Online Appendix

Technology Shocks and the Great Depression

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This document contains three sections. The first section explains how this article's regression equation for estimating technology change is derived. The second section studies to what extent estimated technology shocks reflect changes in government-owned privately operated (GOPO) capital. The third section compares this article's technology series with Inklaar, de Jong, and Gouma's (2011) technology series.

DERIVATION OF THE REGRESSION EQUATION

This section consists of two subsections. The first subsection explains Basu, Fernald, and Kimball's (2006) approach. The second subsection explains how their approach is modified for application to pre-WWII data.

Basu, Fernald, and Kimball's (2006) Approach

Each industry i is assumed to have a production function for gross output:

(1) $$Y_i = F^i(V^i(A_iK_i, E_iH_iN_i), M_i, Z_i),$$

where Y is gross output, V is value added, A is the capital utilization rate, K is the capital stock, E is the effort of each worker, H is hours worked per worker, N is the number of employees, M is intermediate inputs, and Z is the index of technology. By taking logs of both sides of the equation and differentiating with respect to time, we have

(2) $$dy_i = \frac{F_1^iV_1^iA_iK_i}{Y_i}(da_i + dk_i) + \frac{F_1^iV_2^iE_iH_iN_i}{Y_i}(de_i + dh_i + dn_i) + \frac{F_2^iM_i}{Y_i}dm_i + dz_i,$$

where dj is defined as the logarithmic growth rate of any variable J, $\log(J_t/J_{t-1})$, and the output elasticity with respect to technology is normalized equal to one.

As Hall (1990) shows, when firms take all input prices, P_j, as given in competitive markets, the first order conditions derived from a cost-minimization problem imply that:

(3) $$\frac{F_1^iV_1^iA_iK_i}{Y_i} = \gamma_i\frac{P_KA_iK_i}{P_iY_i} \equiv \gamma_i s_k^i,$$

(4) $$\frac{F_1^iV_2^iE_iH_iN_i}{Y_i} = \gamma_i\frac{P_{EHN}E_iH_iN_i}{P_iY_i} \equiv \gamma_i s_{EHN}^i,$$

and

(5) $$\frac{F_2^iM_i}{Y_i} = \gamma_i\frac{P_MM_i}{P_iY_i} \equiv \gamma_i s_M^i,$$

where P_i is the price of the industry i's output and γ_i is the markup. The Euler's theorem implies that the markup, γ_i, equals the degree of returns to scale when firms make zero economic profit (i.e., $s_K^i + s_{EHN}^i + s_M^i = 1$). Basu, Fernald, and Kimball (2006) assume the zero economic profit and this article follows them. Evidences for the zero economic profit are given by Rotemberg and Woodford (1995) and Basu and Fernald (1997). By using (3)–(5), (2) can be rewritten as:

(6) $$dy_i = \gamma_i(dx_i + du_i) + \gamma_i s_M^i dm_i + dz_i,$$

where $dx_i \equiv s_K^i dk_i + s_{EHN}^i(dh_i + dn_i)$ and $du_i \equiv s_K^i da_i + s_{EHN}^i de_i$. dx denotes observed input growth and du denotes unobserved input growth.

By solving a representative firm's cost-minimization problem, Basu, Fernald, and Kimball (2006) show that changes in hours per worker should be proportional to unobserved changes in both labor efforts and capital utilization, because the firm operates on all margins simultaneously, both observed and unobserved (see pp. 1423–24 in Basu, Fernald, and Kimball 2006):

(7) $$da_i = \zeta_i dh_i$$

and

(8) $$de_i = \eta_i dh_i,$$

where $\zeta > 0$ and $\eta > 0$.

By using (7) and (8), (6) is rewritten as

(9) $$dy_i = \gamma_i dx_i + \beta_i dh_i + \gamma_i s_M^i dm_i + dz_i,$$

where $\beta_i \equiv \gamma_i\left(s_K^i \zeta_i + s_{EHN}^i \eta_i\right)$. Basu, Fernald, and Kimball (2006) estimate (9) with a constant term by using postwar data for each industry and aggregate estimated industry technology change, dz_i.

Estimating Pre-WWII Technology Change

Basu, Fernald, and Kimball's (2006) approach is not directly applicable to the pre-WWII data, because long-run, annual data for gross output and intermediate inputs in the pre-WWII period are not available. The first step to modify their approach is to simply note the Divisia definition of gross output:

(10) $$dy_i \equiv \left(1 - s_M^i\right) dv_i + s_M^i dm_i.$$

Second, following Basu (1996), this article assumes Leontief technology for intermediate input use, which means that intermediate inputs are used in strict proportion to value added:

(11) $$dm_i = dv_i.$$

Basu (1996) proposes to eliminate unobserved utilization from (6) by substituting (11) into (6), which is possible because $dv_i = (dx_i + du_i)/\left(1 - s_M^i\right)$. The resultant equation shows that technology changes can be estimated as residuals from regressing gross output on intermediate inputs and he does so. Instead, this article uses (11) to eliminate intermediate input growth. Substituting (11) into (10) yields

(12) $$dy_i = dv_i.$$

The Leontief technology implies that gross output and value added grow at the same rate. By using (11) and (12), we can eliminate gross output and intermediate inputs from (9):

$$(13)\qquad dv_i = \frac{\gamma_i}{1-\gamma_i s_M^i} dx_i + \beta_i^v dh_i + dz_i.$$

where $\beta_i^v \equiv \beta_i/\left(1-\gamma_i s_M^i\right)$ and the elasticity of value added to technology change is normalized to one again.

Though industry-level, long-run, annual data for capital stock and hours worked in the pre-WWII period are not available, Kendrick (1961, 1973) reports the pre-WWII input growth in the whole economy, which is calculated by aggregating capital stock growth and hours worked growth in each industry. To exploit such data, we first re-aggregate observed input growth in (13) with cost shares in value added:

$$(14)\qquad dv_i = \gamma_i^v dx_i^v + \beta_i^v dh_i + dz_i,$$

where $\gamma_i^v \equiv \gamma_i\left(1-s_M^i\right)/\left(1-\gamma_i s_M^i\right)$ and $dx_i^v \equiv dx_i/\left(1-s_M^i\right)$. Aggregating (14) across industries yields

$$(15)\ \sum_{i=1}^{n} w_i dv_i = \gamma^v \sum_{i=1}^{n} w_i dx_i^v + \beta^v \sum_{i=1}^{n} w_i\, dh_i + \sum_{i=1}^{n} (\gamma_i^v - \gamma^v) w_i\, dx_i^v + \sum_{i=1}^{n} (\beta_i^v - \beta^v) w_i\, dh_i + \sum_{i=1}^{n} w_i dz_i,$$

where w_i is the industry's share in aggregate nominal value added. The first variable $\sum_{i=1}^{n} w_i dx_i^v$ is the aggregate input growth and exactly corresponds to the data reported by Kendrick (1961, 1973). Data for the second variable $\sum_{i=1}^{n} w_i dh_i$ are constructed by using data for hours worked and employees reported by Kendrick (1961, 1973) for the whole economy and some industries (mining, manufacturing, and transportation).

The first and second terms represent adjustments for increasing returns to scale and varying input utilization. We ignore the third and fourth terms, which represent a part of reallocation effects arising from industry parameters γ_i^v and β_i^v being different from γ^v and β^v, because of the impossibility of regression at the industry level. The technology series is adjusted for the other reallocation effects, which arise from input movements across industries with different marginal products, because Kendrick (1961, 1973) aggregates inputs with cost shares w_i and the cost shares reflect marginal products. This is shown by rewriting $\sum_{i=1}^{n} w_i dx_i^v$ with (3), (4), and (5):

$$(16)\ \sum_{i=1}^{n} w_i dx_i^v = \sum_{i=1}^{n} w_i \left(\frac{s_K^i}{1-s_M^i} dk_i + \frac{s_{EHN}^i}{1-s_M^i} (dh_i + dn_i) \right)$$
$$= dk + dh + dn - \sum_{i=1}^{n} \left(\frac{K_i}{K} - w_i \frac{\frac{F_1^i V_1^i A_i K_i}{\gamma_i Y_i}}{1 - \frac{F_2^i M_i}{\gamma_i Y_i}} \right) dk_i - \sum_{i=1}^{n} \left(\frac{H_i N_i}{HN} - w_i \frac{\frac{F_1^i V_2^i E_i H_i N_i}{\gamma_i Y_i}}{1 - \frac{F_2^i M_i}{\gamma_i Y_i}} \right) (dh_i + dn_i),$$

where $dk \equiv \sum_{i=1}^{n} (K_i/K) dk_i$ and $dh + dn \equiv \sum_{i=1}^{n} (H_i N_i/(HN))(dh_i + dn_i)$

are capital stock growth and hours worked growth simply aggregated, not with industry shares in aggregate nominal value added. The last two terms represent the adjustments for the reallocation effects.

In sum, this article's regression equation is

$$(17) \qquad dv = constant + \gamma^v dx^v + \beta^v dh + dz,$$

where $dv \equiv \sum_{i=1}^{n} w_i dv_i$, $dx^v \equiv \sum_{i=1}^{n} w_i dx_i^v$, $dh \equiv \sum_{i=1}^{n} w_i\, dh_i$, and $dz \equiv \sum_{i=1}^{n} w_i dz_i$. Technology changes are identified as the residuals, dz.

GOPO CAPITAL

Gordon (1969) and Braun and McGrattan (1993) argue that the government-owned privately operated (GOPO) capital should be counted as private capital in the analysis of productivity in the WWII period. During WWII, the U.S. government built structures and paid for equipments in some industries that were crucial to war efforts (e.g., airframes) and purchased all output produced with the GOPO capital. After the war, the government sold off the GOPO capital to the private sector. Because the GOPO capital statistically entered private capital stock only after the sale, the private sector's TFP growth calculated with data for private capital stock might overestimate wartime technology growth and underestimate postwar technology growth. In other words, if the role of the GOPO capital was significant, the GOPO capital growth should be positively correlated with technology shocks estimated with input data that do not include the GOPO capital. This article regressed this article's technology shocks on the GOPO capital growth for the sample period 1940–1966 and found that the sign of the estimated coefficient was opposite (–0.02) with the *p*-value of 0.04. This result suggests that the effects of the GOPO capital on output were ignorable.[1]

COMPARISON WITH INKLAAR, DE JONG, AND GOUMA (2011)

This article and Inklaar, de Jong, and Gouma (2011) reach the same finding that technology regress is unlikely to have triggered the Great Depression, albeit various potential problems in Inklaar, de Jong, and Gouma's (2011) work that this article points out in the main text. However, it is partly due to coincidence. This article tries to reproduce their technology series by using their data posted on the *Journal of Economic History* website. The figure below plots the reproduced series and this article's new technology series. The reproduced series closely resembles their series plotted in Inklaar, de Jong, and Gouma's (2011) Figure 1, though there seems to be slight differences in levels.

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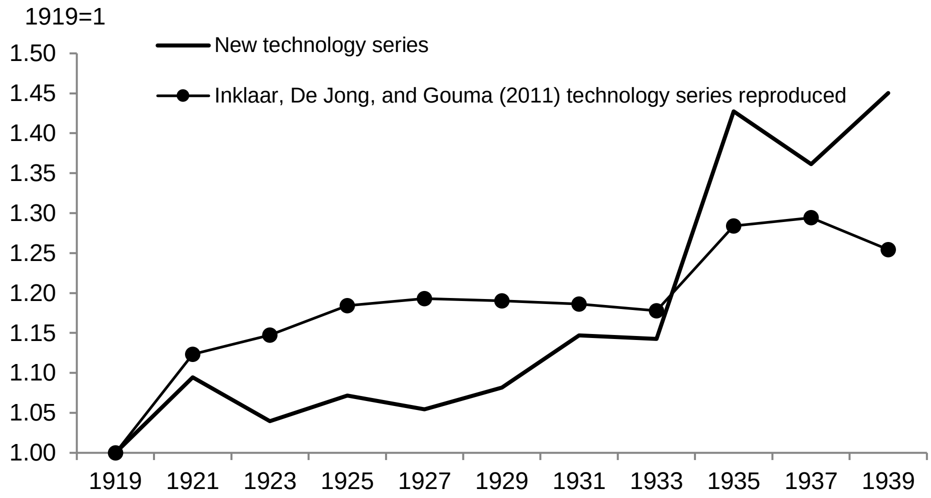
[1] Data for GOPO capital are from Wasson, Musgrave, and Harkins (1970). There are two possible reasons for such small effects of the GOPO capital on output. First, as de Long (1993) argues in the comment on Braun and McGrattan (1993), the amount of GOPO capital may have been so small relative to the U.S. GDP as to only have a second-order impact on wartime productivity. Second, the GOPO capital may have increased wartime GDP by less extent than private capital would. Rotemberg (1993) comments on Braun and McGrattan (1993) that payments for output from the government to firms that used the GOPO capital will have fallen well short of what the firms would earn when they sold the output in the market.



FIGURE

COMPARISON OF TWO TECHNOLOGY SERIES

Sources: See the text.

Both series indicate that technology regress occurred little in 1929–1933, but the two series are different in the sign of change in six of ten periods. Such difference casts doubt on the other results that Inklaar, de Jong, and Gouma (2011) show by using their technology series. For example, they regress hours worked on their technology series for the sample period 1919–1939 and find that the technology improvement had little effects on hours worked. In the main text, this article estimates a near-VAR model by using this article's technology series and finds that the effect of the technology improvement on total hours worked is negative and statistically significant. In this Appendix, this article implements a regression as in Inklaar, de Jong, and Gouma (2011). Variables are growth rates, the explanatory variable is the current technology change only, and the sample period is 1919–1939. This article still finds the contractionary effect of the technology improvement. See the Table following for a comparison between this article and Inklaar, de Jong, and Gouma (2011).

TABLE

REGRESSING TOTAL HOURS ON TECHNOLOGY CHANGE

	Explanatory variable	
Dependent variable	This article's technology	Inklaar, de Jong, and Gouma's (2011) technology
Total hours	–0.41 (0.24)	0.0878 (0.276)

Note: The sample period is 1919–1939. Robust standard errors are shown in parentheses (calculated with RATS command of ROBUSTERRORS, LAGS=3, and LWINDOW=NEWEYWEST). Data are log-differences. Inklaar, de Jong, and Gouma's (2011) result is from their article's Table 2. The coefficient on this article's technology change is statistically significant at the 10 percent significance level.

Sources: See the text.

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