits the economy more in the presence of wage deflation.

In this model, firms' profits are distributed to investors. In order to obtain a non-trivial solution under which the steady-state country risk premium is positive, the entrepreneurs' savings rate δ cannot be too large and the elasticity of substitution between domestic goods, ϑ, cannot be too small. The values of δ and ϑ together determine the steady-state ratio of foreign debt to net worth, $\frac{SD}{PN} \equiv \psi$. To calibrate δ and ϑ, we first estimate the value of ψ based on the empirical data and then choose values of δ and ϑ that jointly produce that value of ψ.

To get some idea of the steady-state ratio of foreign debt to German firms' net worth on the eve of the Great Depression, we use data on foreign commercial debt from Papadia and Schioppa (2020) and, as a measure of the net worth of German firms, the market value of firms listed on the Berlin Stock Exchange.[15] The value of ψ is 3.3 in 1930, the year prior to Brüning's deflationary policy decisions; it increases to 6.0 in mid-1931 owing to the precipitous fall in the market value of listed firms. We take the maximum of these two values, deliberately using a value that is unfavorable to the flexible exchange rates, and set $\psi = 6.0$.[16]

We fix the value of δ at 0.80. To achieve a steady-state ratio ψ of foreign debt to net worth that equals 6.0, as previously calibrated, we set the value of ϑ to 148. Finally, the steady-state country risk premium is equal to 6.0 percent.

[15] Aggregate market capitalization is taken from *Statistisches Jahrbuch für das Deutsche Reich* and is available for the period 1926–1939.

[16] Interwar Germany's ratio of foreign debt to net worth was higher than the corresponding ratios of South Korea and Thailand during the 1997 Asian financial crisis, which were (respectively) 3.9 and 4.8. Germany's situation in the early 1930s was similar to Argentina's during the latter's 2001–2002 crisis; Argentina's ratio of foreign debt to net worth increased from an already high level of 4.6 in 2001 to 9.0 in 2002.

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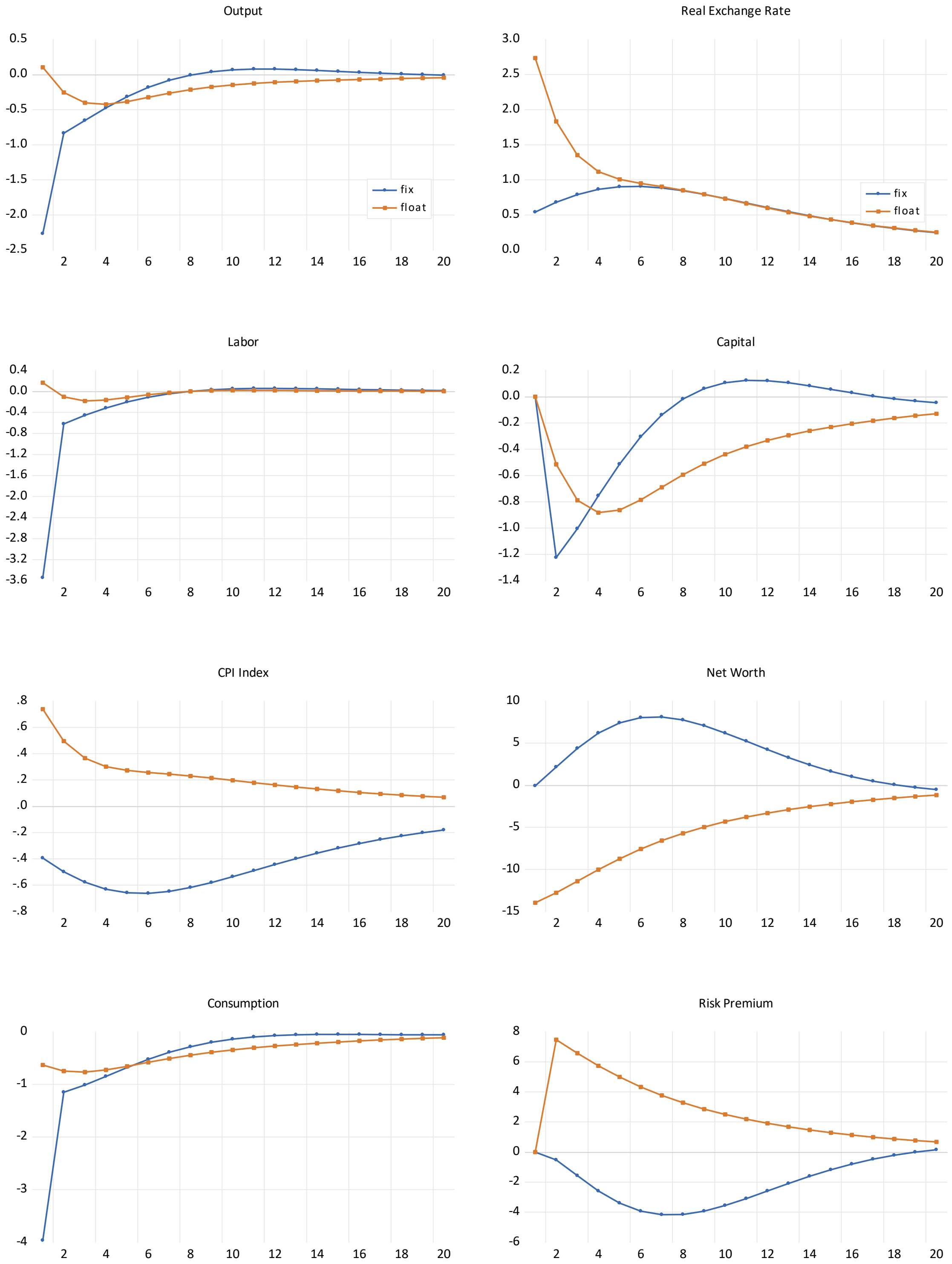
Figure A1: Impulse Response to a Negative Export Demand Shock



Sources: Authors’ calculation.

Note: We assume that the shock to the world interest rate and also to world demand for domestic goods are characterized by a first-order autoregressive process with coefficient equal to 0.9. The x-axis denotes time period and the y-axis denotes log-deviation from the steady state (in decimal).

Table A2. Calibrated Parameter Values

Parameter	Meaning	Range	Value	Method of calibration
δ	Entrepreneurs' savings rate	$0 < \delta < 1$	0.80	The entrepreneurs' savings rate and the elasticity of substitution between domestic goods together determine the steady-state ratio of foreign debt to net worth. We fix the value of the entrepreneurs' savings rate at 0.8.
ϑ	Elasticity of substitution between domestic goods	$1 < \vartheta$	148	We calibrate the parameter value so that (a) the steady-state ratio of foreign debt to net worth is equal to 6.0 and (b) the steady-state country risk premium is equal to 6.0 percent.
α	Capital share in the production of domestic goods	$0 < \alpha < 1$	0.36	According to the estimate of Bengtsson and Waldenström (2018).
ρ	Equilibrium world real interest rate	$0 < \rho$	0.04	The steady-state world real interest rate is set to 4 percent.
μ	Sensitivity of the country risk premium	$0 < \mu$	0.03	Estimated from empirical data by using the relationship between the country risk premium and the ratio of foreign debt to net worth for the years 1928, 1929, and 1930; we take the average value.
χ	Elasticity of world demand for domestic goods	$0 < \chi$	0.37	The calibration follows Madsen (2001).
β	Discount rate	$0 < \beta < 1$	0.99	Assuming that the annualized equilibrium real interest rate is 4 percent.
γ	Share of domestic goods in the production of consumption	$0 < \gamma < 1$	0.73	Approximated by one minus the ratio of imports to consumption for the period 1930-1932 by using the data provided by Ritschl and Spoerer (1997).

ε	Inverse of the elasticity of money demand	$0 < \varepsilon < 1$	1/1.5735	The calibration follows the estimates of Ritschl (2003) for Germany from 1925 to 1929 and of Daniele, Foresti, and Napolitano (2017) for Italy from 1861 to 2011.
σ	Elasticity of substitution for labor	$1 < \sigma$	2	The calibration follows Céspedes, Chang, and Velasco (2003, 2004, 2005).
υ	Elasticity of labor supply	$1 < \upsilon$	2	The calibration follows Céspedes, Chang, and Velasco (2003, 2004, 2005).
θ_p	Degree of price rigidity	$0 < \theta_p < 1$	0.6076	We use the average value of the estimates of price rigidity for the pre-1914 period and for the modern period as a proxy for interwar price rigidity.
θ_w	Degree of wage rigidity	$0 < \theta_w < 1$	0.75	The literature shows that, for interwar Germany, the nominal wage was at least as rigid as nominal prices. Hence, we set this parameter's value to be larger than the degree of price rigidity and to be close to estimates of wage rigidity for the modern-day United States and eurozone.
κ	Degree of the central bank's accommodation to the private sector's inflation expectations	$0 < \kappa$	0.5	Estimated using the German wholesale price index and the dollar/mark exchange rate from 1914 to 1922 provided by Holtfrerich (1986).
φ	Proportion of output loss after defaulting on sovereign debt	$0 < \varphi$	0.055	The value is from Borensztein and Panizza (2009), who run a standard growth regression by using panel data for 83 countries from 1972 to 2000 and find a default causes the level of output to drop forever by 5.5 percent, assuming that the long-run growth rate is 1.5 percent.

Sources: Authors' calculation.