The Great Depression May Have Started Much Earlier Than We Thought

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Abstract

An important open question regarding explanations for the Great Depression is what caused the very rapid initial decline, including a 13 percent drop in real output and a 30 percent drop in business investment in the first year of the downturn, well before the Friedman-Schwartz dated banking panics, significant deflation, or large declines in the money supply which are prominent in the literature. Some theories focus on policies that raised real wages, including Bordo, Erceg and Evans (2000), and Ohanian (2009), which in turn use models building off President Herbert Hoover's program of shifting income to labor, and sharing work. But why did Hoover implement such a policy? This paper shows that in contrast to the standard view that the 1920s economy was on its steady state growth path, that the 1920s economy was in some ways as much of a "one off" event as the 1930s, including 1920s labor, investment, and output far below predicted values from standard growth theory, with deviations nearly as large as those during the Great Depression. The analysis also documents a very large gap between growth in output per hour and real wages in the 1920s, and a large decline in labor's share of income. This provides an explanation for why Hoover pursued his policies, why Roosevelt's New Deal continued them, and suggests that the genesis of the Great Depression may lie in the 1920s economy, which in turn may reflect large changes in the way that businesses were organized and managed and that effectively reduced demand for labor and physical capital.

1 Introduction

Cole and Ohanian (1999, 2001, 2004) and Ohanian (2009) find that Great Depression labor policies aimed at raising real wages above competitive levels and shifting income from capital to labor are important reasons why labor input and output declined so much in the early 1930s, and why they remained depressed at the end of that decade, long after deflation and banking panics ended, and long after productivity growth accelerated.

These studies apply standard, neoclassical balanced growth frameworks, which assume that prior to the Depression, the 1920s economy was on its unique steady-state growth path, that the shocks that generated the Depression were specific to the 1930s, and that in the absence of those shocks, the 1930s economy would have continued on that same long-run growth path.

The view that the 1920s economy was unimportant for understanding the Great Depression, or for understanding the labor-industrial policies of the 1930s, is implicit in other studies, including Friedman and Schwartz (1963), Lucas and Rapping (1969), Lucas (1977), and Bernanke (1983), among others.

In contrast, this paper finds that the 1920s economy may be an important precursor to the Great Depression and the labor and industrial policies implemented by Hoover and Roosevelt. We find that the 1920s economy was significantly depressed relative to the predictions from standard theory. This suggests that the downturn phase of the Great Depression - measured as percent deviations between actual observations and predicted model analogues - may have begun earlier than commonly dated, perhaps a decade earlier.

This finding follows from a three-sector general equilibrium model analysis of the U.S. economy between 1889 to 1929. A multisector model with agriculture, manufacturing, and services is used, as the U.S. economy was still transitioning out of agriculture during this period, and because the most striking economic features of the 1920s that drive the main findings are particularly prominent in the manufacturing sector. The model includes aggregate and sectoral productivity changes, labor and investment wedges as in Cole and Ohanian (2002), Chari, Kehoe and McGrattan (2007), and Brinca, Chari, Kehoe and McGrattan (2016), and intersectoral wedges as in Cheremukhin, Golosov, Guriev and Tsyvinski (2017).

The model captures many of the movements in aggregate output, consumption, investment, labor, and sectoral growth between 1889-1919 in response to the actual levels of aggregate and sectoral productivities. But the model's performance changes substantially between 1919 and 1929. The deviations between actual output, consumption, investment, hours worked, and the model analogues for these variables in the 1920s are very large, with actual output 15 percent below model output, actual hours about 20 percent below model hours, and actual investment nearly 50 percent below model investment. These deviations between the model and data from the 1920s are similar to those from the 1930s in the studies of Ohanian (2009) and Cole and Ohanian (2004).

The finding that output, consumption, investment, and factor inputs in the 1920s were significantly below the levels predicted by standard growth theory presents a different perspective on the timing of the Great Depression and the factors responsible for the Depression. Rather than beginning in 1930 and being driven exclusively by 1930s shocks within the monetary and banking sector, this study suggests the Depression's genesis may be very different, with its roots within the 1920s economy. The decline in hours worked per person between 1919 and 1929 despite rapid productivity growth and labor compensation growing much more slowly than output per hour in this period, sheds light on why Hoover and FDR implemented policies designed to share labor among workers and raise wages above market levels.

We address the pathology of the manufacturing sector in the 1920s by modeling the large technological change in the management and organization of corporations that occurred in the decade. We therefore modify the manufacturing sector production technology by introducing managerial input, whose efficiency increases considerably during the decade as a consequence of the introduction and adoption of modern, scientific management and organizational principles. We find that modifying the model to include a third input that stands in for this increased efficiency changes the model's predictions substantially, including significantly reducing the model's over-predictions for investment, hours worked, output, the gap between output per hour and real wages, and labor's share of income.

The paper is organized as follows. Section 2 presents the data. Section 3 presents the model economy and calibration. Section 4 presents the model findings and discusses them in light of common views about the Great Depression. Section 5 summarizes the technological change within firm management and organization in the 1920s. Section 6 describes the modification of the baseline model and its findings. Section 7 examines how the technological modification impacts the performance of a one-sector version of the model. Section 8 presents a summary and conclusion.

2 Data

The production, hours worked, capital, and productivity data are drawn from Kendrick (1961), which provides annual measures of real output (GNP), consumption, investment, aggregate and sectoral hours worked, aggregate and sectoral capital stocks, and aggregate and sectoral productivity. The period covered is from 1889 to 1929.

We are unaware of other datasets that provide this level of detail and consistency for this period. Cole and Ohanian (1999, 2001, 2004) and Ohanian (2009) also use Kendrick's data, which facilitates comparisons with their results.

We construct per-capita measures of these variables using the working-age population (16 years and over). These data are from the Bureau of the Census.

Some data is available only every ten years, in 1889, 1899, 1909, 1919, and 1929. For these data, we interpolate between their decadal benchmarks. We do not view interpolating over decades as a significant issue, since we are primarily interested in long-run evolutions of these variables, particularly for the decade of the 1920s, in which we will focus on 1929 values compared to 1919 values.

Kendrick provides significant sectoral detail for agriculture and manufacturing, though not for an aggregate service sector. Therefore we use his aggregate data, together with his manufacturing sectoral data. He does report some service sector industry data, such as transportation and utilities. We use that together with other data sources to construct a service sector aggregate and service sector productivity. Details of this construction are in the Appendix.

We split the three sectoral productivities into two components, a common (aggregate) productivity component, and a sector-specific component. To do this, we divide the sectoral TFP data by Kendrick's aggregate TFP data. The sectoral productivities and their decomposition are on page 8. Aggregate TFP data is from Kendrick, which can be seen in Figure 1. This sectoral productivity decomposition yields empirical measures for the sector-specific productivities in the model, which we will denote as B_t^M,B_t^A, and B_t^S, and aggregate productivity, which we denoted as X_t. The sector-specific productivities can be seen in Appendix D in Figure 14.

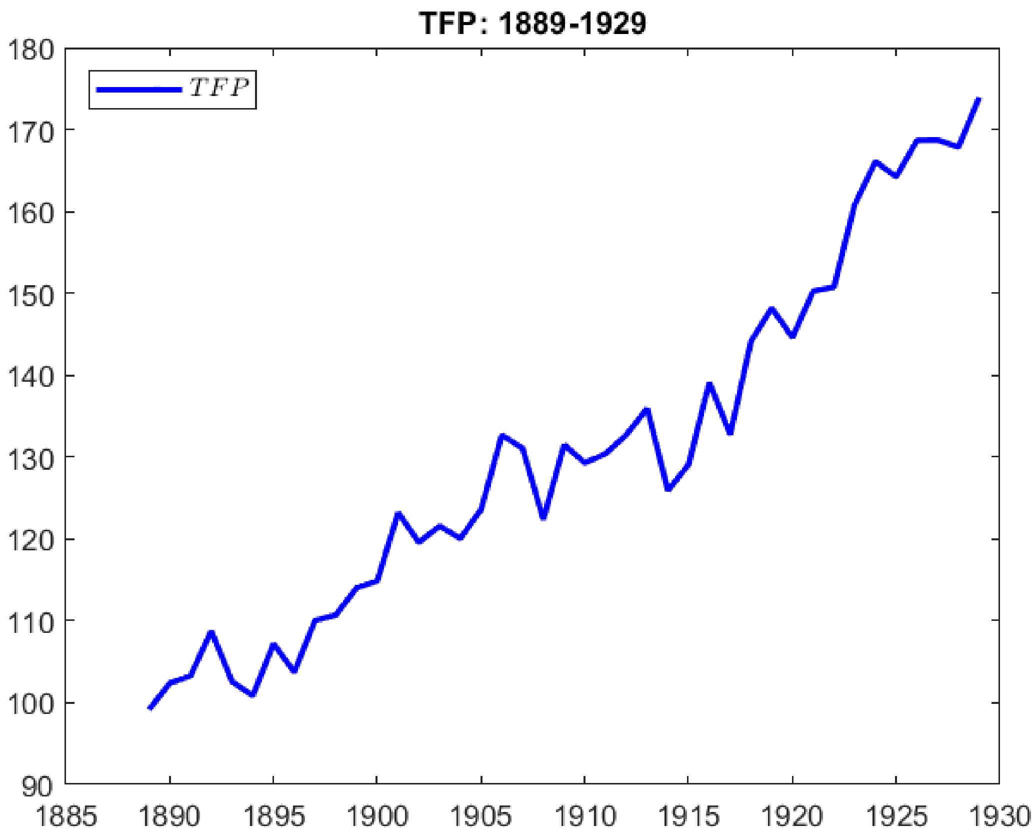

Figure 1: Aggregate TFP.

3 Model

Time is discrete. There is a representative family, and agents have perfect foresight. Although the perfect foresight assumption abstracts from potentially interesting issues regarding uncertainty and shocks, it facilitates understanding the dynamic forces in the economy and also will lead to a conservative estimate of the pathology of the 1920s manufacturing sector, which is described later.

There are three sectors in the economy, agriculture (A), manufacturing (M), and services (S). We include these three sectors since the most striking and pathological features of this period are seen in manufacturing, and since the U.S. is continuing its transformation out of agriculture, and into services.

As is common in the structural transformation literature, the income elasticity of demand for the agriculture good is less than one, the income elasticity for the manufactured good is one, and the income elasticity of demand for services is greater than one. The specific preference specification builds off of Kongsamut, Rebelo and Xie (2001).

Each sector has its own specific productivity, together with the common (economy-wide component). Manufacturing production provides the investment good as well as the manufactured consumption good. There will be an economy-wide market for labor and capital, which means that labor and capital are perfectly mobile across sectors. This assumption is likely to be relatively unimportant given our focus on long-run movements.

3.1 Preferences

The economy is populated by a continuum of households with the following preferences:

$$\sum_{t=0}^{\infty} \rho^t \{\beta \ln(C_t^A - \bar{C^A}) + \gamma \ln(C_t^M) + \theta \ln(C_t^S + \bar{C^S}) + \psi \ln(L_t)\} \tag{1}$$

where C_t^A is consumption of agriculture goods, C_t^M is consumption of manufacturing goods, and C_t^S is consumption of services. The subsistence level of consumption of agriculture goods is denoted by $\bar{C^A} \geq 0$, which generates an income demand elasticity less than one. To create an income elasticity that is greater than one for services, we follow Kongsamut et al. (2001) and include a "subsidy level" for services denoted by $\bar{C^S} \geq 0$. Some authors consider this subsidy term as home production of services. We do not take a stand on the interpretation of this term. Note that with this preference specification, the model economy has an asymptotic balanced growth path, in which the subsistence and subsidy parameters become quantitatively unimportant as the economy grows over time.

The household's discount factor is denoted by $\rho \in (0, 1)$. The parameters β, γ, and θ denote the household's asymptotic expenditure shares on agriculture, manufacturing, and services, respectively.

$$\beta + \gamma + \theta = 1 \tag{2}$$

We let ψ denote the importance of leisure in the utility function. We normalize the total amount of time available at every date to one. Time is allocated either to work in sector s, N_t^s, or for leisure (non-market time):

$$N_t^A + N_t^M + N_t^S + L_t = 1 \tag{3}$$

3.2 Production technology and productivity

Output in sector $s \in \{A, M, S\}$ is produced using the Cobb-Douglas technology:

$$Y_t^s = F_t^s(K_t^s, N_t^s) = B_t^s X_t (\phi_t^s K_t)^\alpha (N_t^s)^{1-\alpha}, \tag{4}$$

where B_t^s, X_t, and ϕ_t^s are respectively, sector s specific productivity, economy-wide productivity, and the share of capital stock used in sector s. We let α denote capital share and X_t^s denote sector s productivity where

$$X_t^s = B_t^s X_t \tag{5}$$

Allocation of capital to sector s in period t is:

$$K_t^s = \phi_t^s K_t \tag{6}$$

We assume that capital and labor freely move across sectors. Capital allocation across sectors yields the following equation.

$$\phi_t^A + \phi_t^M + \phi_t^S = 1 \tag{7}$$

The outputs from the agriculture and service sectors are consumed. The feasibility conditions in these two sectors are:

$$C_t^A = B_t^A X_t (\phi_t^A K_t)^{\alpha} (N_t^A)^{1-\alpha}, \tag{8}$$

$$C_t^S = B_t^S X_t (\phi_t^S K_t)^{\alpha} (N_t^S)^{1-\alpha}. \tag{9}$$

On the other hand, the output from the manufacturing sector can be consumed or invested, $I_t = K_{t+1} - (1 - \delta)K_t$. This standard accumulation equation defines the law of motion for the aggregate capital stock. Investment goods are produced only in the manufacturing sector. Therefore the feasibility condition in the manufacturing sector is

$$C_t^M + K_{t+1} - (1 - \delta)K_t = B_t^M X_t (\phi_t^M K_t)^{\alpha} (N_t^M)^{1-\alpha} \tag{10}$$

3.3 Households

Households maximize

$$\sum_{t=0}^{\infty} \rho^t \{\beta \ln(C_t^A - \bar{C}^A) + \gamma \ln(C_t^M) + \theta \ln(C_t^S + \bar{C}^S) + \psi \ln(L_t)\} \tag{11}$$

subject to

$$P_t^A C_t^A + C_t^M + P_t^S C_t^S + K_{t+1} - (1-\delta)K_t = W_t(1-L_t) + R_t K_t \tag{12}$$

We normalize the price of manufacturing goods equal to one.

3.4 Competitive equilibrium

Given K_{t_0}, as well as a sequence of both sectoral and aggregate productivities $\{B_t^A, B_t^M, B_t^S, X_t\}_{t=t_0}^{\infty}$, a competitive equilibrium consists of sequences of prices $\{P_t^A, P_t^S, W_t, R_t\}_{t=t_0}^{\infty}$, firm allocations $\{K_t^A, K_t^M, K_t^S, N_t^A, N_t^M, N_t^S, Y_t^A, Y_t^M, Y_t^S\}_{t=t_0}^{\infty}$, and household allocations $\{C_t^A, C_t^M, C_t^S, K_{t+1}, L_t\}_{t=t_0}^{\infty}$ such that

- Given the sequence of prices, the firm allocations solve the problems specified for the firms.
- Given the sequence of prices, the households maximize their discounted expected utility subject to their budget constraint.
- Markets clear:
  - $K_t^A + K_t^M + K_t^S = K_t$
  - $N_t^A + N_t^M + N_t^S + L_t = 1$
  - $P_t^A C_t^A + C_t^M + P_t^S C_t^S + K_{t+1} - (1-\delta)K_t = Y_t^A, Y_t^M, Y_t^S$

3.4.1 Households' decisions

Consumption decisions are governed by:

$$\rho^t \frac{\beta}{C_t^A - \bar{C}^A} = P_t^A \lambda_t \tag{13}$$

$$\rho^t \frac{\gamma}{C_t^M} = \lambda_t \tag{14}$$

$$\rho^t \frac{\theta}{C_t^S + \bar{C}^S} = P_t^S \lambda_t \tag{15}$$

The time allocation decision is governed by:

$$\rho^t \frac{\psi}{L_t} = W_t \lambda_t \tag{16}$$

Capital decision:

$$\lambda_t = \lambda_{t+1}(R_{t+1} + 1 - \delta) \tag{17}$$

Because of the representative family, identical production functions across sectors other than their sector-specific productivities, and constant returns to scale, this economy can be aggregated into a one-sector equivalent representation. To do this, we substitute Equation 14 into Equation 13, Equation 15, Equation 16, and Equation 17. Start with Equation 14 into Equation 13.

$$\rho^t \frac{\beta}{C_t^A - \bar{C}^A} = P_t^A \rho^t \frac{\gamma}{C_t^M} \tag{18}$$

which implies

$$\frac{C_t^M}{\gamma} = P_t^A \frac{C_t^A - \bar{C}^A}{\beta} \tag{19}$$

Continue with Equation 14 into Equation 15.

$$\frac{C_t^M}{\gamma} = P_t^S \frac{C_t^S + \bar{C}^S}{\theta} \tag{20}$$

Now Equation 14 into Equation 16.

$$\rho^t \frac{\psi}{L_t} = W_t \rho^t \frac{\gamma}{C_t^M} \tag{21}$$

which implies

$$\frac{C_t^M}{\gamma} = W_t \frac{L_t}{\psi} \tag{22}$$

Then Equation 14 into Equation 17.

$$\rho^t \frac{\gamma}{C_t^M} = \rho^{t+1} \frac{\gamma}{C_{t+1}^M}(R_{t+1} + 1 - \delta) \tag{23}$$

which implies

$$\frac{C_{t+1}^M}{C_t^M} = \rho(R_{t+1} + 1 - \delta) \tag{24}$$

3.4.2 Firms' decisions

Labor demands for each sector $s \in \{A, M, S\}$ are governed by:

$$P_t^s B_t^s X_t (1-\alpha)(K_t^s)^\alpha (N_t^s)^{-\alpha} = W_t \tag{25}$$

Capital demands for each sector $s \in \{A, M, S\}$ are governed by:

$$P_t^s B_t^s X_t \alpha (K_t^s)^{\alpha-1} (N_t^s)^{1-\alpha} = R_t \tag{26}$$

Then we have

$$\frac{1-\alpha}{\alpha}\frac{K_t^S}{N_t^S} = \frac{W_t}{R_t} \tag{27}$$

Given that the manufactured good serves as the numeraire, $P_t^M = 1$, we now determine the relative prices of the agricultural and service sector goods. To do this, one can use Equation 25 (or we can use Equation 26). For example, agriculture and manufacturing.

$$P_t^A B_t^A X_t(1-\alpha)(K_t^A)^{\alpha}(N_t^A)^{-\alpha} = B_t^M X_t(1-\alpha)(K_t^M)^{\alpha}(N_t^M)^{-\alpha} \tag{28}$$

which simplifies below

$$P_t^A B_t^A \left(\frac{K_t^A}{N_t^A}\right)^{\alpha} = B_t^M \left(\frac{K_t^M}{N_t^M}\right)^{\alpha} \tag{29}$$

using Equation 27 we get

$$P_t^A B_t^A = B_t^M \tag{30}$$

When we do the same thing between service and manufacturing we get the following

$$P_t^S B_t^S = B_t^M \tag{31}$$

So that means we have our prices in terms of the followings

$$P_t^A = \frac{B_t^M}{B_t^A} \tag{32}$$

$$P_t^S = \frac{B_t^M}{B_t^S} \tag{33}$$

which are going to be used in the budget constraint. Now we will find out W_t and R_t. Let's use the manufacturing firm as we want to solve through manufacturing goods.

3.5 Simplified model

This model can be simplified into the following problem using the optimality conditions above. Households maximize their discounted utility by choosing consumption of manufacturing goods C_t^M, leisure, L_t, and next period's capital stock, K_{t+1}. The simplified model is as follows.

$$\max_{\{C_t^M, L_t, K_{t+1}\}} \sum_{t=0}^{\infty} \rho^t \{\ln(C_t^M) + \psi \ln(L_t)\} \tag{34}$$

subject to

$$\frac{C_t^M}{\gamma} + \left[\frac{B_t^M}{B_t^A}\right]^{1-\alpha} \bar{C}^A - \left[\frac{B_t^M}{B_t^S}\right]^{1-\alpha} \bar{C}^S + K_{t+1} - (1-\delta)K_t = K_t^{\alpha}[B_t^M X_t(1-L_t)]^{1-\alpha} \tag{35}$$

3.6 Model Calibration

Many parameters in the model can be calibrated using common values. This includes the leisure parameter ψ. This value is chosen so that the household spends 30.5% of their time working in the asymptotic steady state. The household's discount factor, $\rho = 0.93$. We set capital's share parameter, $\alpha = 0.33$ to capital income. We set $\delta = 0.075$. We pick the consumption share parameters in agriculture, manufacturing, and services similar to Kongsamut et al. (2001). These values correspond to the asymptotic consumption expenditure shares for these goods. The preference subsistence $\bar{C}^A$ and subsidy $\bar{C}^S$ terms are chosen so that the model's initial allocation of labor across sectors is similar to that in the data.

3.7 Model Solution

We solve the model through a perfect foresight solution that is similar to Cole and Ohanian (2004) and Ohanian (2009), but is modified to take into account the nonhomotheticities in the model. In summary, given the sequences of the four productivities and initial conditions, the first-order conditions for time allocation and capital accumulation are solved jointly as a system, given a terminal condition that the economy grows asymptotically at its steady-state growth path rate. We use a modified Newton method to solve the system of nonlinear equations.

4 Benchmark Model Versus Data: 1889-1929

This section compares the benchmark model predictions to the data from 1889-1929 in response to the evolution of the four productivities: the common (aggregate) economy productivity, and the productivities that are specific to agriculture, manufacturing, and services. We note that the model tracks hours worked, the sectoral allocation of hours, and output, consumption, and investment relatively closely until 1919. For the 1920s however, we will see that the model predicts much higher levels of aggregate economic activity in response to rapid productivity growth, particularly manufacturing sector productivity growth.

Figure 2 shows real output. Model output is normalized so that it is equal to actual output in 1889. Note that model output tracks actual output quite well until the 1920s, when model output rises considerably faster than in the data, and by 1929 model output is 14 percent higher than actual output.

Figures 3 and 4 show similar patterns for consumption and investment, with similar growth between model and data for the period 1889-1919. However, there is a remarkable deviation between model investment and actual investment in the 1920s, with actual investment 42 percent below model investment by 1929.

Figure 5 shows hours worked. Model hours worked are similar to those in the data from 1889-1919. However, actual hours worked are about 19 percent below the model level in 1929. These 1920s deviations in labor and investment between model and data are comparable to the size of deviations during the Great Depression as reported in Cole and Ohanian (1999).

Figure 6 shows labor allocation among the three sectors.

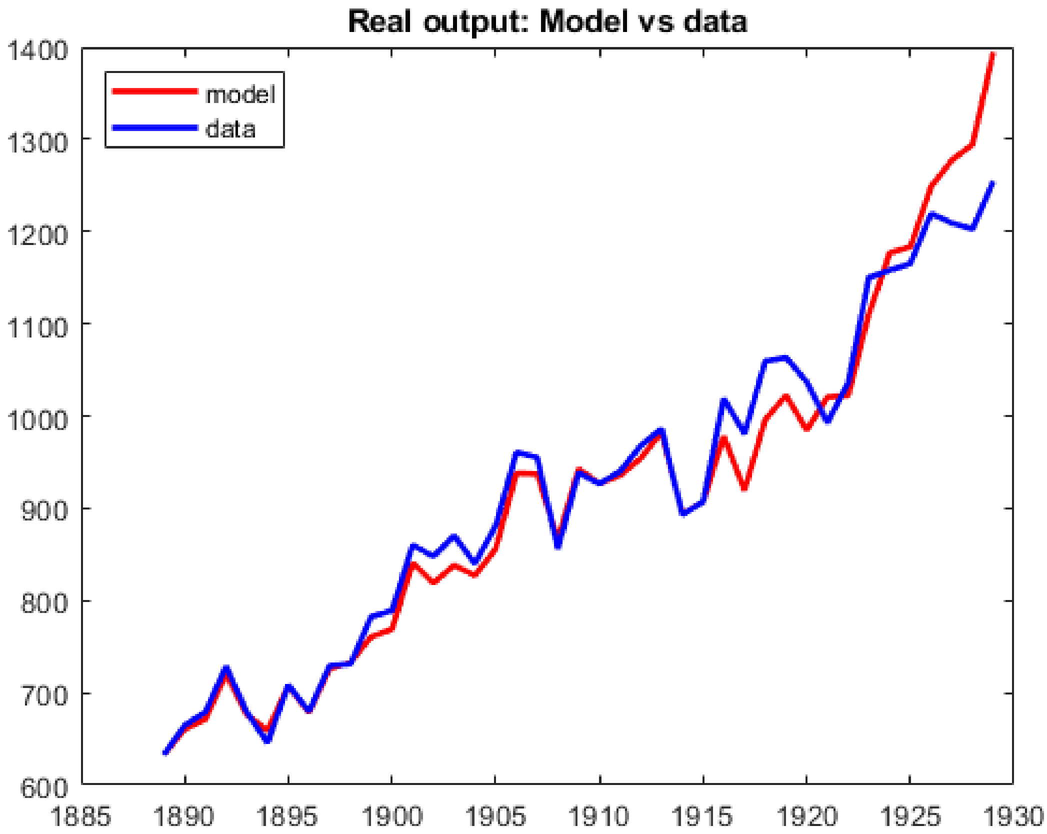

Figure 2: Real output: Model vs data.

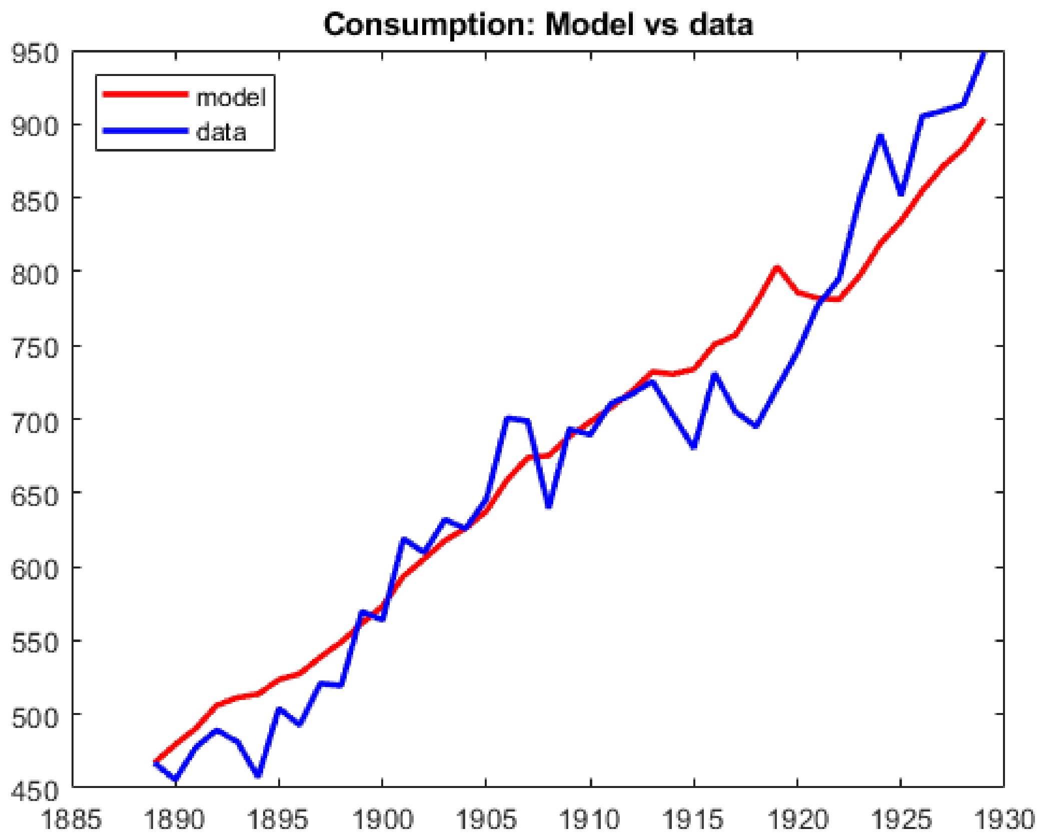

Figure 3: Consumption: Model vs data.

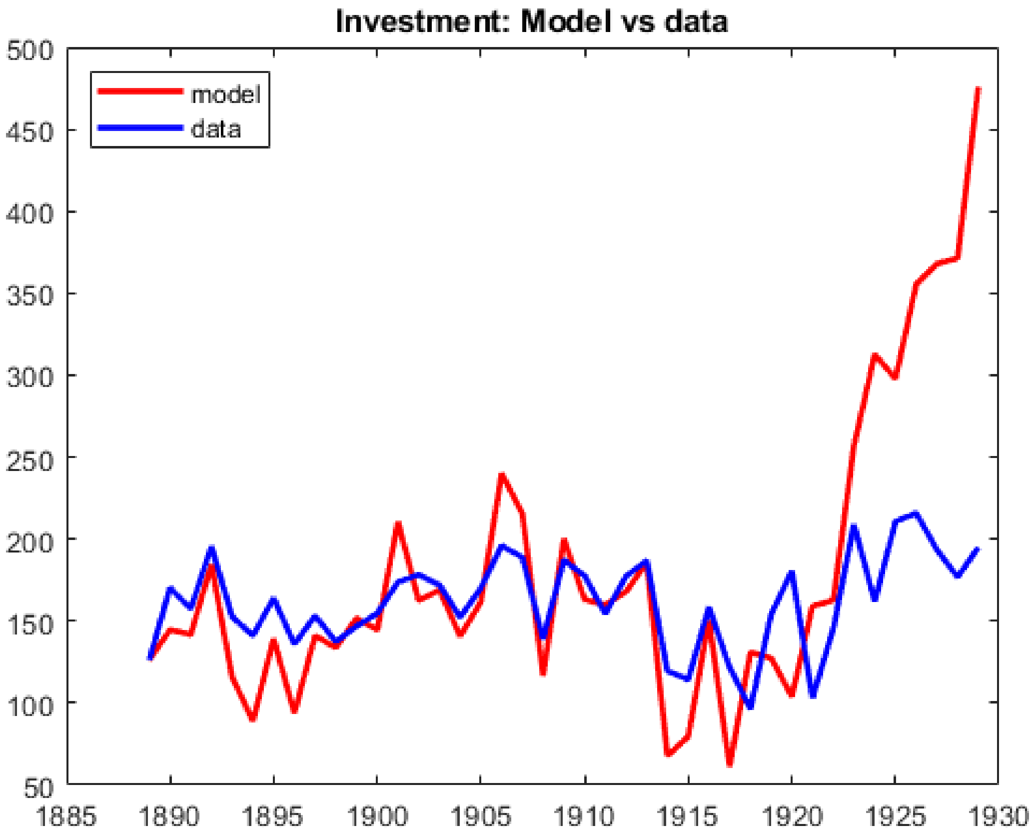

Figure 4: Investment: Model vs data.

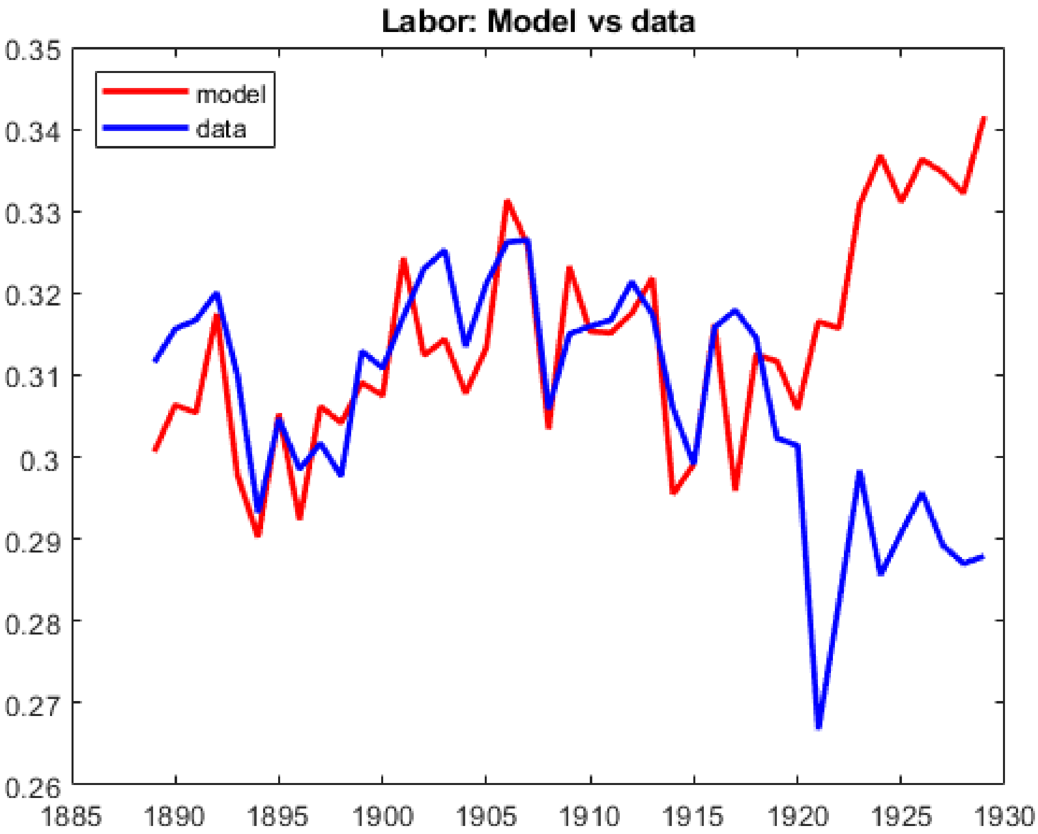

Figure 5: Hours: Model vs data.

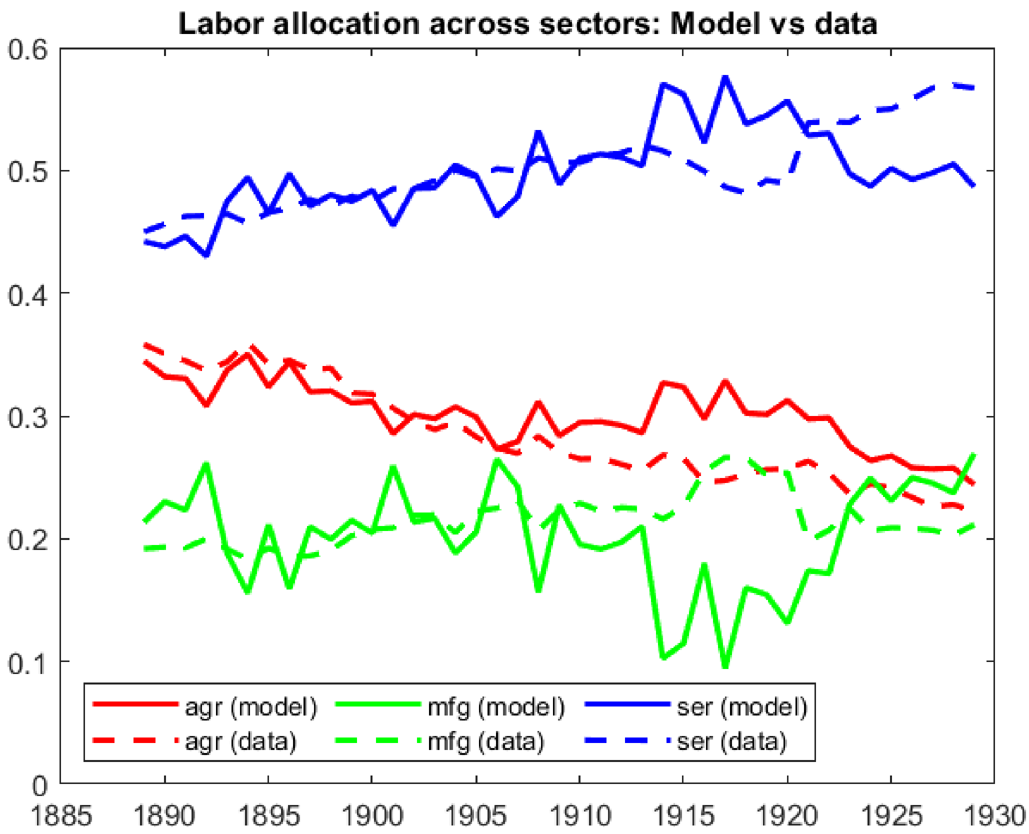

Figure 6: Labor allocation across sectors: Model vs data.

5 Why Were Factor Inputs and Investment Not Higher in the 1920s?

This section discusses some possible factors that may be contributing to the large deviations between the model and data during the 1920s, particularly for understanding why the manufacturing sector did not expand more, and why investment did not rise more. We will also include in this section an additional deviation, which is between observed manufacturing wages and the model. In particular, real output per hour in manufacturing rose 72 percent between 1919 and 1929, whereas actual real manufacturing wages rose by about 15 percent.

One possibility is that the Cobb-Douglas function may be missing some key aspects of production during the 1920s, which is a decade identified by economic historians as a period of large changes in technology, including advances in production methods and in the organization and management of production.

Devine (1983), Jerome (1934), and Oshima (1984) discuss the development and adoption of continuous-process, mechanized production, including many industry-specific innovations, and mass-production methods. Industry-specific technological advances discussed in this literature include new machines developed for bituminous coal mining, road and highway construction, tires, light bulbs, window glass, cigar and cigarette production, textiles, dry cleaning, chemicals, pulp and paper production, and baking. The literature also discusses how technological change and its adoption were facilitated by the spread of electrification and gasoline-powered motors.

Chandler (1990) and Taylor (1911), among others, identify large changes in management practices and corporate organization, including the decentralization of production and the application of scientific and quantitative methods within organizations.

One possibility regarding electrification, productivity growth, declining labor input in manufacturing, and real manufacturing wages is that by the time the 1920s arrived, the accumulation of successful new ideas significantly changed organizational management, design, and production, such that capital became much more productive and more substitutable for labor, and that the 1920s reflected the introduction and dissemination of labor-saving technologies.

We examine this idea by considering a shift in the technology from Cobb-Douglas to CES production with capital-labor substitution greater than one, and in which there is both labor-specific and capital-specific technological change. We will parameterize the technology and apply it to the following facts - a can shed light on the facts regarding real manufacturing wages, which rose about 15 percent, manufacturing output per hour, which rose about 72 percent, manufacturing output, which rose about 65 percent, and manufacturing labor input, which fell about 5 percent.

The technology with capital-specific and labor-specific technological change is given by:

$$Y_t = F(K_t, H_t) = [\mu(A_t K_t)^{\sigma} + (1-\mu)(B_t H_t)^{\sigma}]^{\frac{1}{\sigma}} \tag{36}$$

With competition, factors prices are equal to marginal products:

$$W_t = F_{H_t} = \left(\frac{Y_t}{H_t}\right)^{1-\sigma}(1-\mu)B_t^{\sigma} \tag{37}$$

$$R_t = F_{K_t} = \left(\frac{Y_t}{K_t}\right)^{1-\sigma}\mu A_t^{\sigma} \tag{38}$$

Taking the log derivative of the labor first order condition and evaluating it between 1919 and 1929 yields:

$$d\ln(W) = (1-\sigma)[d\ln(Y) - d\ln(H) + d\ln(B)] \tag{39}$$

Plugging in the observed changes in W, Y, and H, we get:

$$15\% = (1-\sigma)72\% + d\ln(B) \tag{40}$$

This equation has two unknowns, σ, which is bounded above at 1, and the percentage change in labor-specific technology. Note that to have this relationship hold as an equality, we need either a very high value of σ and/or a very small or negative change in labor-specific technology. Assuming that labor-specific technology did not decline, then a value for σ of about 5/6 is needed in this equation. This yields a capital-labor substitution elasticity of about 6, which is far above values reported in the literature, which range from 0.5 – 2.5 (see Lucas (1964) for an estimate for the manufacturing sector, and Karabarbounis and Neiman (2013) and Krusell, Ohanian, Ríos-Rull and Violante (2000) and Ohanian, Orak and Shen (2023) for estimates of the substitutability between capital and labor of different education levels).

This value of σ appears to be empirically implausible. But a high value of σ is also needed for this technology to be classified as a labor-saving technology, which economic historians have focused on, and is one which has a marginal rate of technical substitution between capital and labor (the ratio of the marginal product of labor to capital) that labor declines:

$$MRTS = \frac{\left(\frac{Y_t}{H_t}\right)^{1-\sigma}(1-\mu)B_t^{\sigma}}{\left(\frac{Y_t}{K_t}\right)^{1-\sigma}\mu A_t^{\sigma}} \tag{41}$$

Simplifying, we get:

$$MRTS = \frac{\left(\frac{K_t}{H_t}\right)^{1-\sigma}(1-\mu)}{\mu A_t^{\sigma}} \tag{42}$$

To be considered a labor-saving technology, then we need the *MRTS* to fall, which means we need a large rise in capital-specific technological change, A, between 1919 and 1929, to offset the rise in the capital-labor ratio.

If it was the case that there was no labor-specific technological change in the 1920s, which yields a value of σ = 5/6, then this means capital-specific technological change rose over 100 percent in the decade in order to account for the change in manufacturing output, given the observed changes in manufacturing capital and labor inputs.

Even if capital-labor substitutability rose to such a high level in the 1920s to reconcile the labor efficiency condition, such a high value for σ significantly deepens the puzzle of low investment. To see this, consider how the rental rate and the intertemporal equations change with the CES technology with high K/L substitution:

The rental rate becomes:

$$R_t = F_{K_t} = \left(\frac{Y_t}{K_t}\right)^{1-\sigma} \mu A_t^{\sigma} \tag{43}$$

The intertemporal equation becomes:

$$\frac{C_{t+1}}{C_t} = \beta\left\{\left(\frac{Y_{t+1}}{K_{t+1}}\right)^{1-\sigma} \mu A_{t+1}^{\sigma} + 1 - \delta\right\} \tag{44}$$

Note for a high value of σ that the change in the rental rate will be dominated by changes in capital-specific technological change, and that change is very large. This means as capital-specific technology grows, so does the real return to investment, which motivates households to invest more. Our previous findings with neutral technological change already demonstrated that model investment substantially exceeds actual investment in the 1920s. Thus, while a technology with high-capital labor substitutability can depress the real wage and hours worked, this change has additional implications, which are very rapid growth in capital-specific productivity, which in turn increases the incentive to accumulate capital relative to the baseline model that already is substantially over-predicting investment.

This leads us to consider another change in the manufacturing technology, one which is not only a labor-saving technology but also a capital-saving technology. The next section considers another production technology, one that adds a third input into manufacturing production, and in which there is substitution away from both capital and labor.

6 A Model with a Third Input in Manufacturing

Manufacturing output per hour and output per unit of capital rose substantially between 1919 and 1929, increasing between 62-72 percent, yet manufacturing hours worked declined by about five percent and the manufacturing capital stock rose only about eight percent. This section develops a manufacturing technology that is both labor-saving and capital-saving.

It is motivated by the literature on how firms implemented significant changes in principles of management (see (Taylor, 1911) for a discussion of how firms introduced scientific and quantitative reasoning around this time), and their organization, including decentralizing decisions within the firm and the hiring of more managers to coordinate and develop that decision-making (see (Chandler, 1990)). This in turn allowed firm leaders to focus their time on bigger picture issues.

This literature has stressed how productive efficiency increased substantially in the 1920s, and how management and organizational changes led to firms economizing on the use of labor and capital inputs.

To capture the efficiency increases discussed within this literature, we specify a manufacturing production function with a third input. For the time being, we specify this input as a fixed factor that has a substitution elasticity with capital and labor that is greater than Cobb-Douglas, and which experiences factor-specific efficiency changes. This section specifies the new production technology for just manufacturing, given the emphasis on this sector within the literature. However, the large changes in the organization and management of firms discussed within the literature likely were adopted in other sectors. Therefore, we specify a one-sector model in the following section that specifies this production function across all sectors of the economy.

The manufacturing sector has the following production function:

$$Y_t^M = \left[\eta_t E_t^{\mu} + (1-\eta_t)(B_t^M X_t (K_t^M)^{\alpha}(N_t^M)^{1-\alpha})^{\mu}\right]^{\frac{1}{\mu}} \tag{45}$$

The quantity of the fixed factor is normalized to one unit, and its efficiency is given by E_t. The payment to this factor will be the residual income after paying physical capital and labor for their respective marginal products, and the payment will be received by shareholders and treated as capital income. This specification is related to the literature focusing on organizational capital, which is interpreted as knowledge within a firm, such as Prescott and Visscher (1980) and Atkeson and Kehoe (2005), and McGrattan and Prescott (2005), which includes a third input that is not fixed, but which is in effect a capital good that can be accumulated, and which they refer to as intangible/knowledge capital. Hall (2001) is thematically similar to McGrattan and Prescott. Note that we allow for time variation in the parameter η.

The marginal products of tangible capital, R_t, and labor, W_t are given by:

$$R_t = (Y_t^M)^{1-\mu}\alpha(1-\eta_t)\frac{(B_t^M X_t (K_t^M)^{\alpha}(N_t^M)^{1-\alpha})^{\mu}}{K_t^M} \tag{46}$$

$$W_t = (Y_t^M)^{1-\mu}(1-\alpha)(1-\eta_t)\frac{(B_t^M X_t (K_t^M)^{\alpha}(N_t^M)^{1-\alpha})^{\mu}}{N_t^M} \tag{47}$$

The competitive payments accruing to the fixed factor, which we will assume are paid to the firm owners, are:

$$T_t = Y_t^M - R_t K_t^M - W_t N_t^M \tag{48}$$

6.1 Parameterization of Economy with 3-Input Manufacturing

We are unaware of any macroeconomic studies that have evaluated the large change in firm efficiency reflecting the adoption of modern management and firm organization principles in the 1920s. We, therefore, conduct a set of experiments with parameter values chosen specifically to broadly assess whether modeling these changes may be an interesting approach for assessing the 1920s coincidence of low hours worked, low investment, low growth in wages, and a drop in labor's share.

We consider two values for the substitution elasticity parameter, μ, which are 0.8 and 0.5, which provide substitution elasticities of 2 and 5, the latter of which is an obvious upper bound. We specify the growth rate of the efficiency of the fixed factor, E, to be the same as the growth rate of the economy-wide TFP, X, in the previous section, 1.4 percent per year, between 1889 and 1919. We then increase the growth rate of E to nine percent per year, and we specify the growth rate of the productivity hitting capital and labor such that the model matches output per hour in the data.

The share parameter η is fixed at a value of 0.05 between 1889-1919, then increases to 0.15. We also evaluate a larger change in η, which is 0.02 between 1889-1919 and then increases to 0.20. The preference subsistence and subsidy terms are specified to so that the initial allocation of labor across sectors is similar to the data, as in the prior experiments.

There are four experiments which vary both the parameter governing the substitutability between the fixed factor and capital and labor ($\mu \in \{0.8, 0.5\}$) and η, the parameter that influences the relative income shares between the fixed factor, capital and labor, and how that parameter changes over time, in which η is initially 0.05 up to 1919, then rises to 0.15 in 1920 and remains there, and in which η is initially 0.02, then rises to 0.2 in 1920 and remains there.

6.2 Findings from Model with 3-Input Manufacturing

Introducing the third input into manufacturing production has a substantial and interesting effect on the model economy's predictions. The benchmark model's overpredictions of both hours worked and investment drop significantly, particularly for investment. Investment in the baseline model exceeds actual investment by 125 percent by 1929, whereas in the model with the third manufacturing input, the largest deviation between model investment and actual investment is about 35 percent, which is for the case of a substitution elasticity of two between the fixed factor and the capital-labor aggregate and the share parameter η that is .05 between 1889 and 1919 and then rises to 0.15 in 1920.

For the other parameterizations, the investment deviation ranges between zero and about 20 percent. The investment deviation for the parameterization with a substitution elasticity of two, and a change in η from .02 to 0.2, has a deviation of about 12 percent.

The findings are surprisingly insensitive to changes in the substitution elasticity between the fixed factor and the labor-capital aggregate, as changing this substitution elasticity from 5, which is likely too high, to 2, which may be reasonable, has relatively little effect on the quantitative results. The results are more sensitive to changes in the parameter η, which is a technology parameter that increases the incentive to substitute away from physical capital and labor, as it increases the importance of the fixed factor while reducing the importance of the physical capital-labor aggregate.

The following figures show the result of the experiment in which $\mu = 0.5$ and η increases from 0.02 to 0.20. Figure 7, 8, and 16 show output, labor, and investment, respectively.

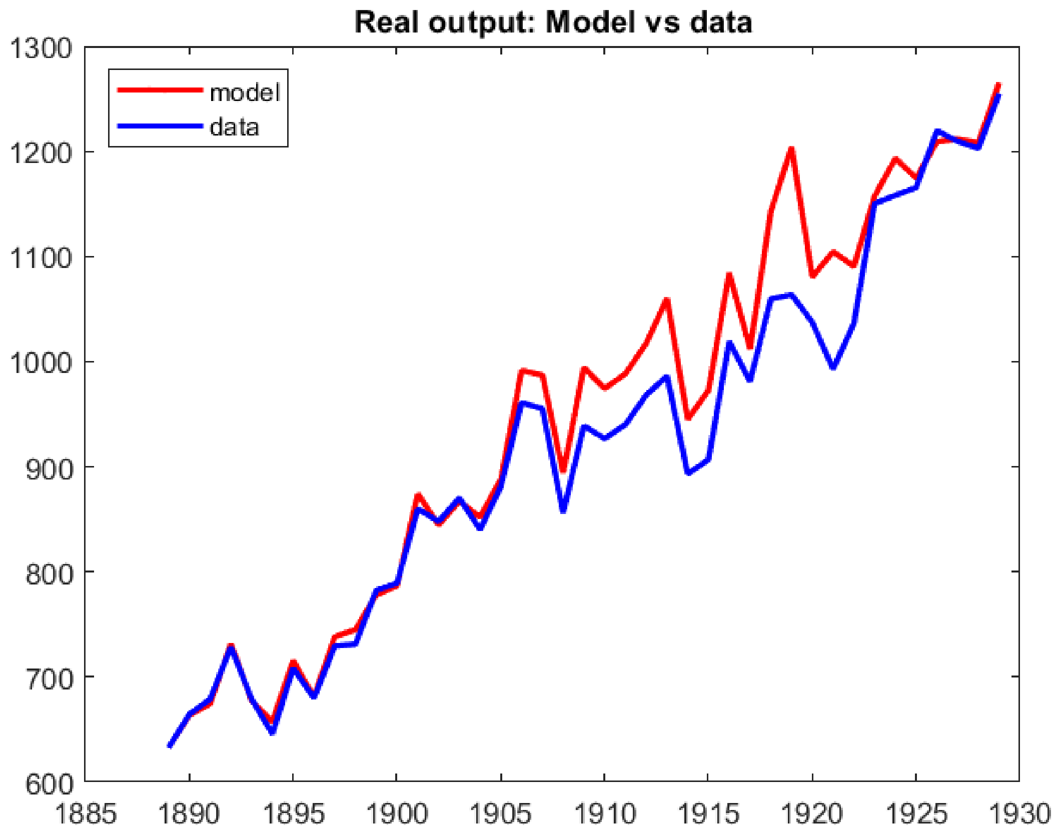

Figure 7: Output: Model vs data. Model with 3-Input Manufacturing.

7 A One-Sector Economy with a Third Input

This section specifies a one-sector economy with the third input in the production technology, so that in effect all sectors, and not just manufacturing, have the additional input.

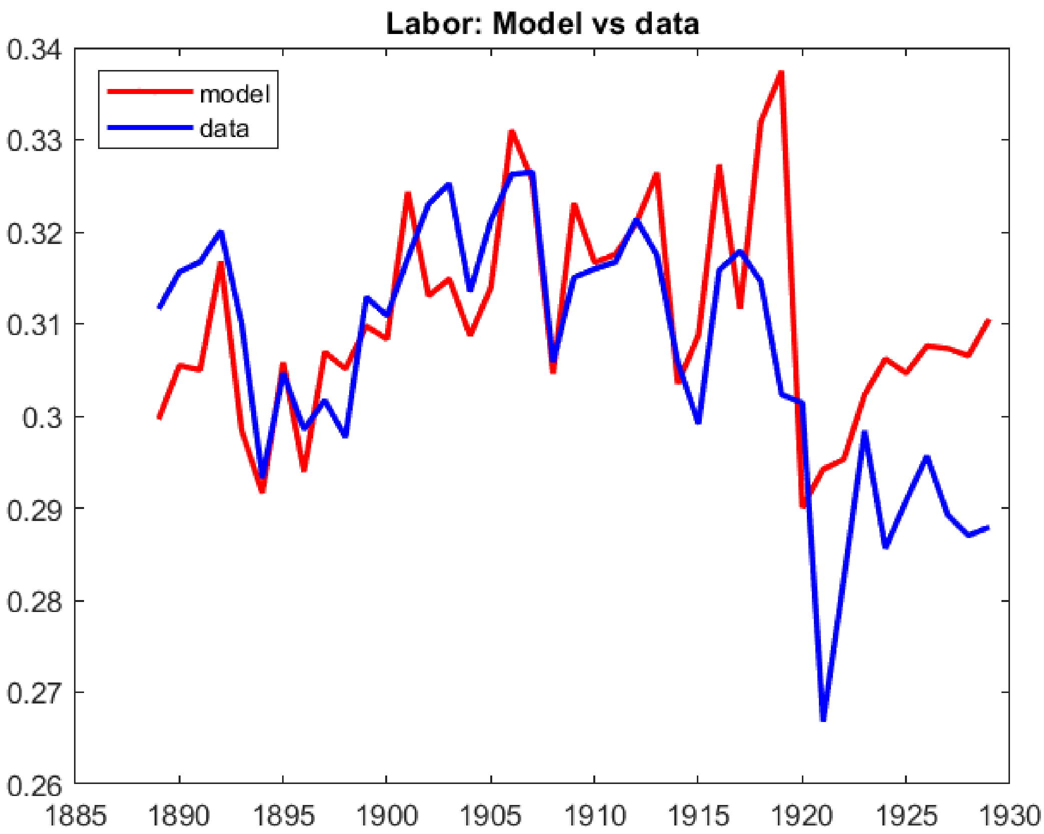

Figure 8: Labor: Model vs data. Model with 3-Input Manufacturing.

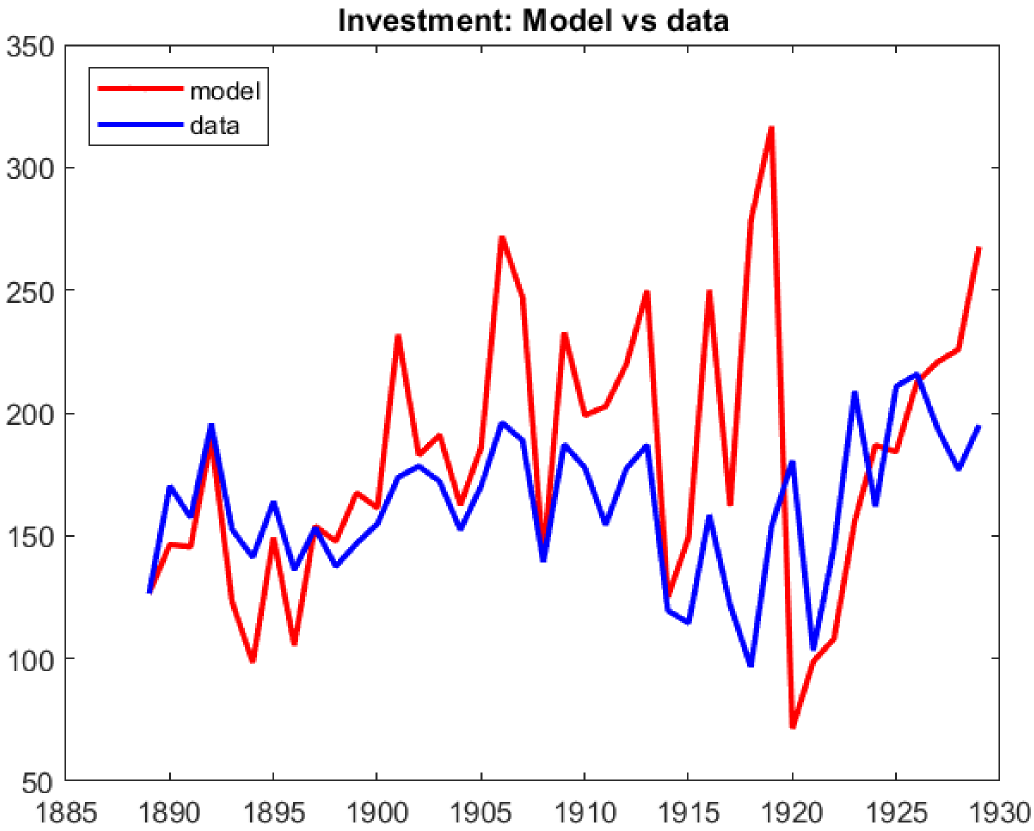

Figure 9: Investment: Model vs data. Model with 3-Input Manufacturing.

Households' problem

$$\max_{\{C_t, L_t, K_{t+1}\}} \sum_{t=0}^{\infty} \rho^t \{\ln(C_t) + \psi \ln(L_t)\} \tag{49}$$

subject to

$$C_t + K_{t+1} - (1-\delta)K_t = W_t(1-L_t) + R_t K_t + T_t \tag{50}$$

where T is transfer which are profits from firms using management capital, E. From households' optimization:

$$\frac{1}{C_t} = \lambda_t \tag{51}$$

$$\frac{\psi}{L_t} = W_t \lambda_t \tag{52}$$

$$\lambda_t = \rho \lambda_{t+1}(R_{t+1} + 1 - \delta) \tag{53}$$

Firms' problem

$$\max_{K_t, H_t} \left[\eta_t E_t^{\mu} + (1-\eta_t)(X_t K_t^{\alpha} H_t^{1-\alpha})^{\mu}\right]^{\frac{1}{\mu}} - R_t K_t - W_t H_t \tag{54}$$

where we define $Y_t = \left[\eta_t E_t^{\mu} + (1-\eta_t)(X_t K_t^{\alpha} H_t^{1-\alpha})^{\mu}\right]^{\frac{1}{\mu}}$. From the firms' optimization:

$$W_t = (Y_t)^{1-\mu}(1-\alpha)(1-\eta_t)\frac{(X_t K_t^{\alpha} H_t^{1-\alpha})^{\mu}}{H_t} \tag{55}$$

$$R_t = (Y_t)^{1-\mu}\alpha(1-\eta_t)\frac{(X_t K_t^{\alpha} H_t^{1-\alpha})^{\mu}}{K_t} \tag{56}$$

The equations to be solved are:

$$\frac{\psi}{L_t} = \frac{W_t}{C_t} \tag{57}$$

$$\frac{C_{t+1}}{C_t} = \rho(R_{t+1} + 1 - \delta) \tag{58}$$

$$C_t + K_{t+1} - (1-\delta)K_t = Y_t \tag{59}$$

$$W_t = (Y_t)^{1-\mu}(1-\alpha)(1-\eta_t)\frac{(X_t K_t^{\alpha} H_t^{1-\alpha})^{\mu}}{H_t} \tag{60}$$

$$R_t = (Y_t)^{1-\mu}\alpha(1-\eta_t)\frac{(X_t K_t^{\alpha} H_t^{1-\alpha})^{\mu}}{K_t} \tag{61}$$

Transfer $T_t = Y_t^M - W_t(1-L_t) - R_t K_t$.

The following figures compare model and data. Figure 10, 11, 12, and 13. The figures show that an increase in the fixed factor's productivity in the 1920s result in output, consumption, and labor that are very similar to the data. Investment is also, though it is higher than the data before the 1920s.

8 Conclusion

The 1920s economy has been viewed within the literature as largely conforming to balanced growth path characteristics, and as such had no influence on the Great Depression. But the 1920s were a decade of significant differences from standard balanced growth path characteristics, including off-the-charts productivity growth in the manufacturing sector, but hours worked in manufacturing declining over the decade, and the capital stock rising by only 8 percent. At the same time, real manufacturing wages rose only about 15 percent in the decade, despite real output per hour worked rising 72 percent, and labor's share of income declined substantially

The decline in hours worked, the large divergence between worker compensation and output per hour, and the drop in labor's share provide a new interpretation for why Herbert Hoover jawboned major manufacturing firms to shift income from shareholders to labor and share work among employees.

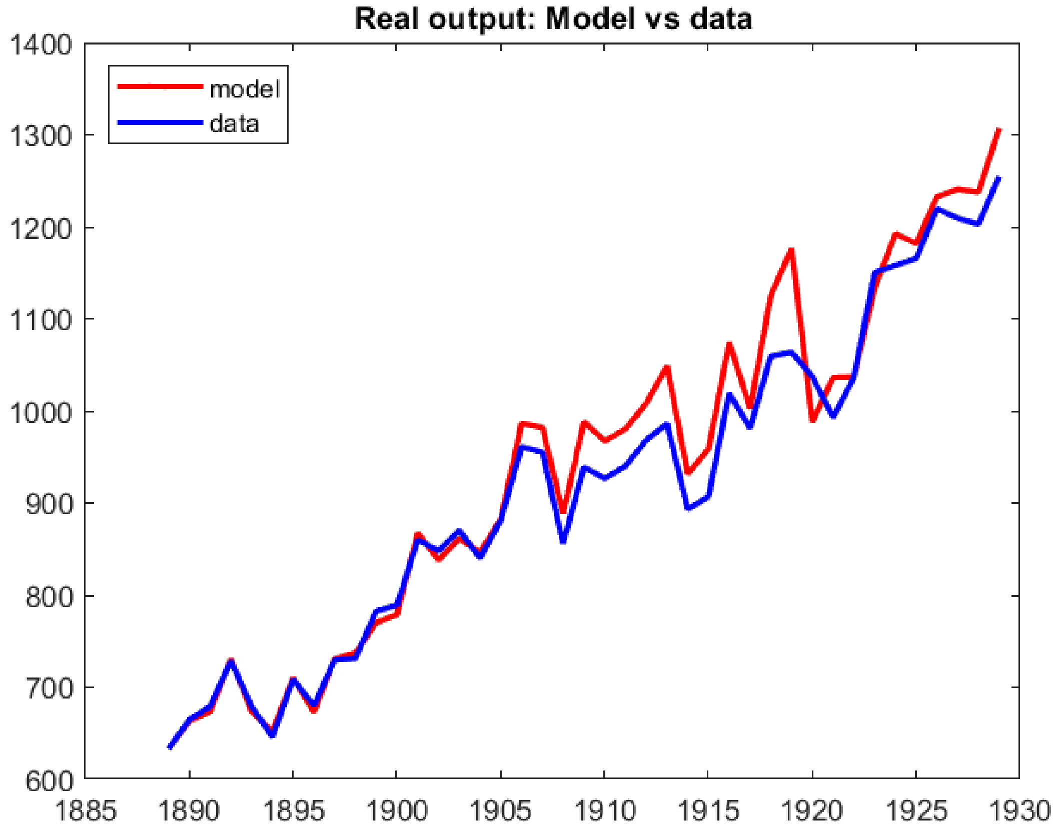

Figure 10: Output: Model vs data. A One-Sector Economy with a Third Input.

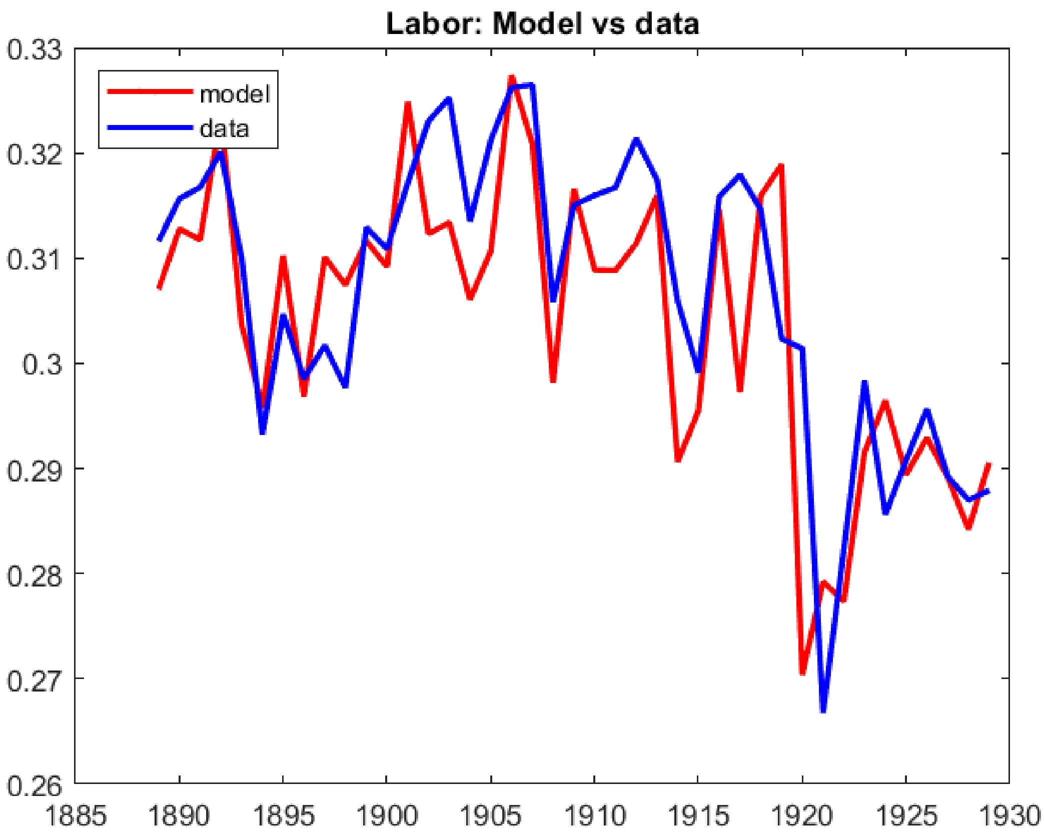

Figure 11: Labor: Model vs data. A One-Sector Economy with a Third Input.

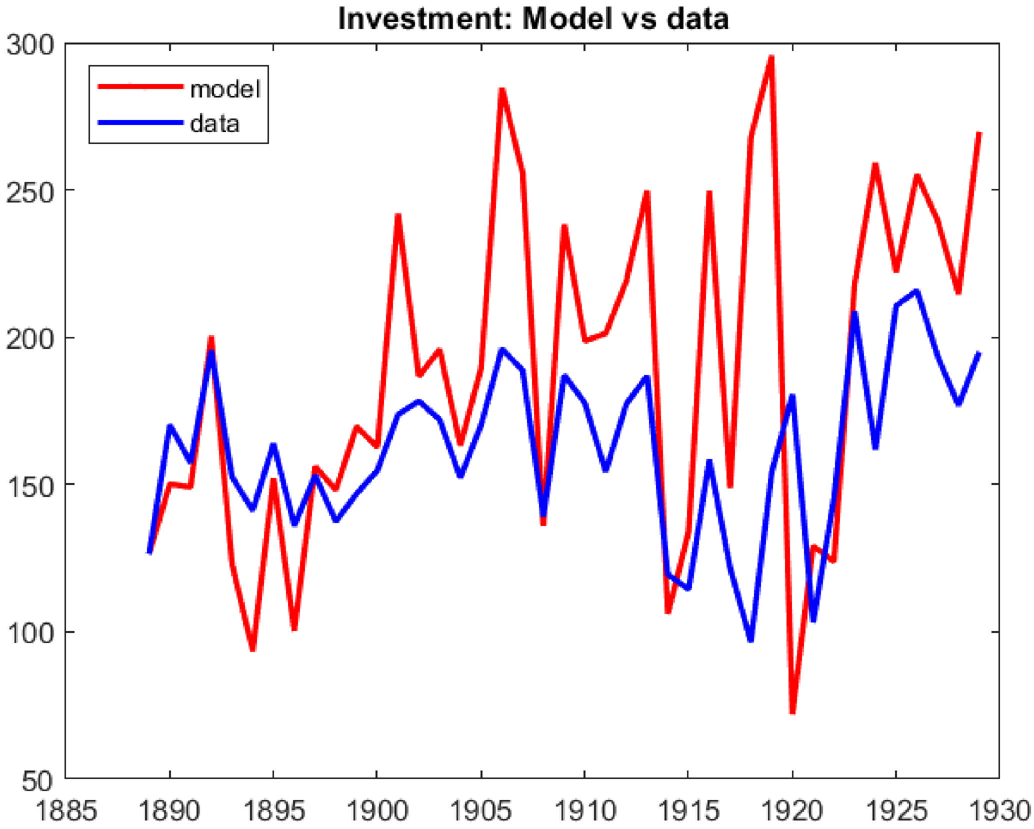

Figure 12: Investment: Model vs data. A One-Sector Economy with a Third Input.

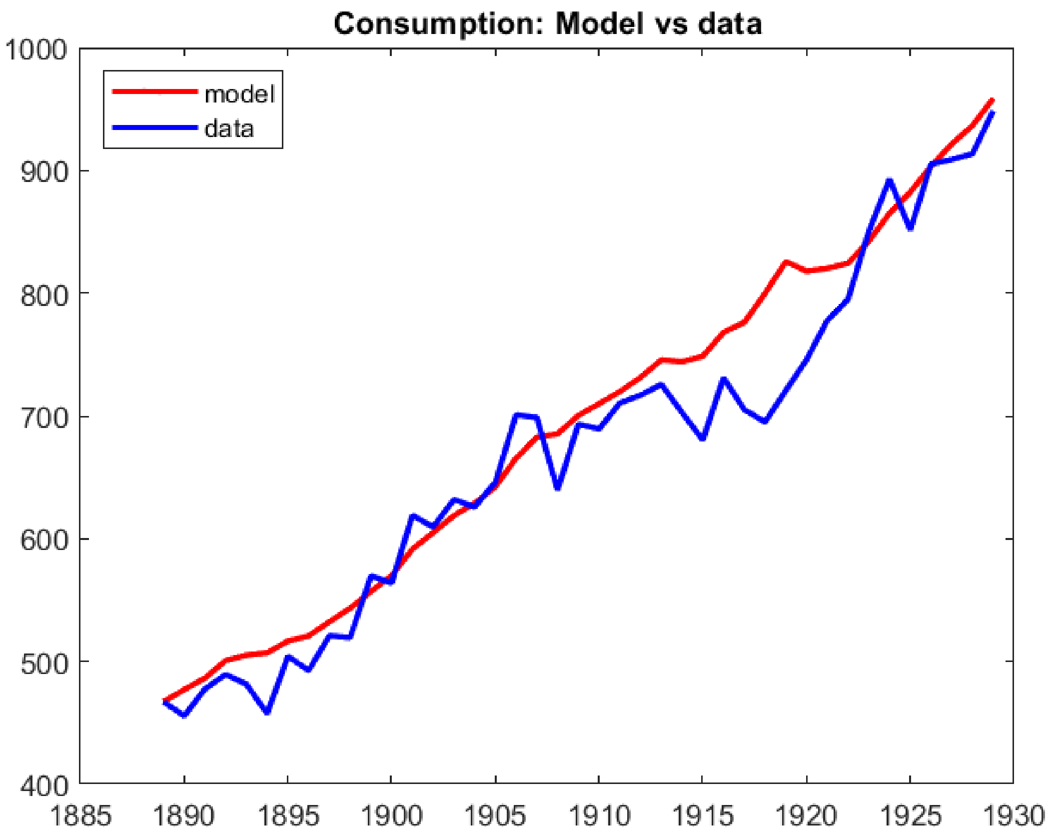

Figure 13: Consumption: Model vs data. A One-Sector Economy with a Third Input.

Standard theory shows that the 1920s economy should have boomed in response to such high productivity, with investment rising roughly 100 percent above actual investment by the end of the 1920s, and labor rising significantly. The analysis shows that the 1920s macroeconomy is so far below model predictions as to be similar to those during the Great Depression.

The literature on technological change highlights significant changes in organization design, organization, and management as key reasons behind the enormous increase in manufacturing productivity that allowed organizations economize on capital and labor.

We modelled this innovation by modifying production within the model economies presented here to include a third factor of production (a fixed factor we interpret as organizational efficiency) whose productivity rises in the 1920s, and which is substitutable with physical capital and labor. We found that this modification brings the model's predictions regarding compensation, investment, output, labor, labor's share, and consumption much closer in line with actual observations.

Future research will evaluate whether this capital and labor-saving technological change may have implications for the size and speed of the Great Depression.

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A Data

A.1 Sectoral TFPs

Kendrick (1961) provides TFPs for the agriculture sector and the manufacturing sector every ten years. The available years are 1889, 1899, 1909, 1919, and 1929. Kendrick (1961) also provides the TFP for the non-farm economy which we think of as the sum of the manufacturing sector and service sector. We think the TFP for the non-farm (NF) economy as manhours (H) weighted average TFPs of the manufacturing (M) sector and the service sector (S).

$$TFP_t^{NF} = \frac{H_t^M}{H_t^M + H_t^S} TFP_t^M + \frac{H_t^S}{H_t^M + H_t^S} TFP_t^S \tag{62}$$

where TFP_t^s (H) is the TFP (manhours) in sector s. We use the following formula to calculate the TFP in the service sector.

$$TFP_t^S = \frac{H_t^M + H_t^S}{H_t^S} TFP_t^{NF} - \frac{H_t^M}{H_t^S} TFP_t^M \tag{63}$$

This method gives us the TFP for the service sector every ten years. We now have the TFPs for the three sectors we are interested in every ten years. We construct the TFPs for the in-between years via interpolation using their decade growth every ten years.

A.2 Manhours

Kendrick (1961) provides manhours in the national economy for the private and the general government in Table A-X. He further divides the private national economy into the farm sector and non-farm sector. We think of the manhours in the farm sector as the manhours in the agriculture sector in our paper. We then construct the manhours in the manufacturing sector using his book's appendix on the manufacturing sector where he reports the manhours (as an index where the manhours in the sector in 1929 are equal to 100 in Table D-II). He also reports the manhours in manufacturing in 1929 in Table D-VII. Using these two pieces of information we construct the manhours in the manufacturing sector. And we construct the manhours in the service sector as the difference between the manhours in the non-farm sector and the ones in the manufacturing sector.

A.3 Capital

Kendrick (1961) presents the capital stock in the economy in Table A-XV reported in the millions of 1929 dollars. He provides the capital stock for the national economy, the domestic economy, and the private domestic economy. We use the capital stock in the farm sector under the private domestic economy as the capital stock in the agriculture sector in our paper. He also provides the capital stock in the private non-farm sector under the private domestic economy. This sector consists of the manufacturing sector and the service sector in our paper.

We access the capital stock in manufacturing from Creamer et al (1961) in Table A-8 on page 241. It is the total capital in book value and in 1929 prices (in million dollars). They have the same value as the Census of Manufactures. It is available for the following years: 1899, 1900, 1904, 1909, 1919, and 1929. They can be also accessible from Historical Statistics of the United States Colonial Times to 1970 (Bicentennial Edition) in Chapter P Series P 123-176 on page 685.

We interpolate this capital stock in-between years to construct the capital stock in the manufacturing sector for each year. The capital stock in the service sector is constructed by the capital stock in the private non-farm sector minus the capital stock in the manufacturing sector.

A.4 Consumption

We use the data from Historical Statistics of the United States, Millennial Edition Online, edited by Susan B. Carter, Scott Sigmund Gartner, Michael R. Haines, Alan L. Olmstead, Richard Sutch, and Gavin Wright, Cambridge University Press 2006. The chapter Cd Consumer Expenditures by Lee A. Craig reports consumer expenditures by type between 1900 and 1929 both in 1987 dollars and nominal terms. The main source here is Stanley Lebergott, Consumer Expenditures: New Measures and Old Motives (Princeton University Press, 1996), Table A1. We follow Alder, Boppart and Muller (2022) to classify the goods into one the three sectors that we have in our paper. Their methodology is explained in their Appendix C.

The consumption of agriculture goods is the sum of Purchased food and meals without alcohol (Cd3), Food to employees (Cd4), Food consumed on farms (Cd5), Alcohol (Cd6).

The consumption of manufacturing goods is the sum of Tobacco (Cd7), Shoes (Cd9), Civilian clothing (Cd10), Military clothing (Cd13), Jewelry (Cd14), Toilet articles (Cd17), Furniture and mattresses (Cd25), Kitchen appliances (Cd26), China (Cd27), Furnishings, other durables (Cd28), Furnishings, semidurables (Cd29), Cleaners and polishes (Cd30), Stationery (Cd31), Wood, gas, and coal (Cd35), Drugs (Cd40), Motor vehicles and wagons (Cd53), Tires and accessories (Cd54), Gasoline and oil (Cd56), Books and maps (Cd61), Magazines and newspapers (Cd62), Nondurable toys (Cd63, Durable toys and wheel goods (Cd64), Music, radio, and television (Cd65), Flowers and plants (Cd66)

The consumption of service goods is the sum of Clothing services (Cd15), Barber and beauty (Cd18), Owner occupied housing (Cd20), Tenant-occupied housing (Cd21), Rent of farmhouse (Cd22), Other housing (Cd23), Electricity (Cd32), Gas (Cd33), Water (Cd34), Telephone and telegraph (Cd36)35, Domestic services (Cd37), Other household operations (Cd38), Ophthalmology (Cd41), Medical, dental, and other professional services (Cd42), Hospitals (Cd43), Health insurance (Cd44), Brokerage (Cd46), Banking and financial services (Cd47), Life insurance (Cd48), Legal services (Cd49), Funeral (Cd50), Other personal business (Cd51), Automobile repair (Cd55), Auto insurance and tolls (Cd57), Local purchased transportation (Cd58), Intercity purchased transportation (Cd59), Recreational services (Cd67), Higher education (Cd69), Elementary education (Cd70), Other education and research (Cd71), Religion (Cd73), Welfare (Cd74), Net foreign travel (Cd75).

A.5 Wages

We access the average annual earnings from Historical Statistics of the United States, Colonial Times to 1970 (Bicentennial Edition). In Chapter D of Part 1, we access we access it under Series D 739-764. This data is available between 1900 and 1970. And it is in current dollars. The table consists of the wages in Agriculture, forestry, and fisheries (739), Manufacturing (740), Mining (741), Construction (745), Transportation (746), Communications and public utilities (750), Wholesale and retail trade (753), Finance, insurance, and retail trade (754), Services (755), Government (761). We think that Agriculture, forestry, and fisheries (739) refer to the agriculture sector in our model and Manufacturing (740) refers to the manufacturing sector. The service sector in our model refers to the sum of all sectors except Agriculture, forestry, and fisheries (739) and Manufacturing (740).

Kendrick (1961) reports the manhours which we mentioned above and also the persons engaged (which are in thousands). The persons engaged follow the same structure as in the manhours. They are reported in Table A-V.

We calculate the hourly wages as persons engaged times average annual earnings and then we divide this by manhours.

$$\text{Wage}_t^i = \frac{\text{Persons Engaged}_t^i \times \text{Average annual earnings}_t^i}{\text{Manhours}_t^i} \tag{64}$$

A.6 Prices

To construct the price indexes in each sector, we divide the real expenditure (taking the base year as 1929) by the nominal expenditure. The real and nominal expenditures in sectors are explained above.

B NIPA accounting

We want to compare the model outcomes with the data from the Kendrick (1961). In this section, we describe how the NIPA accounting is done in our model. The accountant is after the following equation.

$$P^{AM}_{1929}B^A_t X_t(K^A_t)^{\alpha}(N^A_t)^{1-\alpha} + B^M_t X_t(K^M_t)^{\alpha}(N^M_t)^{1-\alpha} + P^{SM}_{1929}B^S_t X_t(K^S_t)^{\alpha}(N^S_t)^{1-\alpha} \tag{65}$$

where $P^{AM}_{1929} = \frac{B^M_{1929}}{B^A_{1929}}$ and $P^{SM}_{1929} = \frac{B^M_{1929}}{B^S_{1929}}$. Please note that the reference year is 1929 and $B^A_{1929} = B^M_{1929} = B^S_{1929} = 1$. That is the say the index prices are equal to 1 in the year of 1929. Then we write the above equation as follows:

$$=B^A_t X_t\left(\frac{K^A_t}{N^A_t}\right)^{\alpha} N^A_t + B^M_t X_t\left(\frac{K^M_t}{N^M_t}\right)^{\alpha} N^M_t + B^S_t X_t\left(\frac{K^S_t}{N^S_t}\right)^{\alpha} N^S_t \tag{66}$$

First, observe that the following identity:

$$\frac{K^A_t}{N^A_t} = \frac{K^M_t}{N^M_t} = \frac{K^S_t}{N^S_t} = \frac{K_t}{1-L_t} \tag{67}$$

Substitute this back into the above equation:

$$B^A_t X_t\left(\frac{K_t}{1-L_t}\right)^{\alpha} N^A_t + B^M_t X_t\left(\frac{K_t}{L_t}\right)^{\alpha} N^M_t + B^S_t X_t\left(\frac{K_t}{1-L_t}\right)^{\alpha} N^S_t \tag{68}$$

Then divide and multiply each term by $1 - L_t$ to write the following:

$$B^A_t X_t\left(\frac{K_t}{1-L_t}\right)^{\alpha} N^A_t\frac{1-L_t}{1-L_t} + B^M_t X_t\left(\frac{K_t}{L_t}\right)^{\alpha} N^M_t\frac{1-L_t}{1-L_t} + B^S_t X_t\left(\frac{K_t}{1-L_t}\right)^{\alpha} N^S_t\frac{1-L_t}{1-L_t} \tag{69}$$

Now re-organize the terms

$$B^A_t X_t K^{\alpha}_t(1-L_t)^{1-\alpha}\frac{N^A_t}{1-L_t} + B^M_t X_t K^{\alpha}_t(1-L_t)^{1-\alpha}\frac{N^M_t}{1-L_t} + B^S_t X_t K^{\alpha}_t(1-L_t)^{1-\alpha}\frac{N^S_t}{1-L_t} \tag{70}$$

You can see that each of the products is scaled by its labor share. We now take the common terms, which are $X_t K^{\alpha}_t(1-L_t)^{1-\alpha}$.

$$=B^M_t X_t K^{\alpha}_t(1-L_t)^{1-\alpha}\left(\frac{B^A_t}{B^M_t}\frac{N^A_t}{1-L_t} + \frac{B^M_t}{B^M_t}\frac{N^M_t}{1-L_t} + \frac{B^S_t}{B^M_t}\frac{N^S_t}{1-L_t}\right) \tag{71}$$

This is going to be our output when we compare our model with the data constructed by the NIPA accountant. Please note that the reference year is 1929 and $B^A_{1929} = B^M_{1929} = B^S_{1929} = 1$. That is the say the index prices are equal to 1 in the year of 1929. To conclude the discussion let us summarize what is output, investment, and consumption when we compare the model with the data. The output is the above equation:

$$\text{Output}_t = B^M_t X_t K^\alpha_t (1 - L_t)^{1-\alpha} \left(\frac{B^A_t}{B^M_t} \frac{N^A_t}{1 - L_t} + \frac{B^M_t}{B^M_t} \frac{N^M_t}{1 - L_t} + \frac{B^S_t}{B^M_t} \frac{N^S_t}{1 - L_t} \right) \tag{72}$$

Next is the investment:

$$\text{Investment}_t = K_{t+1} - (1 - \delta) K_t \tag{73}$$

The last is the consumption:

$$\text{Consumption}_t = \text{Output}_t - \text{Investment}_t \tag{74}$$

C Economy with Third Input

The manufacturing sector follows the following production function:

$$Y^M_t = \left[\eta_t E^\mu_t + (1 - \eta_t)(B^M_t X_t (K^M_t)^\alpha (N^M_t)^{1-\alpha})^\mu \right]^{\frac{1}{\mu}} \tag{75}$$

The optimization problem for the manufacturing firm:

$$\max_{K^M_t, N^M_t} \left[\eta_t E^\mu_t + (1 - \eta_t)(B^M_t X_t (K^M_t)^\alpha (N^M_t)^{1-\alpha})^\mu \right]^{\frac{1}{\mu}} - R_t K^M_t - W_t N^M_t \tag{76}$$

First-order condition with respect to K_t^M:

$$R_t = \frac{1}{\mu}\left[\eta_t E_t^\mu + (1-\eta_t)(B_t^M X_t (K_t^M)^\alpha (N_t^M)^{1-\alpha})^\mu\right]^{\frac{1}{\mu}-1} \mu\alpha \frac{(1-\eta_t) B_t^M X_t (K_t^M)^\alpha (N_t^M)^{1-\alpha})^\mu}{K_t^M} \tag{77}$$

$$= \left[\eta_t E_t^\mu + (1-\eta_t)(B_t^M X_t (K_t^M)^\alpha (N_t^M)^{1-\alpha})^\mu\right]^{\frac{1}{\mu}-1} \alpha \frac{(1-\eta_t) B_t^M X_t (K_t^M)^\alpha (N_t^M)^{1-\alpha})^\mu}{K_t^M} \tag{78}$$

First-order condition with respect to N_t^M:

$$W_t = \frac{1}{\mu}\left[\eta_t E_t^\mu + (1-\eta_t)(B_t^M X_t (K_t^M)^\alpha (N_t^M)^{1-\alpha})^\mu\right]^{\frac{1}{\mu}-1} \mu(1-\alpha) \frac{(1-\eta_t) B_t^M X_t (K_t^M)^\alpha (N_t^M)^{1-\alpha})^\mu}{N_t^M} \tag{79}$$

$$= \left[\eta_t E_t^\mu + (1-\eta_t)(B_t^M X_t (K_t^M)^\alpha (N_t^M)^{1-\alpha})^\mu\right]^{\frac{1}{\mu}-1} (1-\alpha) \frac{(1-\eta_t) B_t^M X_t (K_t^M)^\alpha (N_t^M)^{1-\alpha})^\mu}{N_t^M} \tag{80}$$

Then we have:

$$\frac{1-\alpha}{\alpha}\frac{K_t^M}{N_t^M} = \frac{W_t}{R_t} \tag{81}$$

But then when we sum $W_t N_t^M + R_t K_t^M$ we get:

$$W_t N_t^M + R_t K_t^M = \left[\eta_t E_t^\mu + (1-\eta_t)(B_t^M X_t (K_t^M)^\alpha (N_t^M)^{1-\alpha})^\mu\right]^{\frac{1}{\mu}-1} (1-\eta_t)(B_t^M X_t (K_t^M)^\alpha (N_t^M)^{1-\alpha})^\mu \tag{82}$$

The rest of the profits is distributed to the households as lump-sum.

C.1 Relative prices

The relative prices are going to change accordingly. For example, agriculture and manufacturing:

$$P_t^A B_t^A X_t(1-\alpha)(K_t^A)^{\alpha}(N_t^A)^{-\alpha} = \frac{1}{\mu}\left[\eta_t E_t^{\mu} + (1-\eta_t)(B_t^M X_t(K_t^M)^{\alpha}(N_t^M)^{1-\alpha})^{\mu}\right]^{\frac{1}{\mu}-1}\mu(1-\alpha)\frac{(1-\eta_t)B_t^M X_t(K_t^M)^{\alpha}}{N_t^M} \tag{83}$$

And between service and manufacturing:

$$P_t^S B_t^S X_t(1-\alpha)(K_t^S)^{\alpha}(N_t^S)^{-\alpha} = \frac{1}{\mu}\left[\eta_t E_t^{\mu} + (1-\eta_t)(B_t^M X_t(K_t^M)^{\alpha}(N_t^M)^{1-\alpha})^{\mu}\right]^{\frac{1}{\mu}-1}\mu(1-\alpha)\frac{(1-\eta_t)B_t^M X_t(K_t^M)^{\alpha}(}{N_t^M} \tag{84}$$

D Figures

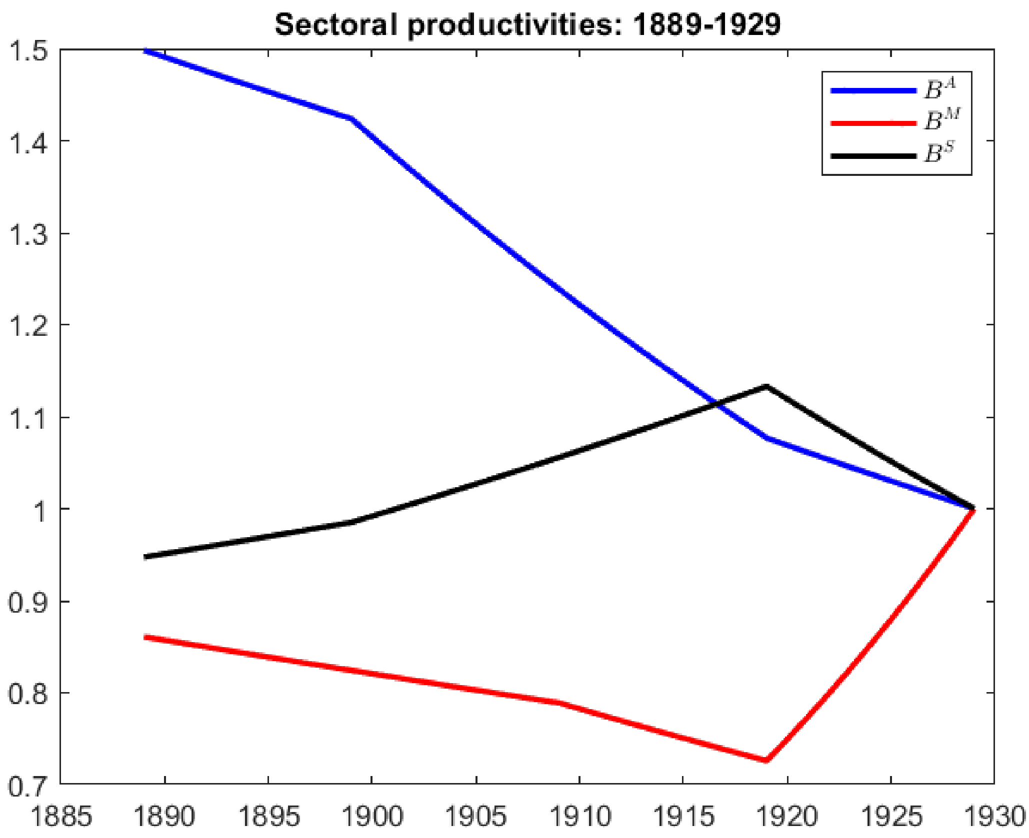

Figure 14: Sector-specific productivities.

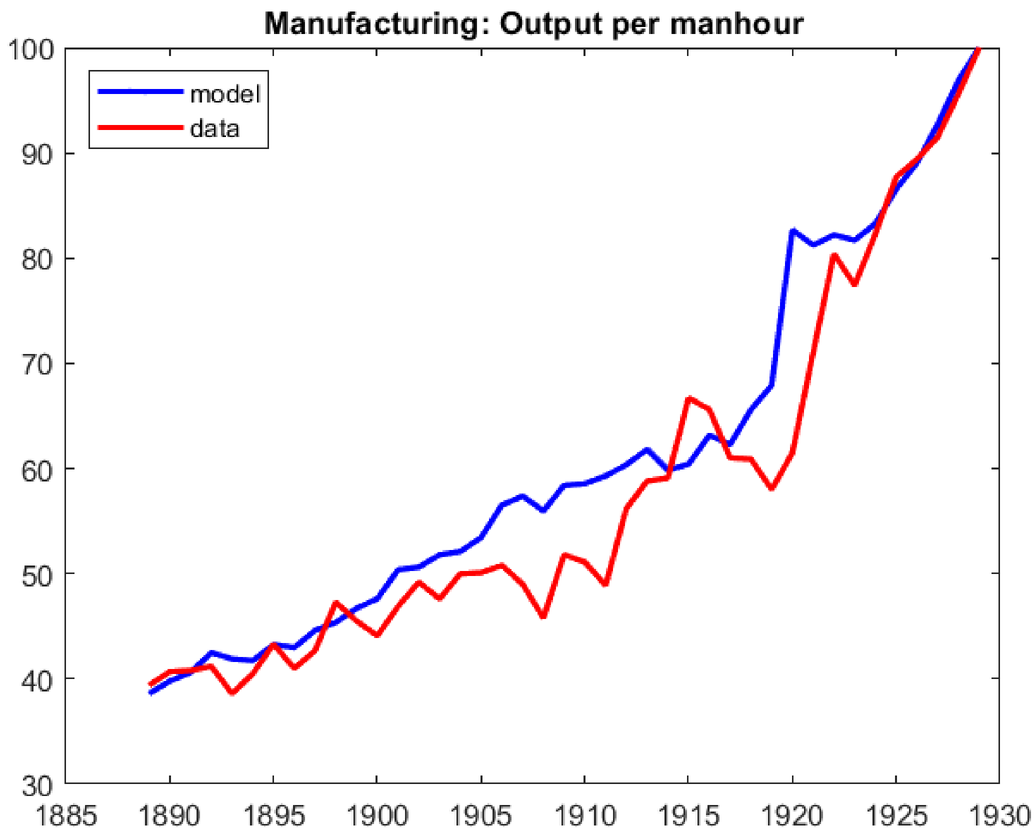

Figure 15: Output per manhour in manufacturing. Model with 3-Input Manufacturing.

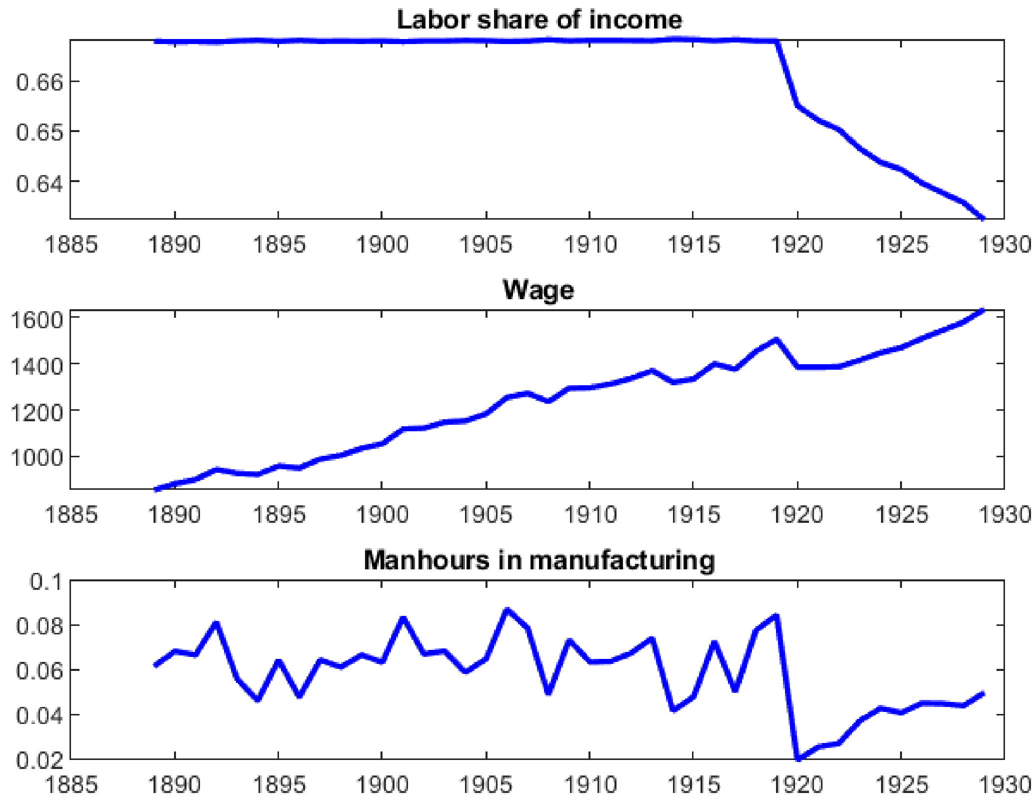

Figure 16: Labor share of income. Wage. Manhours in manufacturing. Model with 3-Input Manufacturing.