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Wars as Large Depreciation Shocks*

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Abstract

In this paper, we propose a theoretical framework to investigate the impact of conflicts and wars on key macroeconomic aggregates and welfare. Using a panel data with 12 countries from 1875 onwards we first show that consumption drops more than output during conflicts, while the opposite is true during "peaceful" recessions. To handle both cases, we build a variation of a Real Business Cycle model first proposed by Hercowitz and Sampson [1991]. We extend the initial model to account for specific shocks that destroy capital stocks – as conflicts do– by assuming an (exogenously) time–varying depreciation rate of the stock of capital. In addition to these shocks, the model also imbeds generalized TFP shocks capturing standard technological factors as well as the potential effects of human losses on production. The model is able to reproduce the different responses of macroeconomic aggregate to productivity shocks during peaceful periods as well as their responses during conflicts. We describe how these two sources of randomness in the model may be extracted from the available data, and analyze how they interact. We conclude that conflicts have significant and persistent influence on generalized TFP shocks, while the "reverse" effect is not statistically significant. Finally, we show that the welfare costs of conflicts such as World War II are substantially larger than the welfare costs of business cycles usually reported in the literature.

Keywords: War, military conflicts, depreciation shocks, real business cycle model, random coefficient autoregressive model.

JEL Class.: E13, E32, H56.

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1 Introduction

Wars and conflicts destroy both human and physical capital, with dramatic consequences on the economy. Yet this simple assessment received little attention in the literature on war economics. This paper is an attempt to model wars and conflicts in their destructive dimension, so as to analyze their effects on key macroeconomic aggregates and welfare.

Using post–war data for developed countries has become customary in the current macro-econometric literature. At first sight, one reason may be that the relevance of the neoclassical framework during war episodes is questionable. First, wars may induce very large shocks in the economy. This is at odd with the usual practice that considers small perturbations around a deterministic steady state and uses linear approximations of equilibrium conditions to characterize models dynamics. Second, the modern macro-econometric literature typically treats government spending as unanticipated "shocks" while central policies may account for more than half of the GDP during major conflicts.

Despite this difficulties, several recent empirical works have emphasized the importance of a careful look at military and conflict data in macroeconomics. McGrattan and Ohanian [2008] show that properly written Real Business Cycle (RBC hereafter) models are able to capture many economic phenomena of World War II (WWII hereafter). One of the reason may be the following: even during war episodes the very basic needs – consumption – and means of production – capital and labor – remain and RBC models precisely rely on these basic means and needs. Ramey [2008] emphasizes that much of the variability of the shocks in public expenditure is explained by military expenditures because other sources of public expenditures (education, health, ...) are much more stable over time. Hence, once trends are removed, unexpected shocks in public expenditures are mainly military. Moreover, the "narrative approach" (Ramey and Shapiro [1997]) highlights the role of wars/peace episodes in the identification of unexpected fiscal shocks. Ramey [2008] argues that the distinction between military and civilian public expenditures induces major differences in the analysis of private responses to unexpected central policy shocks.

In addition, much empirical effort has been devoted to precise accounting of the costs of war.

As one can expect, there is a considerable disagreement among authors (see Arias and Ardila [2003] for a discussion). Most empirical contributions show that net effects of wars (including destructions and potential positive effects induced by larger public expenditures) are negative. For instance, Collier [1999] argues that a civil war might cause a 2.2 percentage point loss in the annual growth rate. A welfare analysis conducted by Hess [2003] obtains an average cost of conflicts equal to 102.3 USD per person and shows that agents would be willing to give up about 7% of permanent consumption to live in a peaceful world. Bilmes and Stiglitz [2008] count the cost of Iraq war in trillions of dollars highlighting that globalization and technical progress make wars more costly. The massive role played by engineering and logistics problems has also been made clear for WWII while specialists of WWI put forth the major impact of human losses.

Adopting an alternative perspective, Martin, Mayer and Thoenig [2008b] identify the impact of international trade on the occurrence of armed conflicts. Using an extensive data set on bilateral trade and armed conflicts, they show that increasing bilateral trade flows (through bilateral trade agreements for example) significantly reduces the probability of armed conflict with the corresponding trade partner without increasing the probability of conflicts with other trade partners. In this sense, trade openness could be seen as a peace–promoting technology. However, they show that multilateral trade openness reduces the bilateral trade dependence, and thus the cost of bilateral armed conflicts, which increases the probability of war. This mixed evidence shows that trade openness and armed conflicts are closely related in the data but that both the sign and the magnitude of the relationship depend on the specific characteristics of trade flows and agreements. To sum up, data show that major conflicts reduce international trade flows, and are therefore a possible source of economic downturns.

Finally, in two recent contributions Barro, Nakamura, Steinsson and Ursùa [2011] and Barro and Ursùa [2011] made clear that modern wars (especially WWII) have disastrous consequences on civilian economics both for "winners" and "losers". They analyze a rich panel data with 24 countries and more than 100 years. Consequences of wars on consumption are analyzed using a small neoclassical model. These extremely bad events induce a major increase in volatility measurement, that may account for the observed equity premium without relying on implausible and/or sophisticated models of risk–aversion.

In terms of reliable data during war episodes, the successive efforts of Maddison [2001] and of Barro et al. [2011] and Barro and Ursùa [2011] provide consensual figures about private consumption and GDP for several countries on an annual basis for a long period of time, that includes both WWI and WWII. In this paper, we make extensive use of these data, both to uncover crucial features of the dynamics of key macroeconomic variables during wars, and to assess the ability of a simple modified RBC model to explain them. Data show that most countries that actively participated to WWII experienced the lowest consumption–to–product ratio during this period. In addition, six years after the minimum of the consumption–to–product ratio was reached, all countries experienced larger–than–average ratios. Further, consumption contracts more than product during wars. How could these facts be accounted for?

We argue that a standard simple neoclassical dynamic model can not. If wars were modeled as negative productivity shocks, consumption would drop less than product, due to consumption smoothing. If they were modeled as positive productivity shocks, output would rise more than consumption does. Now, if they were modeled as military build-up episodes, output would rise. We show that a simple variation of the standard RBC model proposed by Hercowitz and Sampson [1991] is able to account for the macroeconomic effects of wars. The model admits a closed form solution, which allows to accurately quantify the effects of large shocks, since the analysis will not rely on first–order approximations. Wars indeed can not be viewed as small deviations from the steady state. We extend the initial model to account for specific shocks that destroy capital stocks, by assuming an (exogenously) time-varying depreciation rate of the stock of capital and model wars as depreciation shocks. In addition to these shocks, the model also imbeds standard TFP shocks, and an exogenous enrollment mechanism by which a fraction of the labor force may become unproductive. We show that this mechanism acts as a negative productivity shock. We therefore consider generalized TFP shocks that include both standard TFP shocks and enrollment shocks. Our way of modeling those shocks is in accordance with the modeling choices of Barro [2009] to take into account the effects of rare disasters on the economy. It allows to represent the permanent effects on the level of output, rather than transitory disturbances to the level.

The model is able to reproduce the different responses of the consumption–to–product ratio and investment during ordinary (i.e. peaceful) economic downturns and during major conflicts. On the one hand, as a response to negative productivity shocks, both consumption and investment drop. On the other hand, consumption shrinks and investment grows as an immediate response to conflicts. Because output is being stimulated by investment growth, output drops less than consumption, and the consumption–to–product ratio falls, as observed in the data.

We show that the two sources of randomness (the depreciation rate of capital and the generalized TFP process) in the model can be extracted from the available data. Once the depreciation rate process and the generalized TFP shocks have been extracted, we proceed to a VAR analysis of interactions between both sources of shocks. Several authors have suggested or investigated a positive relation between conflicts and TFP, via positive technological spillovers of military R&D on civilian technologies (see Morales-Ramos [2002] or Goel, Payne and Ram [2008]). If positive effects are strong enough, then the negative impact of destructions could be mitigated. One can also consider a "reverse" effect, by which TFP shocks may affect the quality of the installed capital, and therefore the depreciation rate. Finally, these potential relations may be affected by lags. For instance, military enrollment or human losses may exert significant downward pressure on the working force only when destructions are very large. A VAR approach thus seems suitable to investigate the issue of how both sources of shocks extracted from the data interact. We show that depreciation rates have large and persistent effects on generalized TFP shocks, while the "reverse" effect is not statistically significant.

Finally, we proceed to a welfare analysis of WWII by feeding the model with the observed depreciation process during this period. Our simulations indicate that the welfare costs of WWII induced by the increased depreciation of capital are much larger than the usual welfare costs of business cycles. Those results are due to the large and persistent effects of the depreciation shock on the capital stock, and therefore on output. For major WWII participants, the welfare losses range from 1% of permanent consumption for countries like France to more than 7% for Japan, supporting the views of Hess [2003].

The paper is organized as follows. Section 2 proposes a presentation of the related literature and describes the data. Section 3 details the model, and shows how varying the depreciation rate of capital is able to capture the specific patterns of the ratio consumption–to–product observed during conflicts. Section 4 proposes an inference strategy to calibrate the parameters and to extract depreciation and generalized TFP shocks. Section 5 is devoted to the analysis of the dynamic effects of conflicts. Section 6 concludes.

2 Measuring macro-economic consequences of conflicts

We use a data set provided by Barro and Ursùa [2011] to highlight the effects of conflicts on the consumption–to–product ratio.

Our goal is to fill the existing gap between empirical contributions and macroeconomic models dealing with the economic gains/costs of conflicts. A careful look at Barro et al. [2011] data set reveals that specific features are needed to account for major conflicts episodes. We make extensive use of these data and consider the following countries: Canada, Finland, France, Germany, Italy, Japan, Netherlands, Spain, Sweden, Switzerland, United Kingdom and USA. We select those 12 countries because the data are reliable enough and we start the database in 1875. Other countries present in Barro's data set have not been included since consumption is regularly unobserved before 1945 for these countries. Our sample of countries includes all major participants of WWI and WWII except Russia and Turkey.[1] It also includes two long–standing neutral countries (Sweden and Switzerland) and one country that experienced a major civil war (Spain).

The approach followed by Barro and his co-authors focuses on consumption and GDP. It is also useful to examine the ratio of these quantities. Table 1 gives the years when the consumption–to–product ratio was the lowest from 1875 onwards, together with the ratio of its average to its minimal value. We also compute this ratio six years after its minimum value has been reached and compare it to its average value, since Barro et al. [2011] findings are consistent with a six years average duration of major conflicts.

Major WWII participants all experienced the lowest ratio during that war. Minor participants and neutral countries did not experience such large drops at this time. A quick glance at the charts for Sweden reveals that the drop in the consumption–to–product ratio is largely due to

[1]For Turkey, the sample starts in 1923, which is too recent since Turkey was more mostly involved in WWI but not in WWII.

Table 1: Variations of consumption–to–product ratios

Country	Minimal Year	Minimum value	Six years after min. year	Average ratio
Canada	1943	46	62	61
Finland	1944	39	55	56
France	1943	40	61	68
Germany	1944	22	54	53
Italy	1943	50	67	69
Japan	1945	25	54	69
Netherlands	1943	34	56	54
Spain	1936	54	64	65
Sweden	2008	46	NA	64
Switzerland	1961	57	58	64
United Kingdom	1943	43	60	63
USA	1944	46	64	76

Data source: Barro and Ursùa [2011]. We use GDP and consumption in levels in 2006 (the base year of the data set) from the OECD national account database to build the time series in levels.

the recent (i.e. post–war) upward trend in government budget expenditures. Spain reaches its lowest level during the Civil War in 1936, which makes sense because the country remained neutral during WWI and WWII. Finally, the last column reports the strength of the recovery effect. Six years after the minimum of this ratio was reached all countries ratios are back close to their average ratio. The worst bellicose episodes induce a major drop in civilian activities. Yet, the above figures shows that consumption contracts *more* than product during wars. This is at odd with the characteristics of post–war data, in which private consumption is the most stable component of GDP. If one considers a closed economy, it also contrasts with the fact that saving rates are usually weakly procyclical. A potential explanation is that during wars consumption data are not reliable. Yet the consumption–to–product ratio displays significant inner dynamic. An exploratory analysis may be provided by a simple autoregressive panel with temporal fixed effects based on this ratio. The estimated autoregressive coefficient using Blundell and Bond [1998] method is 0.874 with an estimated (robust) standard error equal to 0.0132, which shows that the identified switches in the consumption–to–product ratio cannot be considered as purely erratic. In addition, individual temporal effect are significant (at the 1% level) for years 1918, 1940 to 1942 and 1944-1945. Again, we see that wars "shows up" in the data. It is thus unlikely that such patterns result from mere erratic movements.

We argue that RBC models are a proper tool to handle some of these questions. Indeed, these models are well–suited to analyze both the long and short–run consequences of macroeconomic shocks. In particular, they rely on explicit transmission mechanisms that explain the propagation of these shocks in the economy. Further, RBC models provide very simple yet elegant rationale for the arbitrage between consumption and investment/savings. However, the latter imbed consumption–smoothing mechanisms, at odds with the swings documented in Table 1. We therefore enrich a standard RBC model with an extra source of shocks. We assume a multiplicative law of accumulation of capital allowing to derive a solution of the model where the saving rate depends on the discount factor, the capital share and the depreciation rate of capital. The saving rate will be constant provided these parameters are constant. We thus introduce shocks to the depreciation rate of capital (i) to account for destructions of installed physical capital and (ii) to generate temporary countercyclical fluctuations of the saving rate, consistent with elements reported in Table 1.

3 The model

In this section, we develop a simple representative agent model that allows for (exogenously) time–varying depreciation rate of the stock of capital.

3.1 Assumptions

Assuming preferences similar to King, Plosser and Rebelo [1988], the representative household maximizes its lifetime welfare

$$E_0 \sum_{t=0}^{\infty} \beta^t \left(\log C_t + \chi \log(1 - N_t) \right), \tag{1}$$

subject to the budget constraint

$$Y_t = C_t + I_t. \tag{2}$$

In these expressions, β is the discount factor, C_t is consumption, I_t represents investment in physical capital, N_t is the total amount of hours worked in period t, and χ is a scale parameter. Only a share $(1 - e_t) \in [0, 1]$ of total hours worked will be effectively used in the private production sector, while a fraction e_t will be unproductive. The fraction of unproductive hours worked e_t is determined exogenously either by demographic factors or by enrollment policies. For instance, higher e_t may account for an increase in the number of draftees or for human losses due to military conflicts. During peacetime, lower e_t can be due to a demographic boom.[2] Capital accumulation follows an original law of motion, adapted from Hercowitz and Sampson [1991] and Collard [1999]:

$$K_t = A_K K_{t-1}^{\delta_t} I_t^{1-\delta_t}, \tag{3}$$

where $(1-\delta_t) \in]0,1[$ is the stochastic depreciation rate of the capital stock. This specification is a slight variation of the usual linear case, where δ_t can be interpreted as the quality of installed capital. It may also account for the presence of adjustment costs, the capital stock at time t being a concave function of investment. We use this particular specification because it allows to derive an explicit solution of the model and permits the explicit derivation of the dynamic structure of economic aggregates. In addition, as in Ambler and Paquet [1994], we allow for time–varying effects on the depreciation rate of capital, designed to capture the effect of short and/or long lasting conflicts on the structure of the economy, and more precisely on the stock of productive capital. Indeed, ceteris paribus, as long as $K_{t-1}/I_t > 1$, a negative shock on δ_t increases the depreciation rate and lowers the capital stock at the end of period t. The production function of the representative household exhibits constant returns to scale and is given by

$$Y_t = A_t K_{t-1}^{\alpha} \left((1-e_t) N_t\right)^{1-\alpha}, \tag{4}$$

where A_t is a standard TFP measure. Defining $A'_t = A_t (1-e_t)^{1-\alpha}$ shows that exogenous variations in the share of unproductive hours can be considered together with technological factors within a generalized TFP measure A'_t. The production function thus writes

$$Y_t = A'_t K_{t-1}^{\alpha} N_t^{1-\alpha}. \tag{5}$$

The household thus maximizes its utility with respect to C_t, N_t and K_t subject to the following modified constraint

$$K_t = A_K K_{t-1}^{\delta_t} \left(A'_t K_{t-1}^{\alpha} N_t^{1-\alpha} - C_t\right)^{1-\delta_t}. \tag{6}$$

[2] More generally, e_t can be viewed as a tax. Assume that the government taxes hourly wages to pay draftees. The state's budget balance implies $w_t^m e_t N_t = \tau_t (w_t^m e_t N_t + w_t(1-e_t)N_t)$, where w_t^m and w_t are military and civilians wages, and τ_t is the tax rate on labor income. Then, $e_t = \frac{\tau_t w_t}{(1-\tau_t) w_t^m + \tau_t w_t}$. In the particular case where military and civilian wages are equal, $e_t = \tau_t$.

First order conditions imply

$$\chi \frac{C_t}{1-N_t} = (1-\alpha)\frac{Y_t}{N_t}, \tag{7}$$

$$\frac{1}{C_t} = \lambda_t (1-\delta_t)\left(\frac{K_t}{I_t}\right), \tag{8}$$

$$\lambda_t K_t = \beta E_t \left[\lambda_{t+1} K_{t+1}\left(\delta_{t+1} + (1-\delta_{t+1})\,\alpha \frac{Y_{t+1}}{I_{t+1}}\right)\right], \tag{9}$$

where λ_t is the Lagrange multiplier associated to the budget constraint. Equation (7) is a labor supply equation equating the marginal disutility of hours to their marginal productivity. Remark that preferences are compatible with balanced growth since the labor supply equation allows per capita output and consumption to grow at the same rate without any particular adjustment in hours worked. Equation (8) states that the marginal utility of consumption has to equal the marginal cost of not investing. Equation (9) describes the dynamics of wealth as a function of the depreciation rate, returns on investment and the investment rate.

Denoting $S_t = I_t/Y_t$ as the saving rate, these conditions can be rearranged to characterize its dynamics. Defining $X_t = \lambda_t K_t$, Equation (8) writes

$$\frac{I_t}{C_t} = X_t (1-\delta_t), \tag{10}$$

which, using the market clearing condition $C_t = Y_t - I_t$ implies

$$\frac{I_t}{Y_t - I_t} = X_t (1-\delta_t), \tag{11}$$

and finally

$$S_t = \frac{X_t (1-\delta_t)}{1 + X_t (1-\delta_t)}, \tag{12}$$

where

$$X_t = \beta E_t \left[X_{t+1}\left(\delta_{t+1} + (1-\delta_{t+1})\,\alpha S_{t+1}^{-1}\right)\right]. \tag{13}$$

An immediate implication is that the saving rate is always bounded and less than one, i.e. $S_t \in [0,1]$, as long as $X_t > 0$. These equations characterize the dynamics of the saving rate, conditionally on the exogenous process δ_t. If the depreciation rate is constant, then X_t is constant (up to bubble) and so is the saving rate.

3.2 Equilibrium

The equilibrium of the economy is simply defined by the system of Equations (12)-(13), together with the equations describing the dynamics of output, capital and hours worked. The latter can be derived explicitly as follows. First, use Equation (7) to express hours as a function of the saving rate

$$N_t = \frac{(1-\alpha)}{\chi(1-S_t)+(1-\alpha)}, \tag{14}$$

and substitute for hours in the production function

$$Y_t = A_t' K_{t-1}^{\alpha}\left(1+\tfrac{\chi(1-S_t)}{(1-\alpha)}\right)^{\alpha-1}. \tag{15}$$

Denoting $u_t = \log(U_t)$, $\forall U$, $\forall t$, we get:

$$y_t = a_t' + \alpha k_{t-1} + (\alpha-1)\log\left(1+\tfrac{\chi(1-S_t)}{(1-\alpha)}\right). \tag{16}$$

The dynamics of capital accumulation is given by

$$k_t = a_K + \delta_t k_{t-1} + (1-\delta_t)\, i_t, \tag{17}$$

or, given that $i_t = s_t + y_t$ and plugging equation (16) in the previous equation:

$$k_t = (\delta_t + \alpha(1-\delta_t))\, k_{t-1} + a_{k,t} + (1-\delta_t)\, a_t', \tag{18}$$

where

$$a_{k,t} = a_K + (1-\delta_t)\left(s_t + (\alpha-1)\log\left(1+\tfrac{\chi(1-S_t)}{(1-\alpha)}\right)\right). \tag{19}$$

Summarizing the equilibrium conditions, the saving rate evolves according to Equations (12)-(13), and the dynamics of hours, output and capital are respectively given by Equations (14), (16) and (18).

Importantly, the stock of capital admits a Random Coefficient Autoregressive representation. The randomness of the process δ_t implies that k_t evolves according to a random autoregressive coefficient with random volatility. This particular source of randomness is the consequence of the stochastic nature of the depreciation. Ambler and Paquet [1994] obtain a similar result (see their Equation (5)).

3.3 Some intuition

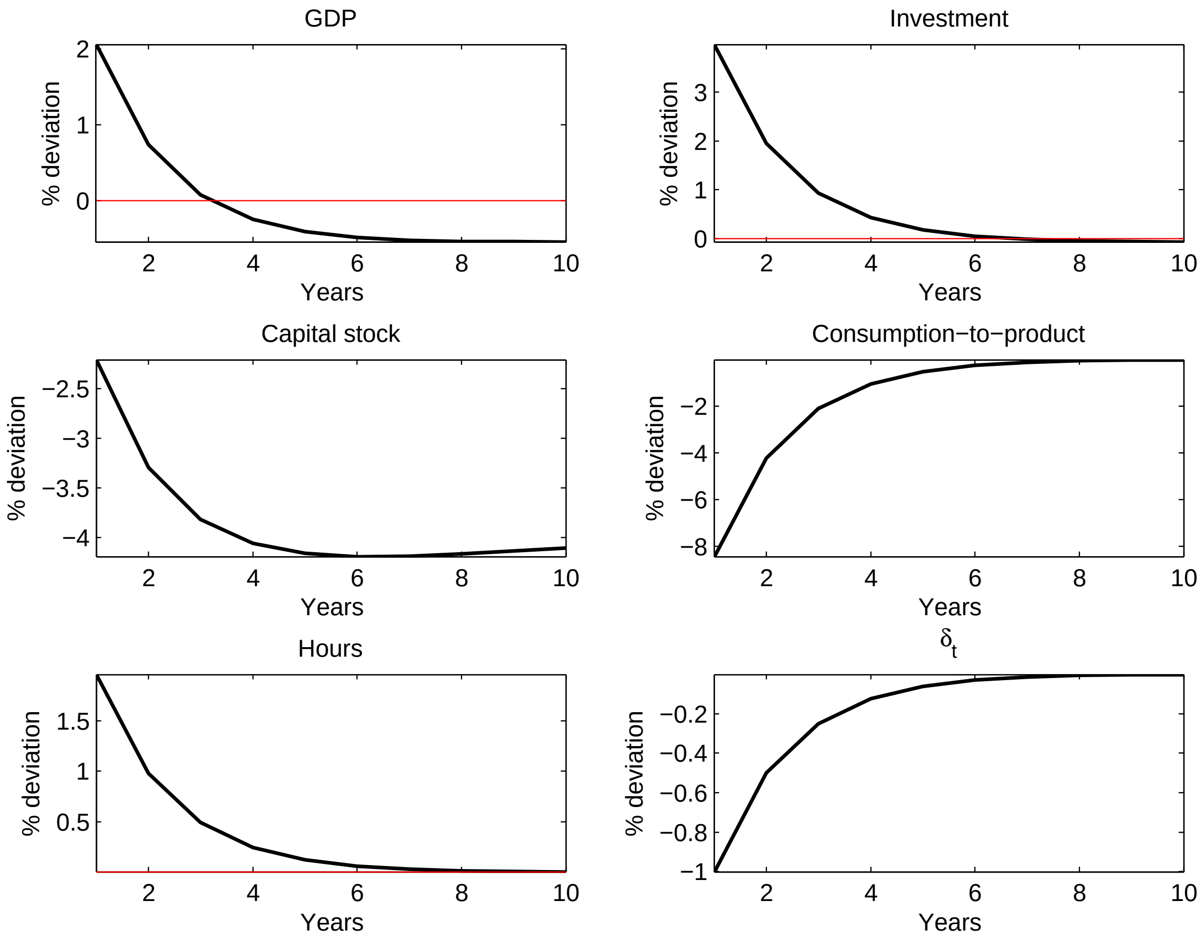
Our analysis of conflicts and/or destruction of the capital stock relies on negative shocks affecting the process δ_t. A careful analysis of long economic time series reveals that the dynamics of the consumption–to–product ratio may not always be consistent with the dynamics implied by TFP shocks. Section 2 shows that, during historic episodes of war such as WWII or major destructions of the capital stock, output shrinks as well as consumption, but the saving rate increases to enable domestic investment to rise for reconstruction motives. Unless investment can be financed by borrowing significantly from abroad, in these situations, consumption smoothing is absent, and the saving rate is episodically countercyclical. It is this pattern that our model seeks to replicate.

In standard models, recessions implied by TFP shocks imply that consumption drops, but less than output due to consumption smoothing, and the saving rate is procyclical. Indeed, a decrease in consumption together with increasing investment is difficult to justify with usual technological shocks. If conflicts induce negative productivity shocks then investment would typically fall during wars. Now, if conflicts are interpreted as positive technological shocks (for instance because of implied R&D enhancements), then consumption would grow during wars. As we have shown in Section 2, both conclusions are at odds with the data. As conflicts typically destroy installed capital they may be captured by shocks affecting the accumulation process. However, to obtain the desired effect, such a shock must be modeled with care. Let us consider for instance the case where $K_t = A_{k,t}K_{t-1}^{\delta}I_t^{1-\delta}$ and assume that conflicts cause a decrease in $A_{k,t}$. Straightforward computation shows that such shocks are simply part of a "generalized" productivity shock $a''_t = a_{k,t} + (1-\delta)(a'_t + (1-\alpha)\log(1-e_t))$. A model embedding this type of shocks thus suffers from the same weaknesses than a model with TFP shocks only. As shown in Figure 1, a negative shock on δ_t generates the effects identified in the data. Figure 1 plots the responses in deviation from the steady state of key macroeconomic aggregates to a negative one percent shock on δ_t tailored to last about 6 years.[3]

As expected, a depreciation shock deteriorates the capital stock, thereby increasing the marginal productiveness of capital and providing incentives to invest. Consumption thus decreases more than output. Output is boosted in the very first periods but persistently falls under its initial

[3] The figure serves as an illustration. It is drawn assuming that key parameters are calibrated using averages of values reported in Table 2, and imposing arbitrarily that δ_t follows an AR(1) process with a persistence adjusted to obtain a six–period duration of the shock.

Figure 1: Impulse responses to a 1% negative shock on δ_t



level three periods after the shock. The initial upward jump is entirely due to the reconstruction effect. Notice this effect does not last, contrarily to the depressive impact due to the lower capital stock. Working hours increase due to increase in the saving rate (recall Equation (14)). The joint dynamics of output and the consumption–to–product ratio is thus similar to the pattern identified in the data. Put differently, persistent (though not necessarily permanent) depreciation shocks will lead the saving rate to be countercyclical with respect to output.

4 Shocks extractions and inference

Our goal is to investigate whether changes in δ_t can account for major destructive episodes related to war or civil wars. The section describes how the two sources of randomness in the model may be extracted from the available data $(S_t, y_t)_{t \in \{1,T\}}$. We first consider the case of the process δ_t. Second, we describe our approach to extract the TFP process.

4.1 Extraction of the δ_t process

The extraction of the δ_t process proceeds as follows. First, we make use of structural Equations (12)-(13) to express δ_t as a function of the saving rate and of the deep parameters α and β. Second, we build a model–consistent measure of saving rates. Third, we calibrate the deep parameters over consensual values. Finally, we use our saving rates time series to uncover the dynamics of the δ_t process for each country of our sample.

We start from the rational expectation Equation (13)

$$X_t = \beta E_t[X_{t+1}] + \beta\alpha E_t\left[\frac{X_{t+1}(1-\delta_{t+1})}{S_{t+1}}\right] - \beta E_t[X_{t+1}(1-\delta_{t+1})].$$

Now using

$$X_t(1-\delta_t) = \frac{S_t}{1-S_t},$$

we can rewrite X_t as

$$X_t = \beta E_t[X_{t+1}] + \beta\alpha - \beta(1-\alpha)E_t\left[\frac{S_{t+1}}{1-S_{t+1}}\right].$$

Ruling out explosive bubbles, forward iteration gives

$$X_t = \frac{\alpha\beta}{1-\beta} - (1-\alpha)E_t\left[\sum_{i=1}^{\infty}\beta^i\frac{S_{t+i}}{1-S_{t+i}}\right].$$

We then derive

$$\delta_t = 1 - \frac{S_t}{1-S_t}\left(\frac{\alpha\beta}{1-\beta} - (1-\alpha)E_t\left[\sum_{i=1}^{\infty}\beta^i\frac{S_{t+i}}{1-S_{t+i}}\right]\right)^{-1}.$$

A proxy to the unobserved terms $E_t\left[S_{t+i}/(1-S_{t+i})\right]$ may be derived assuming that the process $S_t/(1-S_t)$ admits a weak AR(1) stationary representation. Indeed, in this case we have

$$E_t\left[\frac{S_{t+i}}{1-S_{t+i}}\right] = \rho_S^i\frac{S_t}{1-S_t},$$

and

$$\delta_t = 1 - \frac{S_t}{1-S_t}\left(\frac{\alpha\beta}{1-\beta} - \frac{1-\alpha}{1-\beta\rho_S}\frac{S_t}{1-S_t}\right)^{-1}.$$

We now need to build a model–consistent measure of the saving rates. We use GDP and consumption in levels in 2006 (the base year of the data set) from the OECD national account database to build the time series in levels. Then, we compute the non–consumed share of output. In our model, savings and investment will be equal due to the absence of financial openness in the economy and due to the absence of public spending and taxes. In the data however, the share of non–consumed output does not equal the investment rate. As our interest is the investment rate, we correct for this by using OECD data from 1990 to 2009 for the considered countries. We compute the non–consumed share of output and the investment rate, pool the data (which for 12 countries over 20 years gives 240 observations) and estimate how the non–consumed share of output affects the investment rate with a simple OLS specification.[4] We then make use of this relation to build model–consistent investment/saving rates. The obtained saving rates are reported in Figure 2.

We then turn to the calibration of the deep parameters. Parameters β and α are calibrated as follows. We set α based on the 1970 labor shares reported by Bentolila and Saint-Paul [2003]. For β, we use average GDP growth rates – denoted g_y – calculated on Barro and Ursùa [2011] data, and approximate discount factors by $\beta = 1/(1+g_y)$. We will later need to calibrate the parameter χ. Calibration may be derived from occupation time from the OECD database. We compute mean values for N and S in all countries from 1970 onwards and then use the equation $N_t = (1+\chi(1-S_t)/(1-\alpha))^{-1}$ to calibrate values for the χ parameter in each country. Finally, the values for the coefficient ρ_S have been computed directly from the sequences $S_t/(1-S_t)$. Table 2 summarizes the main features of our calibration.

[4]The estimation results and data are available upon request.

Figure 2: Saving rates

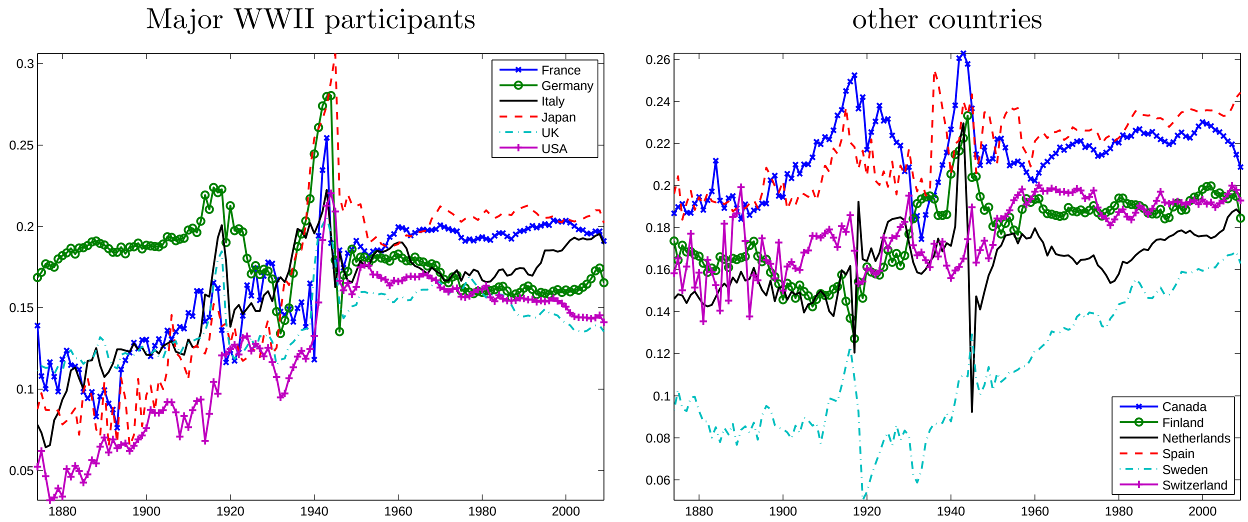


Table 2: Calibration of α, β, ρ_S and χ

Country	α	β	ρ_S	χ
Canada	0.331	0.9800	0.9078	1.91
Finland	0.314	0.9775	0.9491	1.88
France	0.324	0.9817	0.9304	1.98
Germany	0.359	0.9793	0.8662	2.25
Italy	0.329	0.9797	0.9444	1.78
Japan	0.425	0.9733	0.9577	1.39
Netherlands	0.320	0.9812	0.6534	2.71
Spain	0.324	0.9820	0.8309	1.99
Sweden	0.303	0.9792	0.9615	2.21
Switzerland	0.324	0.9857	0.7570	2.08
United Kingdom	0.286	0.9854	0.9229	1.90
USA	0.303	0.9792	0.9714	1.77

Figure 3 presents the pattern of the δ_t processes that our procedure allowed to extract. For WWII participants, δ_t goes down very deeply (depreciation increases) between 1939 and 1945. For neutral countries, depreciation increases though to a much lesser extent (the magnitude of downturns in δ_t is clearly smaller) for some countries (Canada, Finland, Netherlands) and shows no particular break for other countries (Spain, Sweden and Switzerland). The Spanish Civil War is well captured by our extraction as δ_t goes down quite sharply in 1936. Downturns in the dynamics of δ_t during WWI are both less clear and of shorter magnitude, which matches quite well with historical records of destructions of physical capital, according to which destructions occurred during WWI were small in comparison of those occurred during WWII.

Figure 3: Extracted δ_t processes

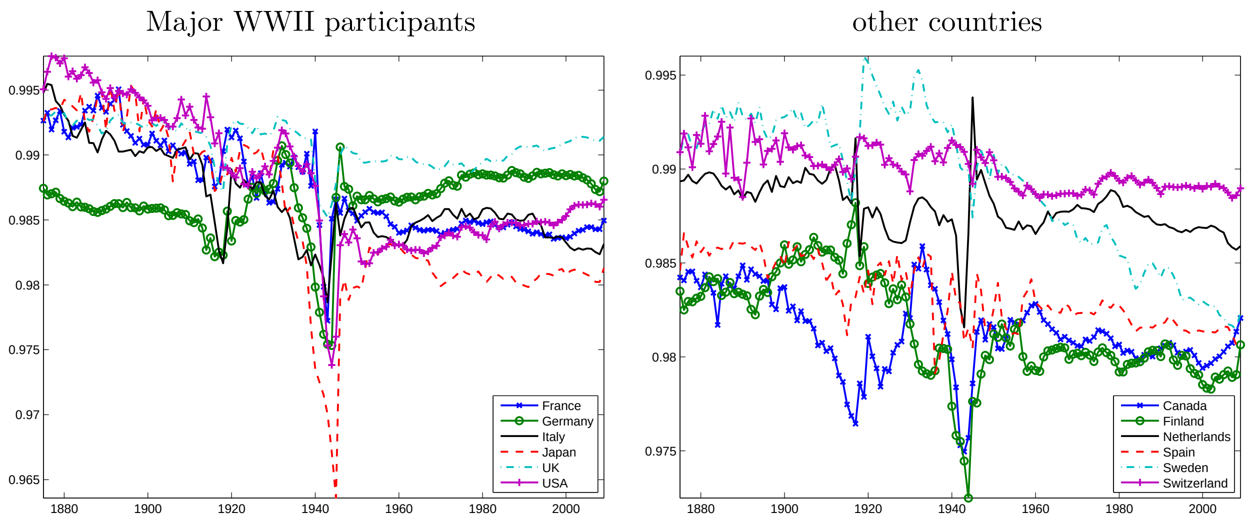


Table 3 reports the main descriptive statistics attached to the extracted processes of δ_t. First, the means of the extracted δ_t processes are in accordance with the values put forth in the literature (see Collard [1999] and references therein). Second, the processes clearly exhibit large persistence supporting our assumption that swings in the saving rate are not only due to erratic errors in the data.

4.2 TFP processes and innovations

We now consider the generalized TFP process. From Equation (14), we get

$$n_t = \log(1 + \frac{\chi}{1-\alpha}(1 - S_t))^{-1}.$$

Table 3: Descriptive statistics of the extracted δ_t

Country	$\overline{\delta_t}$	ρ_{δ_t}	σ_{δ_t}
Canada	0.9813	0.9060	0.0021
Finland	0.9815	0.9458	0.0027
France	0.9875	0.9205	0.0036
Germany	0.9865	0.8613	0.0025
Italy	0.9865	0.9374	0.0035
Japan	0.9852	0.9522	0.0064
Netherlands	0.9879	0.6666	0.0015
Spain	0.9833	0.8287	0.0018
Sweden	0.9894	0.9669	0.0039
Switzerland	0.9900	0.7687	0.0011
United Kingdom	0.9908	0.9197	0.0017
USA	0.9880	0.9690	0.0052

Now using the dynamics of capital accumulation $k_t = a_k + \delta_t k_{t-1} + (1-\delta_t)(s_t + y_t)$ and substituting for y_t using the production function $y_t = a_t + \alpha k_{t-1} + (1-\alpha)n_t$, we get

$$k_t = a_k + (\delta_t + \alpha(1-\delta_t))k_{t-1} + (1-\delta_t)\left(s_t + (1-\alpha)n_t\right) + (1-\delta_t)a'_t.$$

Making use of the previous equation and combining again with the production function, the dynamics of y_t may now be written as

$$\begin{aligned} y_{t+1} - a'_{t+1} - (1-\alpha)n_{t+1} &= \alpha a_k + (\delta_t + \alpha(1-\delta_t))(y_t - a'_t - (1-\alpha)n_t) \\ &\quad + \alpha(1-\delta_t)(s_t + (1-\alpha)n_t) + \alpha(1-\delta_t)a'_t, \end{aligned}$$

or

$$y_{t+1} = \alpha a_k + (\delta_t + \alpha(1-\delta_t))y_t + (1-\alpha)(n_{t+1} - \delta_t n_t) + \alpha(1-\delta_t)s_t + a'_{t+1} - \delta_t a'_t.$$

Consider the quantity

$$z_{t+1} = y_{t+1} - (\delta_t + \alpha(1-\delta_t))y_t - (1-\alpha)(n_{t+1} - \delta_t n_t) - \alpha(1-\delta_t)s_t.$$

Notice that in z_t, everything is known since we have data for y_t and S_t, key parameters have been calibrated, and δ_t have been extracted. Now assume that generalized TFP measures admit the following representation

$$a'_t = (1-\rho)a_\infty + \rho a'_{t-1} + \epsilon'_t,$$

where ϵ'_t is the generalized TFP shock. We get

$$\begin{aligned} z_{t+1} &= \alpha a_k + (1-\rho)a_\infty(1+\rho-\delta_t) + (\rho-\delta_t)\rho a'_{t-1} + (\rho-\delta_t)\epsilon'_t + \epsilon'_{t+1}, \\ z_t &= \alpha a_k + (1-\rho)a_\infty + (\rho-\delta_{t-1})a'_{t-1} + \epsilon'_t, \end{aligned}$$

from which we deduce

$$\begin{aligned} (\rho-\delta_{t-1})z_{t+1} - \rho(\rho-\delta_t)z_t &= \alpha a_k(\rho-\rho^2+\rho\delta_t-\delta_{t-1}) \\ &+ (1-\rho)a_\infty((1+\rho-\delta_t)(\rho-\delta_{t-1}) - \rho(\rho-\delta_t)) \\ &+ \epsilon'_{t+1}(\rho-\delta_{t-1}) + \epsilon'_t((\rho-\delta_t)(\rho-\delta_{t-1}) - \rho(\rho-\delta_t)), \end{aligned}$$

or

$$\begin{aligned} (\rho-\delta_{t-1})z_{t+1} - \rho(\rho-\delta_t)z_t &= \alpha a_k(\rho-\rho^2+\rho\delta_t-\delta_{t-1}) \\ &+ (1-\rho)a_\infty(\rho-\delta_{t-1}(1+\rho-\delta_t)) \\ &+ \epsilon'_{t+1}(\rho-\delta_{t-1}) - \epsilon'_t\delta_{t-1}(\rho-\delta_t). \end{aligned} \tag{20}$$

Using our data set for y_t and S_t, the calibrated values of α and χ and the extracted δ_t process, the left hand side quantity in Equation (20) may be explicitly computed if ρ is known. The same is true for the "explanatory" variables $\alpha(\rho-\rho^2+\rho\delta_t-\delta_{t-1})$ and $(1-\rho)(\rho-\delta_{t-1}(1+\rho-\delta_t))$. We estimate the parameters a_k, a_∞ and ρ by asymptotic least squares. Indeed, assume ρ is known then a_k and a_∞ parameters may be derived by two stage least squares after controlling for heteroskedasticity of the term $(\rho-\delta_{t-1})\epsilon'_{t+1} - \delta_{t-1}(\rho-\delta_t)\epsilon'_t$. Instrumentation is also required since the two sources of shocks may not be independent. Assuming $\rho = \delta_t$ is a zero probability event, we may extract the sequence of generalized TFP innovations ϵ_t for all given value of ρ, a_k, a_∞. Our approach is to compute ρ so as to minimize the correlation between the extracted shocks at various lags. We perform this estimation technique for all countries using various lagged values of the processes δ_t as instruments. The values of ρ have been obtained by minimizing the correlation between the extracted innovations at lag 1 and 2 via GMM.[5] Values of a_k and a_∞ are not reported and are available upon request. One important information, however, is that estimates of a_k are always positive. As a consequence, $A_K > 1$ and $K/I > 1$, which means that

[5] Using two lags provides us with a simple specification test of the model. It turns out P-values are very high and the model is never rejected.

negative shocks to δ_t (an increase in depreciation) will lead the capital stock to drop. Table 4 displays the estimated autocorrelations of the TFP processes together with the standard errors of innovations. Obviously our estimates fall in the range of values reported in the literature. The persistence of generalized TFP processes is high and pretty close to unity for all countries.

Table 4: Autocorrelation of the TFP process and Std. Dev. of innovations

Country	ρ	σ_ϵ
Canada	0.977	0.029
Finland	0.979	0.021
France	0.983	0.027
Germany	0.983	0.046
Italy	0.999	0.030
Japan	0.985	0.038
Netherlands	0.993	0.032
Spain	0.976	0.023
Sweden	0.988	0.023
Switzerland	0.990	0.112
United Kingdom	0.988	0.012
USA	0.980	0.020

5 Macroeconomic dynamics, causality and welfare

Once δ_t processes and generalized TFP shocks have been extracted, we proceed to a VAR analysis of interactions between both sources of shocks. Finally, we measure the welfare losses implied by wars as the percentage of steady state consumption tha agent would be willing to give up to live in a peaceful world.

5.1 Positive or negative impacts of conflicts on productivity

It seems reasonable to account for potential correlation between both sources of shocks. Recall indeed a'_t process is a generalized TFP which possibly accounts for downward pressure on the working force due to military enrollment or human losses. This argument leads us to hypothesize a positive link between the shocks on δ_t and the shocks on the TFP process. One can also consider a "reverse" effect, by which TFP shocks may affect the quality of the installed capital, and therefore the depreciation rate. Finally, these potential relations may be affected by lags as military enrollment or human losses may exert significant downward pressure on the working force only when destructions are very large. For these reasons, we adopt a VAR approach to investigate the issue of how both sources of shocks extracted from the data interact.

Before engaging in an extensive analysis of the potential causality between innovations affecting the generalized TFP process and innovations affecting the δ_t process, we need to extract the latter properly. In the absence of any prior information about the dynamics of δ_t, we adopt an agnostic view and fit ARMA processes. We test various orders both for the AR and the MA components, and make use of the Aikake Information Criterion to select the best specification. As indicated in Table 5, the final specification used to extract innovations on the δ_t processes differ across countries. Finally, innovations have been computed using Kalman Fiter.

Table 5: ARMA(ϕ,θ) estimates of δ_t processes

Country	Cst	ϕ_1	ϕ_2	ϕ_3	θ_1	θ_2	θ_3	θ_4	Std(ϵ_δ)
Canada	0.981	1.580	-0.642	–	-0.515	–	–	–	0.0008
Finland	0.982	0.944	–	–	–	–	–	–	0.0009
France	0.988	0.817	0.174	–	0.039	-0.225	-0.390	–	0.0012
Germany	0.987	1.093	-0.270	–	–	–	–	–	0.0012
Italy	0.988	0.978	–	–	0.158	-0.194	–	–	0.0009
Japan	0.986	0.957	–	–	–	–	–	–	0.0018
Netherlands	0.988	0.676	–	–	–	–	–	–	0.0011
Spain	0.983	1.810	-1.684	0.855	-1.294	1.262	-0.573	–	0.0009
Sweden	0.988	0.982	–	–	–	–	–	–	0.0008
Switzerland	0.990	0.122	0.747	–	0.342	-0.269	–	–	0.0006
United Kingdom	0.991	0.825	–	–	0.550	0.262	–	–	0.0005
USA	0.989	0.970	–	–	0.340	0.050	0.022	-0.213	0.0010

Using the extracted generalized TFP innovations and the innovations affecting δ_t, we proceed to a separate VAR estimation with lags up to order 3 for each country.

We first consider the causality from shocks affecting δ_t to generalized TFP shocks. Negative shocks on δ_t, understood here as destructions of installed capital, have large and significant negative impacts on the TFP innovations for all countries (see Figures 4 and 5). This is true even for neutral countries, although the effect may be shown to be significantly larger for the first group of countries. The responses for USA and United Kingdom display significant lags. The results for Switzerland are surprisingly large, but they are due to the very large swings in the TFP process (notice the large value of the standard errors of the shocks in Table 4).

Figure 4: Response of generalized TFP innovations (in %) to a negative shock on δ_t (Major WWII participants)

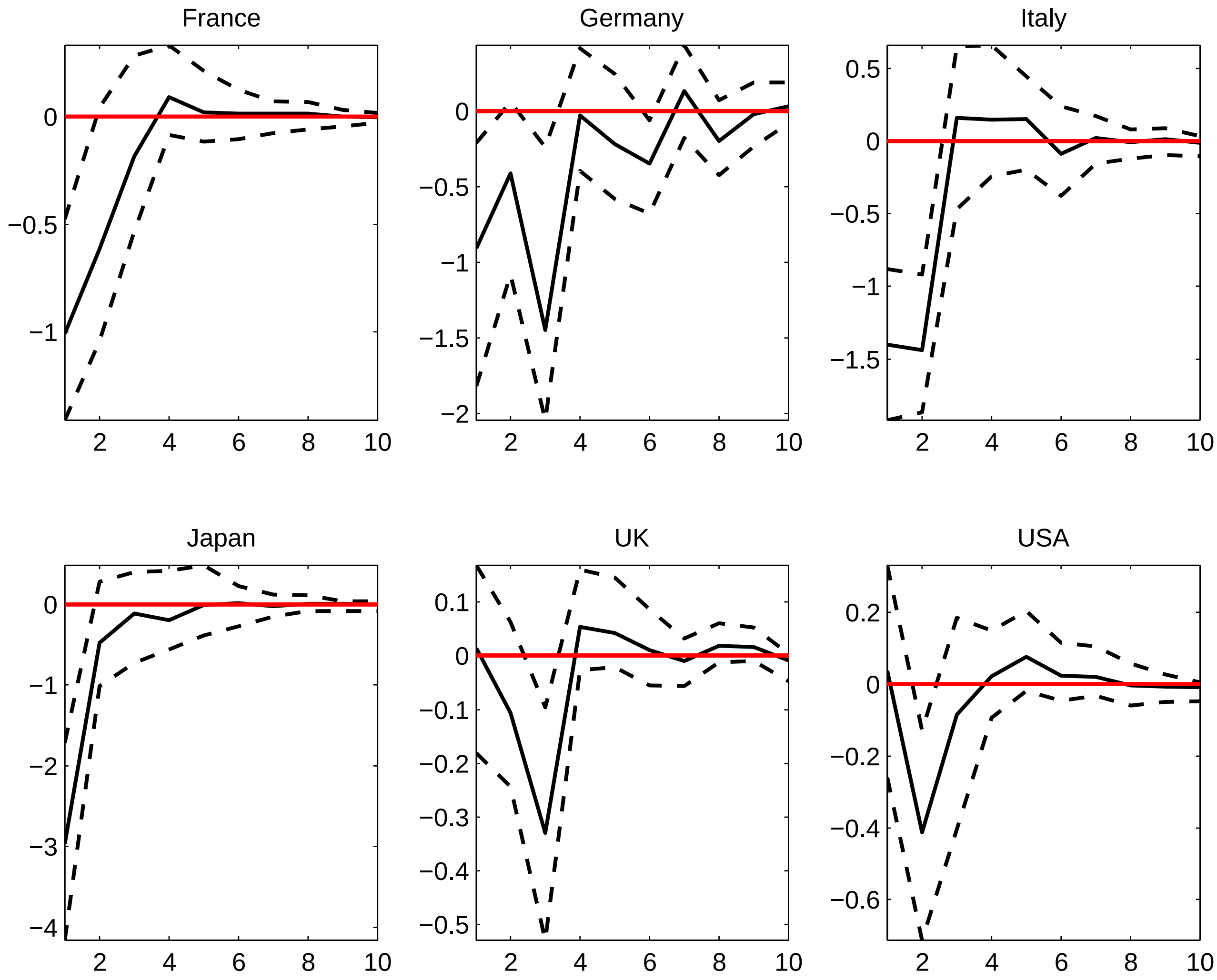


Figure 5: Response of generalized TFP innovations (in %) to a negative shock on δ_t (other countries)

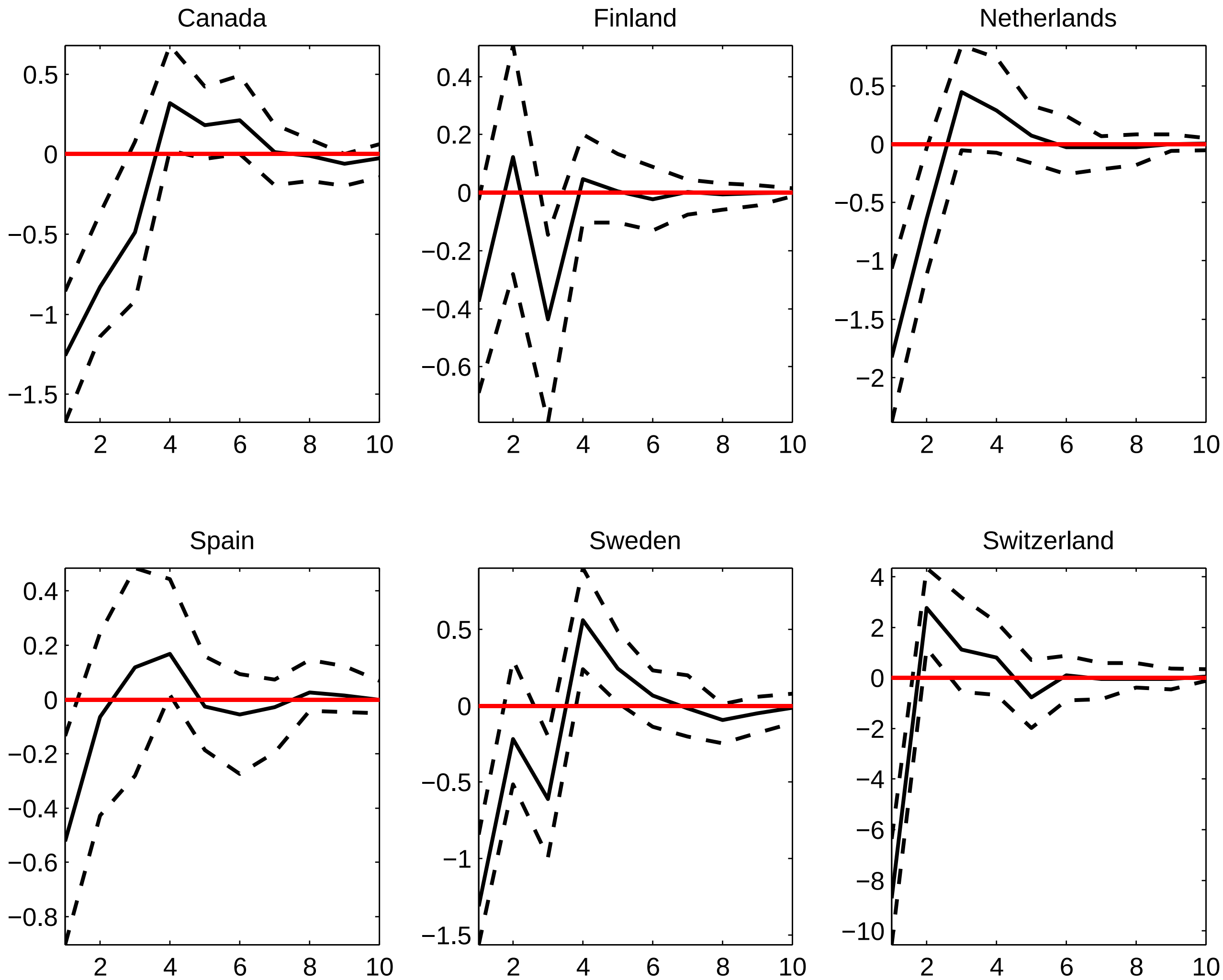


Table 6: Causality $a'_t \to \delta_t$

Country	1-lag	2-lags	3-lags
Canada	n.s.	n.s.	n.s
Finland	n.s.	n.s.	n.s.
France	0.009	0.011	n.s.
Germany	-0.01	0.008	n.s.
Italy	n.s.	n.s.	n.s
Japan	n.s.	n.s	n.s.
Netherlands	n.s.	0.007	n.s.
Spain	n.s.	n.s.	n.s
Sweden	n.s.	n.s.	n.s
Switzerland	n.s.	0.001	n.s.
United Kingdom	n.s.	n.s.	n.s
USA	n.s.	n.s.	-0.009

These results back our prior intuition that generalized TFP worsen after a negative shock on δ_t. One may simply interpret those results as the effects of conflicts on the labor force, as exemplified by the enrollment mechanism highlighted in the model. Indeed, enrollment policies and/or human losses during conflicts severely cut productive resources and therefore act as negative productivity shocks in the economy. However, the model is not suitable to provide a full description of participation in the labor market and the corresponding workforce flows. A full characterization of such issues is left for future research.

Second, we consider the "reverse" causality effect. Table 6 displays the coefficients of lagged values of a'_t in the VAR equation with δ_t as a dependent variable. The effects are either very small or not significant. These results incidentally support our choice of an extraction method for the δ_t processes that solely relies on the dynamics of saving rates, and not on the dynamics of generalized TFP.

As these coefficients are difficult to interpret directly, consider the French case (which may be the most significant one). When a'_t display a 1% positive shock, δ_t increases by 2.64×10^{-4} units the first year and the maximum response is 3.09×10^{-4} (obtained after two years). For the ease of comparison, the overall amplitude of the δ_t process is 0.017 for France. Therefore, if a reverse effect ever exists, it is at best negligible.

Table 7: The welfare losses from WWII, in % of steady state consumption

Country	1933-46	1934-46	1935-46	1936-46	1937-46	1938-46
Canada	0.27	0.54	0.74	0.89	1.04	1.15
Finland	2.30	2.23	2.15	2.07	1.99	1.97
France	0.30	0.43	0.54	0.71	0.83	0.92
Germany	2.12	2.43	2.68	2.81	2.83	2.80
Italy	2.77	2.79	2.76	2.63	2.41	2.19
Japan	6.47	6.67	6.91	7.04	7.08	7.13
Netherlands	0.43	0.48	0.52	0.53	0.52	0.47
Spain	0.46	0.54	0.68	0.80	0.59	0.42
Sweden	-2.10	-1.72	-1.44	-1.22	-1.01	-0.79
Switzerland	-0.65	-0.61	-0.56	-0.49	-0.47	-0.43
United Kingdom	0.92	1.04	1.13	1.21	1.28	1.33
USA	1.83	2.12	2.33	2.51	2.63	2.73

5.2 Welfare analysis

Using the model and the extracted δ_t processes, we now engage in a welfare quantification of WWII. This period is indeed the largest downward swing in the δ_t process for many countries. To do so, we feed the model with the extracted δ_t process for the period corresponding to WWII, compute the dynamic path toward the steady state using parameter values described in the earlier sections, and abstract from TFP shocks. We do this for various sample periods. We start by feeding the model with shocks on δ_t between 1933 and 1946 and progressively shorten the sample to the 1938-1946 period. Of course the path of the economy is calculated for a large number of periods after the initial shocks, as shocks to δ_t have very persistent effects.[6] Welfare is expressed as the percentage of steady state consumption that agents would be willing to give up to live in a peaceful world, i.e. a world with a constant δ_t. We denote this percentage by Λ and define it as

$$E_0 \sum_{t=0}^{\infty} \beta^t \left(U\left(C_t, N_t\right)\right) = (1-\beta)^{-1} \left(U\left((1-\Lambda)C, N\right)\right),$$

where C and N are the steady state values of consumption and hours worked respectively.

Table 7 reports the welfare losses of WWII implied by our extraction of the δ_t and our model. A first insight from Table 7 is that not all countries suffered from welfare losses during the WWII period. In particular, neutral countries such as Sweden and Switzerland exhibit welfare

[6]The model is solved for 1000 periods.

gains. Second, the size of welfare losses is significantly larger than those usually associated to the business cycles (see Lucas [2003]). For major WWII participants, welfare losses typically amount to more than 1% of steady state consumption, skyrocketing to about 7% for Japan. One limitation is that these simulations neglect the recovery effects that have been observed during the post–WWII period and abstracts from any dynamics of TFP. Those factors may change the welfare costs of WWII since the latter is calculated over the whole path implied by large and negative shocks to the depreciation rate of capital, with highly persistent effects on key macroeconomic aggregates. However, one could also argue that those figures are underestimated since, according to our causality analysis, large depreciation shocks should also imply large negative TFP shocks. Therefore, our estimates of the economic losses associated with WWII appear reasonable.

6 Conclusion

It is well recognized both in economics and history that war typically produce large downturns. Yet most of the current macro economic models focus on post war data. Recent papers have tried to use the large swings induce by WWII to derive precise estimates of fiscal policy and/or government spending, or to capture the effects of dramatic downturns. In this paper, we argue that empirical reaction of consumption to product ratio calls for a specific treatment of the economics of war. To do so, we evaluate the impact of conflicts on macroeconomic aggregates using a panel data with 12 countries from 1875 onwards. We highlight that consumption drops more than output during conflicts, while the opposite is true during "peaceful" times. We then build a model that can represent the impact of conflicts on the economy by assuming an (exogenously) time-varying depreciation rate of the stock of capital and consider wars as large depreciation shocks. The model also imbeds standard TFP shocks and an enrollment mechanism that acts as a TFP shock. We show that the model is able to reproduce the different responses of macroeconomic aggregates to productivity shocks during peaceful periods as well as their responses during conflicts. In addition, we are able to extract depreciation and TFP shocks from the data and conclude that conflicts have significant and persistent influence on TFP shocks, while the "reverse" effect is not significant in the data. Finally, our welfare analysis shows that the economic costs of massive conflicts, such as WWII, are very large.

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