Explorations in Economic History 46 (2009) 186–202

Contents lists available at ScienceDirect

Explorations in Economic History

journal homepage: www.elsevier.com/locate/eeh

Engel versus Baumol: Accounting for structural change using two centuries of U.S. data ☆

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ARTICLE INFO

Article history:
Received 28 March 2008
Available online 13 December 2008

Keywords:
Long-run structural change
Engel's law
Differential sectoral productivity growth
Differential sectoral capital deepening

ABSTRACT

In the last two centuries, the reallocation of labor out of agriculture has been a dominant feature of structural change and economic growth in the United States. This paper uses an accounting framework founded in economic theory to decompose this reallocation into three components: a demand-side effect due to the low income elasticity of demand for agricultural goods (Engel effect), and two supply-side effects, one due to differential sectoral productivity growth rates (Baumol effect), and the other to differential capital deepening. The results show that the Engel effect accounts for almost all labor reallocation until the 1950s, after which the Baumol effect becomes a key determinant. Our framework provides a unified account of long-run structural change, and demonstrates that historical interpretations and theoretical models that emphasize only one dimension of this process cannot properly account for the dramatic history of labor reallocation in the United States.

1. Introduction

In the last two centuries, the reallocation of labor out of agriculture has been a dominant feature of structural change and economic growth in the United States. The following figures put this striking transformation into perspective: the share of farm employment in the United States dwindled from 75% in 1800 to less than 3% in 2000, while the share of farm output in GDP declined from 40% in 1840 to slightly above 1% in 2000; see Fig. 1. These secular changes in farm shares took place both when large scale immigration increased the farm *population* (up until 1910), as well as when the farm population decreased dramatically during the twentieth century.[1] What then are the key sources of this transformation?[2] Not surprisingly, the existing literature has advanced numerous explanations to account for this complex but nevertheless highly secular process. These

☆ We thank Chris Hanes, Chris Pissarides, Ranjit Dighe, two anonymous referees, participants at the 2007 North American Econometric Society Winter Meetings, and 2006 Canadian Economic Association Meetings for comments, Laura O'Hearn for editorial comments, and Tom Weiss and Chris Hanes for making their data available in electronic format. Part of this research was conducted while İşcan was visiting Cornell University. The data used in this article are available at http://myweb.dal.ca/tiscan/.
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[1] Available data indicate that there was only one brief episode, coinciding with the Great Depression, when both the farm share of employment and the farm population increased slightly.

[2] Understanding structural change also sheds light on the remarkable growth performance of the United States in the nineteenth and twentieth centuries. For instance, Gallman (2000) discusses nineteenth century U.S. economic growth specifically within the context of structural change. Excellent histories of industrialization in the nineteenth century by North (1966) and Engerman and Sokoloff (2000), and of the farm sector by Atack et al. (2000), discuss sectoral dimensions of economic growth in the United States and place structural change as the centerpiece of their analysis.

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doi:10.1016/j.eeh.2008.11.003

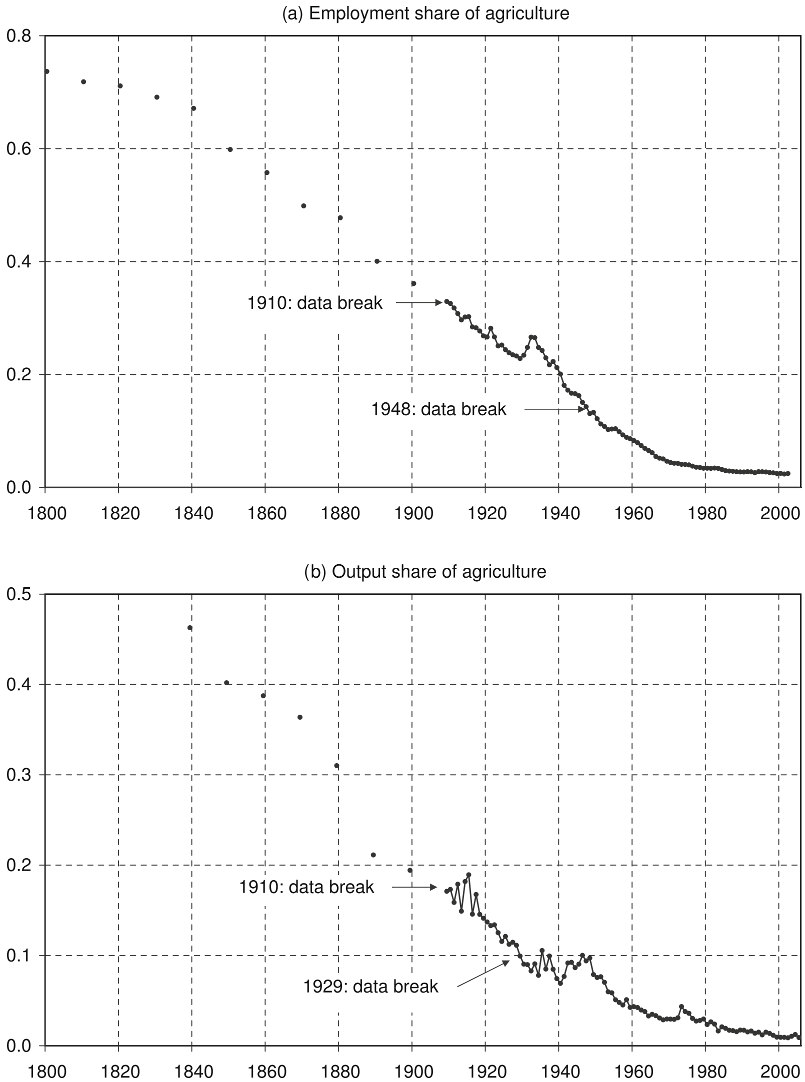

Fig. 1. Two centuries of U.S. structural transformation. *Sources:* Employment share: 1800–1900, Weiss (1992 and unpublished worksheets); 1910–1947, Gallman (1975, series D5 and D6), and 1948–2000, Bureau of Labor Statistics (series LNU02000000). Output share: 1839–1899, Gallman (1960) and Gallman and Weiss (1969); 1910–1929, U.S. Department of Commerce (1975, series F126 and F127); and 1929–2000, Bureau of Economic Analysis (Table 1.3.5). See also Dennis and İşcan (2008).

range from demand-driven factors to purely technological determinants of structural change. We list the most prominent ones here [see also Gallman (2000, pp. 47, and 50–51)]:

1. A version of Engel's Law operating on employment shares: as incomes rise, agriculture sheds labor due to the low income elasticity of demand for farm goods.[3]
2. A version of Baumol's (1967) "cost disease": relatively faster productivity growth in agriculture pushes farm workers to produce complementary non-farm goods.[4]
3. Different capital intensities in production: agricultural production is more conducive to rapid capital deepening, which in turn pulls labor into the more labor intensive non-farm sector.

[3] In our usage, the Engel effect operates on employment shares, although strictly speaking Engel's Law refers to consumption shares. Crafts (1980) examines the significance of this factor for the British industrialization.

[4] Economic historians have long recognized the importance of *sectoral* measures of productivity growth for explaining industrialization and economic development; see Sokoloff (1986) and Williamson (1986).

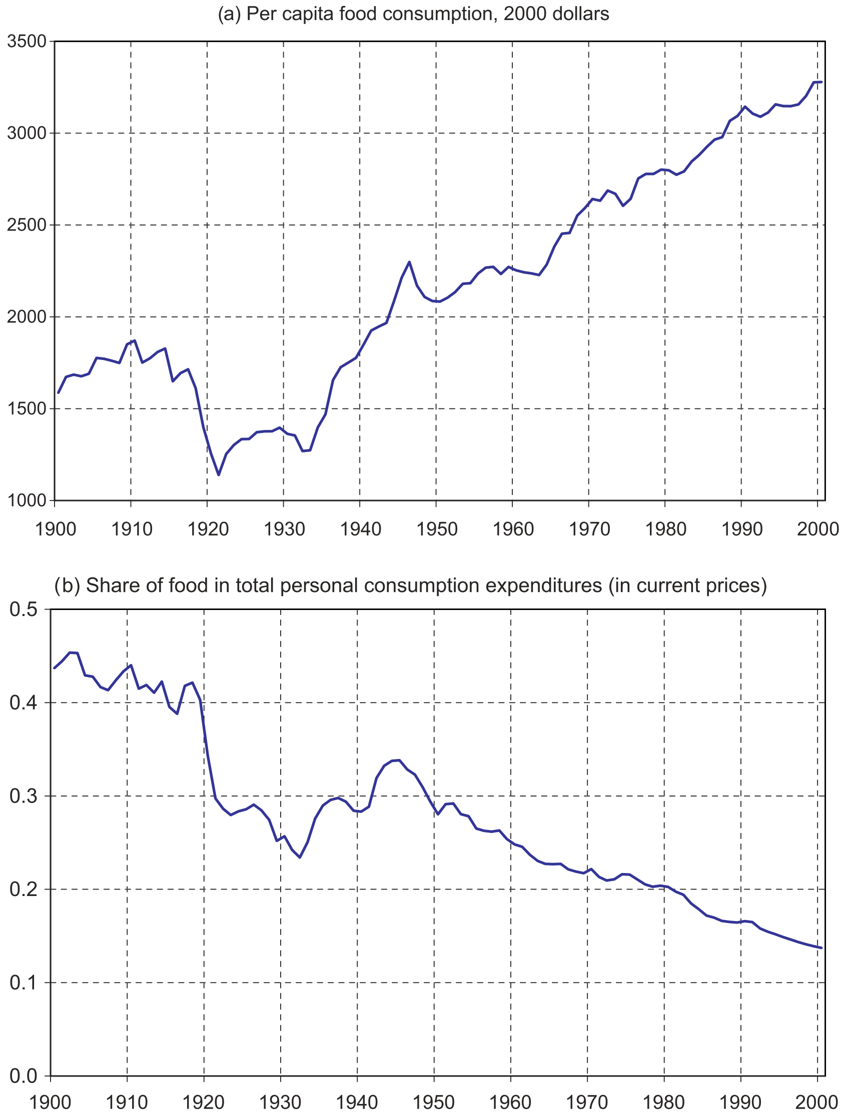

Fig. 2. Consumption expenditures on food. *Source*: Lebergott (1996) and Bureau of Economic Analysis.

How much has each of these factors *accounted for* the structural transformation in the United States in the last two centuries? In this paper we address this central question.[5]

Before we empirically address this question, however, we need appropriate data. Hence, an important contribution of our paper is collecting and carefully parsing the available data series. Almost all the facts and trends we draw upon in this paper have been extensively documented by economic historians in various contexts. However, this is the first time to our knowledge that all of the data required to address the specific theoretical considerations considered here, over a two hundred year time frame, are brought together in one place. Section 2 documents these historical data and tendencies.

In order to systematically quantify the contribution of individual forces to the declining share of agricultural employment in the United States, we also require a *unified* accounting framework. Section 3 develops a framework founded in economic theory that disaggregates the changes in the employment share of non-agriculture attributable to each of the three drivers of

[5] These three sources of structural change have also received the most attention in the theoretical literatures, and in recent years, these sources have been formalized within the context of non-balanced growth in multi-sector models. In particular, Kongsamut et al. (2001) introduce non-homothetic preferences, which lead to differential income elasticities of demand across sectors, Ngai and Pissarides (2007) allow for differences in sectoral productivity growth rates, and Acemoglu and Guerrieri (2008) allow for differences in sectoral factor intensities, which lead to differential capital deepening across sectors. Echevarria (1997) uses a quantitative approach, which incorporates all of these features. These studies are, however, primarily concerned about the theoretical contribution of a single factor to structural change in a way that is consistent with aggregate balanced growth. Our accounting framework makes no attempt to reconcile these different theoretical approaches.

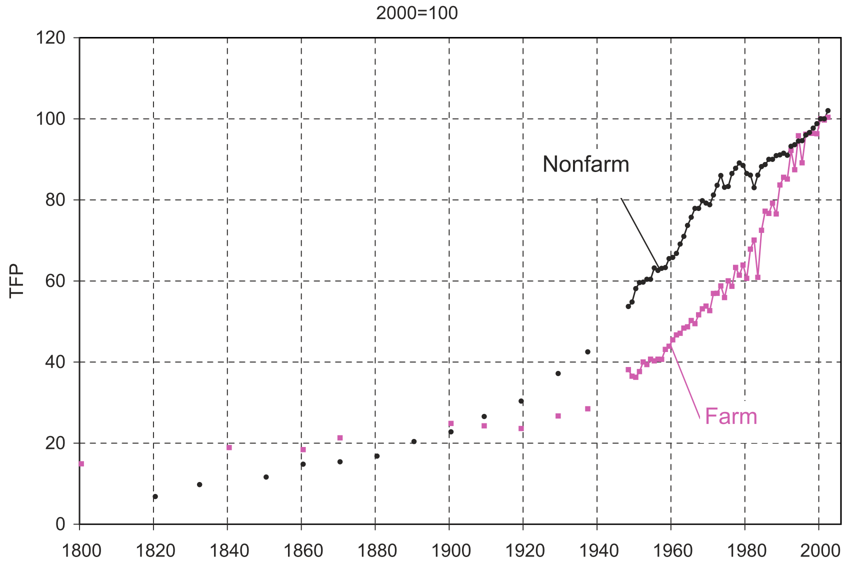

Fig. 3. Farm and non-farm TFP. *Sources:* Farm: 1800–140, Gallman (1972); 1840–1900, Craig and Weiss (2000); 1900–1947, Kendrick (1961, Table B-I), and 1948–2000, U.S. Department of Agriculture, Economic Research Services. Non-farm: 1820–1860, Sokoloff (1986); 1860–1870, Gallman (2000); 1870–1900, Kendrick (1961, Table D-I); 1900–1947, Kendrick (1961, Table A-XXIII); 1948–2000, Bureau of Labor Statistics. See also Dennis and İşcan (2008).

structural change listed above. While similar in spirit to Solow-style growth accounting in its use of production efficiency conditions, this approach builds on a two-sector model to capture labor reallocation between sectors. Although the final accounting expression is non-linear in its components, all the key drivers of structural change emerge in a clear and economically intuitive way. The framework also highlights the often-overlooked but potentially significant interaction between the differential sectoral productivity growth and differential capital deepening effects.

Section 4 presents the quantitative implementation of this accounting framework. The results show that the combination of an income elasticity of demand for farm goods below one and differential sectoral productivity growth in favor of agriculture has been a very significant determinant of the U.S. labor reallocation process. However, over the last two centuries, the *relative contributions* of these two effects have changed in important ways. We find that a low income elasticity of demand accounts for the bulk of labor reallocation until about the 1950s, after which differential sectoral productivity growth becomes a key determinant.

Working with two centuries of data also reveals that the contribution of the differential sectoral productivity growth effect differed significantly between the nineteenth and twentieth centuries: during the nineteenth century, productivity growth in agriculture lagged behind that of non-agriculture and as such acted as a headwind that slowed the reallocation of labor out of agriculture. We also find that, although the difference in sectoral factor intensities underlying the differential capital deepening effect has amplified the relative productivity effect, the independent contribution of the capital deepening effect has not significantly contributed to the reallocation of labor out of agriculture in the last two centuries. Our empirical findings therefore suggest that historical interpretations (and theoretical models) that emphasize only one dimension of this process cannot adequately account for the dramatic trends in historical U.S. structural change.

We also examine one important extension of the baseline framework—international trade—in Section 5. Although exports and imports are a relatively small share of U.S. GDP and their overall importance has varied over time, we extend the model to evaluate the significance of international trade in agricultural goods given the United States's historic openness to trade in this sector. We find that extending the accounting framework to an open economy context does not substantially affect our earlier conclusions.

The sources of structural change we discuss in this paper are ultimately driven by endogenous and exogenous sources of economic growth, such as technological progress and (transitional) capital accumulation.[6] The accounting framework we use in this paper is *not* designed to capture these ultimate sources of structural change. The objective of this exercise is rather to ask whether several reasonable statements about technology and preferences are capable of quantitatively accounting for U.S. structural change. This is reminiscent of the approach taken by Solow (1957) in his classic study on aggregate growth accounting. This paper therefore represents an important intermediate step in a more encompassing (and demanding) exercise that links structural change to all the institutional and market forces that determine observed technological progress. Nevertheless,

[6] Many authors have emphasized technological change as the *ultimate* long-run determinant of the reallocation of labor out of agriculture. North (1966, p. 675), argues that initially the primary source of industrialization in the United States was the adaption and application of existing knowledge and technology developed elsewhere, and that endogenous drivers of technological change became more pronounced over time. Similarly, Engerman and Sokoloff's (2000) account of U.S. industrialization includes both endogenously- and exogenously-determined technological change.

we conclude in Section 6 by offering our thoughts on the implications of our findings for models of directed technological progress.

2. Three sources of structural change: basic facts

To illustrate the potential relevance of the three distinct drivers of structural change emphasized by the existing literature for the United States, we begin the analysis with an overview of fundamental trends in the data. First, consider the evidence for low (less than unitary) *income elasticity of demand* for agricultural goods. We have high quality data from the twentieth century: despite an almost secular rise in per capita food expenditures, the share of food in total expenditures has continuously declined in the United States; see Fig. 2.[7] Since this *demand*-side phenomenon has been repeatedly documented in the empirical literature, we do not elaborate on this issue further.[8]

Second, consider the evidence on *differential productivity growth rates* across sectors. Fig. 3 shows that over time farm and non-farm total factor productivity growth rates have varied substantially both in absolute and relative terms.[9] There are essentially three distinct episodes within which we can examine the productivity growth rate in the farm sector: c1800–c1900 with relatively low TFP growth in the farm sector, c1900–c1937 with modest productivity growth rates, and c1937–2000 with an accelerated and rapid TFP growth rate in the farm sector. More importantly for our purposes, the TFP data reveal the following chronology of *relative* TFP growth: a faster TFP growth rate in non-agriculture in the postbellum nineteenth century, an even sectoral performance during the interwar period, and an acceleration of the TFP growth rate in agriculture relative to that of non-agriculture thereafter.[10]

This interpretation of the data in Fig. 3 is entirely consistent with the historical accounts of the relative productivity performance in the United States. (See also a detailed discussion of these issues in Dennis and İşcan (2008).) For example, all the available evidence suggests that during the nineteenth century the TFP growth rate in the farm sector was significantly below that of the non-farm sector. Despite numerous innovations in farm implements that led to substantial savings of labor through the use of animal power on a variety of farm tasks (McClelland, 1997; Atack, Bateman, and Parker, 2000), the nineteenth century was still a period of low TFP growth in agriculture. However, sometime in the mid- to late-1930s, farm sector productivity started to accelerate and even to outperform the rest of the economy (including manufacturing) by a wide margin. Although the precise causes of this turnaround are still debated, this remarkable structural break in the farm TFP series has been noted by many scholars, and there has been no noticeable slowdown in the farm TFP growth rate in recent decades (Gardner, 2002).[11]

Relative prices provide indirect but supporting evidence on differential sectoral productivity growth rates. As we discuss below, the change in relative prices depends on two principal forces: relative productivity growth and differential growth in capital per effective worker (with each sector weighted by its respective capital intensity parameter). Leaving the differential capital deepening effect aside for the moment, economic theory suggests that a higher non-farm productivity growth rate relative to that of the farm sector would lead to a rise in the price of farm products relative to non-farm goods.

Given the chronology of the relative productivity growth rate we document above, this relative price increase is indeed what we observe in the nineteenth and twentieth century data. Fig. 4 shows farm prices relative to non-farm prices. Starting from about 1820, the prices of farm products increase relative to those of non-farm products over the course of the nineteenth century, and this secular trend continues until about 1918.[12] Recall that this is precisely the period during which our relative productivity series indicate a faster non-farm productivity growth rate. In the second half of the twentieth century, however, there is a distinct secular decline in the relative price of farm goods, accompanied, as we discussed above, by a relatively faster productivity growth rate in the farm sector.

Third, consider the evidence on *differential capital intensity* across sectors. In our conceptual framework, factor shares in each sector are equivalent to the elasticity of output with respect to the factors of production, which we take as a measure of factor intensity in production. Our reading of the literature suggests that, overall, there is considerable uncertainty regarding the relative factor intensity in the farm versus the non-farm sectors. For the nineteenth century, we have comprehensive estimates of factor shares in agriculture by Gallman (1972) which suggest that the share of capital (including land) had steadily increased from about 22% in the 1840s to about 30% by 1900. Sokoloff (1986) takes 30% as the share of capital in manufacturing, suggesting negligible differences between agriculture and non-agriculture.

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[7] Only part of agricultural output is food, and Engel's Law applies to only a subset of agricultural output. However, it has long been recognized that the elasticity of demand for non-food agricultural goods is also less than one (e.g., Schultz, 1945), which preserves the basic mechanism highlighted by this driver.

[8] In fact, Houthakker (1987, p.143), concludes that "of all empirical regularities observed in economic data, Engel's Law is probably the best established."

[9] As we discuss below, the 'differential sectoral productivity growth' explanation of structural change requires non-unitary elasticity of substitution in consumption across goods. Empirically, this condition is satisfied for farm and non-farm goods in the United States; see, e.g., Dennis and İşcan (2007).

[10] Documenting the often-overlooked changes in the relative agricultural productivity growth rate over the last two centuries also helps avoid the confusion that frequently arises in (wrongly) interpreting the relative price of agricultural goods as corresponding to an unchanging relative productivity trend since the late nineteenth century. See also Johnson (2002).

[11] See Meiburg and Brandt (1962) for a comprehensive analysis of the acceleration in farm productivity. See also Jorgenson and Gallop (1992) for a postwar assessment of farm–non-farm relative TFP growth. Due to data limitations, we are unable to formally date these "turning points" through statistical structural break tests.

[12] Dennis and İşcan (2008) provide a detailed discussion of alternative relative price series, all of which suggest that the relative price of farm goods increased significantly during the nineteenth century. These include historically consistent price series constructed by Hanes (1998).

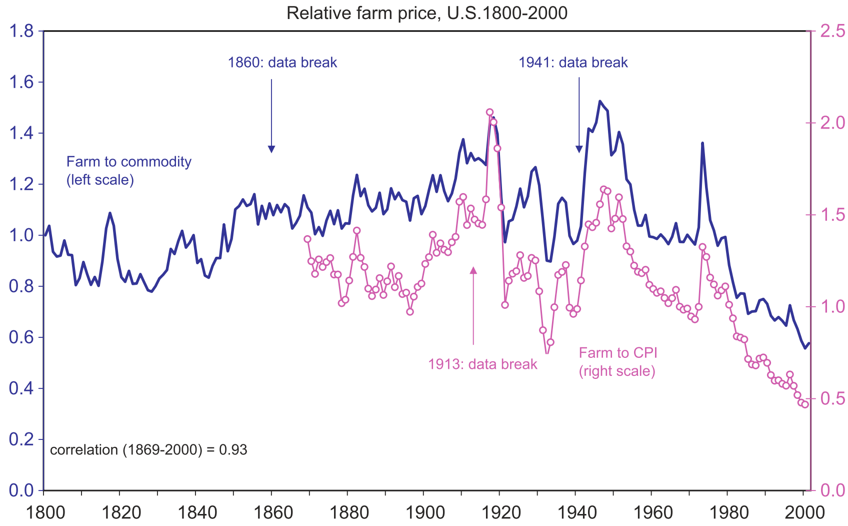

Fig. 4. Ratio of farm to non-farm prices, U.S. (1800–2000). *Sources:* Farm divided by commodity prices; 1800–1860: Warren-Pearson; 1860–1941: Hanes (1998); 1941–2000: BLS. Farm divided by CPI; 1869–1913: Perez and Siegler (2003) and Hanes; 1913–2000: BLS. *Notes*: Farm divided by commodity prices 1800 = 1, and farm divided by CPI 1967 = 1.

For the second half of the twentieth century, we have the estimates of Jorgenson et al. (1987). Their econometric results show that for the farm sector (Table 7.3), the share of capital in the value of output (net of intermediate inputs) is about 30%, and for aggregate output (Table 9.8), it is about 38%—indicating lower capital intensity in farming. Gardner (2002, p.37), on the other hand, compares several estimates of the share of labor in agriculture used for growth accounting purposes, and suggests a much larger share for capital in the farm sector.[13] Finally, we should note that most quantitative analysis in macroeconomics uses 0.33 for the share of physical capital in the non-farm business sector.

Unfortunately, we have no empirical evidence on the relative rates of capital deepening in the farm versus non-farm sectors, which would have helped to settle the issue. We know that differential capital deepening was pervasive in both agriculture and non-agriculture during the nineteenth century: see McClelland (1997) for agriculture, and Atack et al. (2005) for non-agriculture. However, we are not in a strong position to conclude anything firm about their relative magnitudes. Hence, in accounting for U.S. structural change, we allow for both identical sectoral capital intensity as well as the possibility that the non-farm sector uniformly had a higher capital intensity than the farm sector over the last two centuries.[14]

3. An accounting framework for structural change

The conceptual framework we develop below is related to recent work by Caselli and Coleman (2001), and Dennis and İşcan (2007) who also empirically examine structural change in the United States by emphasizing the decline of the agricultural sector. However, these papers primarily rely on twentieth century data and, as we discuss below, some of the trends identified in these papers do not apply to the nineteenth century. Moreover, these papers either limit their analysis to a few sources of structural change and ignore others, or they do not provide a transparent accounting for the contribution of each source.[15]

Our conceptual framework is deliberately specialized, and we provide below a minimal description of the environment. (Detailed derivations are available from the authors upon request.) Our objective is to develop a structural change accounting framework that apportions the reallocation of labor out of agriculture to the three key drivers identified above. To maintain as much compatibility as possible with previous literature, we model a closed economy—but see Section 5 for an open economy extension.

[13] For the first half of the twentieth century, Kendrick (1961, Table A-10, p. 285) presents estimates of factor shares for the farm and private non-farm sectors, indicating higher capital intensity in the farm sector. However, there is a strong downward trend in his capital share estimates in both sectors.

[14] Gallman (2000, p.47), suggests that the *aggregate* capital-output ratio increased over the nineteenth century while the share of agriculture declined, which implies a lower capital-output ratio in agriculture relative to that in non-agriculture (but not necessarily in manufacturing).

[15] See, e.g., Johnson (2002).

3.1. Production and preferences

There are two sectors in the model: agriculture, denoted by A, produces a consumption good, which is possibly a necessity, and non-agriculture ("manufacturing"), denoted by M, produces a good that can be consumed or invested in physical capital.

Production.—At time t output Y in each sector is given by

$$Y_{At} = B_A K_{At}^{\beta}(Z_{At}L_{At})^{1-\beta},$$
$$Y_{Mt} = B_M K_{Mt}^{\alpha}(Z_{Mt}L_{Mt})^{1-\alpha}.$$

where, for each sector $i = A, M$, Y_i is output (the equivalent of value added in national accounts), $K_i \geqslant 0$ is the capital stock, $Z_i > 0$ is labor augmenting technology, $L_i \geqslant 0$ is labor input, and $B_i > 0$ is an efficiency parameter. All labor augmenting technological change is exogenous. We refer to ZL as effective labor. The elasticities of output with respect to capital (α and β) are constant. These technology parameters satisfy $0 < \beta < 1$ and $0 < \alpha < 1$ (constant returns to scale), and throughout we refer to them as capital shares.[16]

Resource constraints.—All resources are fully used:

$$K_{At} + K_{Mt} = K_t \quad \text{and} \quad L_{At} + L_{Mt} = 1. \tag{1}$$

With total employment normalized to one, in what follows all aggregate variables can be interpreted in per worker terms.[17]

Sectoral specialization.—The non-agricultural good can either be consumed, C_M, or invested in the form of physical capital, I. The agricultural good can only be consumed, C_A. Thus, market clearing in product markets implies

$$C_{At} = B_A K_{At}^{\beta}(Z_{At}L_{At})^{1-\beta}, \tag{2}$$
$$I_t = B_M K_{Mt}^{\alpha}(Z_{Mt}L_{Mt})^{1-\alpha} - C_{Mt}. \tag{3}$$

As we discuss below, restricting the production of capital goods to the manufacturing sector also contributes to the changing composition of output and employment shares over time.

Preferences.—Preferences are represented by an additively separable lifetime utility function. Instantaneous utility depends on a composite consumption good C

$$C_t = [\eta^{1/v} C_{Mt}^{(v-1)/v} + (1-\eta)^{1/v}(C_{At} - \gamma_A)^{(v-1)/v}]^{v/(v-1)}. \tag{4}$$

In Eq. (4), $\gamma_A \geqslant 0$ represents the "subsistence" level of food consumption, η is a scaling factor reflecting the weight on non-farm goods, and $v > 0$ is the elasticity of substitution between the consumption of farm goods (net of subsistence) and non-farm goods. When $\gamma_A > 0$, the income elasticity of demand for agricultural goods is less than one (see also footnote 7).[18]

3.2. Optimality conditions

Production efficiency.—There is perfect factor mobility across sectors, and product markets are competitive. As a result, returns to factors of production are always equalized. This yields the equality of marginal rates of transformation across sectors:

$$\left(\frac{1-\beta}{\beta}\right)\left(\frac{K_A}{Z_A L_A}\right) = \left(\frac{1-\alpha}{\alpha}\right)\left(\frac{K_M}{Z_M L_M}\right). \tag{5}$$

Eq. (5) is an intratemporal optimality condition and it determines the sectoral allocation of capital per worker for given values of relative productivity Z_M/Z_A, and capital intensities α and β.

Relative prices.—Since there is factor mobility across sectors, there is a unique wage rate and interest rate.[19] Normalize the price of the M-good to 1, and let P_A denote the relative price of the A-good. We solve for the relative price of the A-good using Eq. (5) and the equilibrium condition that the marginal value product of labor is identical across sectors:

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[16] Specifically, there is no fixed factor such as land in this model. In fact, at least in the United States, land can best be understood as a "variable factor." Gardner (2002, p. 53), writes: "Land in farms in 2000 was larger than in 1900 by 110 million acres, an increase of 13%. But land in farms had declined by almost 25% from its peak of over 1.2 billion acres in 1950." Since farmland is not a fixed factor, we include it in the composite capital stock K_A.

[17] Because production technologies are constant returns to scale, there is *no* loss in generality in normalizing the labor force to one. Introducing population growth would not affect any of the efficiency and optimality conditions below. Both the Bureau of Economic Analysis and the USDA Economic Research Services use constant returns to scale technologies in measuring non-farm business and farm TFP, respectively.

[18] Of course, in practice, there is no "fixed" level of subsistence food consumption independent of height and weight, both of which have evolved with economic growth (Fogel, 2004). In the quantitative analysis in Section 4.2.2, we take these considerations into account.

[19] Clearly, not *all* workers in the United States are mobile. Nonetheless, as long as *capital* is mobile and a sufficiently large fraction of the labor force is free to move, the returns to capital and labor in different sectors will be equalized.

$$P_A = \left(\frac{1-\alpha}{1-\beta}\right)\left(\frac{Z_M}{Z_A}\right)\left(\frac{B_M}{B_A}\right)\frac{[K_M/(Z_M L_M)]^{\alpha}}{[K_A/(Z_A L_A)]^{\beta}}. \tag{6}$$

Consumption demand.—Finally, the equality of the marginal rates of substitution between A- and M-goods corresponds to

$$\left(\frac{1-\eta}{\eta}\right)\left(\frac{C_{Mt}}{C_{At}-\gamma_A}\right) = P_{At}^{\nu}. \tag{7}$$

3.3. Sectoral allocation of labor

We derive the sectoral allocation of labor when both product and factor markets clear, and when the equilibrium satisfies two optimality conditions—(i) that marginal rates of transformation between agricultural (A) and non-agricultural (M) goods are equalized (i.e., productive efficiency in Eq. (5)), and (ii) that there is equality of marginal rates of substitution between A- and M-goods (consumption optimality in Eq. (7)).

To this end, first define the following ratios:

$$b = \frac{B_M}{B_A}, \quad z_t = \frac{Z_{Mt}}{Z_{At}}, \quad y_A = \frac{Y_A}{L_A}, \quad k_A = \frac{K_A}{Z_A L_A}, \quad k_M = \frac{K_M}{Z_M L_M}.$$

Then, using the market clearing and optimality conditions, we obtain an expression for the employment share of non-agriculture

$$L_{Mt} = \frac{1 - s_A(y_{At})}{1 + p(z_t)\, s_k(k_{At}, k_{Mt})(1 - s_{Mt})}, \tag{8}$$

where the *relative productivity* (Baumol) effect is[20]

$$p(z_t) = \left(\frac{1-\eta}{\eta}\right) b^{1-\nu} z_t^{1-\nu}, \tag{9}$$

the *subsistence consumption* (Engel) effect, which leads to a low income elasticity of demand for farm goods, is

$$s_A(y_{At}) = \frac{\gamma_A}{y_{At}}, \tag{10}$$

the *capital accumulation* effect is

$$s_{Mt} = \frac{I_t}{Y_{Mt}}, \tag{11}$$

and the *differential capital deepening* effect is

$$s_k(k_{At}, k_{Mt}) = \left(\frac{1-\beta}{1-\alpha}\right)^{\nu}\left(\frac{k_{Mt}^{\alpha}}{k_{At}^{\beta}}\right)^{1-\nu}. \tag{12}$$

Let us discuss in turn the relevance of each of these for structural change. The Baumol effect $p(z_t)$ in Eq. (9) originates from differences in sectoral productivity growth rates (i.e., $\dot{z}\neq 0$). This expression also demonstrates that the influence of the Baumol effect on structural change depends on the elasticity of substitution between the consumption of agricultural and non-agricultural goods, ν. When this elasticity is unitary, this effect vanishes regardless of the magnitude of the differences between sectoral productivity levels. When $\nu < 1$ (gross complementarity), faster productivity growth in agriculture leads to a "cost disease" for non-agriculture with labor moving out of agriculture.

The Engel effect $s_A(y_A)$ in Eq. (10) is the ratio of subsistence agricultural consumption to output per agricultural worker in agriculture. As productivity in agriculture increases, C_A tends to increase (since $C_A = Y_A$). However, the demand for agricultural goods increases proportionately less than the increase in aggregate income, leading to a reallocation of labor out of agriculture. The presence of subsistence consumption is ultimately responsible for the low elasticity of demand effect for agricultural goods (Engel's Law). The capital accumulation effect, s_M in Eq. (11), is the share of investment in non-agricultural output. In the model, only non-agricultural goods can be converted into physical capital, and this specialization is responsible for the capital accumulation effect.

The differential capital deepening effect, s_k in Eq. (12), originates from differential capital intensities ($\alpha\neq\beta$). This expression shows that the influence of the differential capital deepening effect on structural change also depends on the elasticity of substitution between agricultural and non-agricultural goods, ν. As in the case of the Baumol effect, this effect vanishes when this elasticity is unitary regardless of the magnitude of the differences between sectoral capital intensities. When $\nu < 1$, the sector that uses the non-reproducible factor (labor) more intensively would tend to employ proportionately *more*

[20] We include the constant terms $\left(\frac{1-\eta}{\eta}\right) b^{1-\nu}$ in the relative productivity effect so that the differential capital deepening effect we discuss below only depends on factor share parameters, and the capital accumulation effect has a simple economic interpretation. This is inconsequential for our quantitative results below.

Table 1
Summary of variable descriptions and data sources.

Variable	Description	Source
Output	Gross value added by the business sector, farm and non-farm	Gallman (1960), Gallman and Weiss (1969), U.S. Department of Commerce (1975), and Bureau of Economic Analysis (BEA)
Consumption	Private consumption expenditures, food and all items	Lebergott (1996), and BEA
Employment	Farm and non-farm employment, 10 years and older (1800–1900), 14 years old and older (1910–1947), 16 years old and older (1948–2000)	Weiss (1992 and unpublished worksheets), and Bureau of Labor Statistics
Capital stock	Farm capital stock (net of cropland value, inventories, livestock and workstock), and private domestic economy, nonresidential stock of equipment, software, and structures	Gallman (1986), Kendrick (1961), and U.S. Department of Commerce (2006)
Gross investment	Gross domestic private nonresidential fixed investment. No data for the nineteenth century	Kendrick (1961), and BEA
Farm TFP	Farm total factor productivity	Gallman (1972), Craig and Weiss (2000); 1900–1947, Kendrick (1961, Table B-I), and 1948–2000, U.S. Department of Agriculture, Economic Research Services
Non-farm TFP	Manufacturing TFP for 1820–1890, and private non-farm business sector TFP for the twentieth century	Sokoloff (1986); 1860–1870, Gallman (2000); 1870–1900, Kendrick (1961, Table D-I); 1900–1947, Kendrick (1961, Table A-XXIII); 1948–2000, Bureau of Labor Statistics
Prices	Wholesale price indexes for farm products and all commodities other than farm products	1800–1860, Warren and Pearson series; 1860–1941, Hanes (1998); 1941–2000, Bureau of Labor Statistics
Factor shares	Share of labor in total agricultural income and in non-farm income	1840–1890 (farm only): Gallman (1972); 1948–1979: Jorgenson and Gallop (1987)
Trade shares	Net farm and non-farm exports (imports) as a percent of total farm and non-farm output	U.S. Department of Agriculture, Economic Research Services; BEA, U.S. International Transactions Accounts Data, Table 1

Note: See Dennis and İşcan (2008) more detailed information on variable descriptions, and data sources.

labor (and capital) over time. This is similar in principle to the Baumol effect, with the understanding that, in this case, the sector with lower capital intensity is the relatively constraining factor for economic growth and amasses (in relative terms) all the factors of production (Acemoglu and Guerrieri, 2008).

If agriculture is indeed more labor intensive relative to non-agriculture, this tendency would, of course, thwart the secular reallocation of labor out of agriculture that we observe in the data. Therefore, for the differential capital deepening effect alone to generate farm out-migration, we need a combination of a higher capital share in agriculture ($\beta > \alpha$) and gross complementarity ($\nu < 1$), which would correspond to agriculture becoming more capital intensive relative to non-agriculture over time.

Most of the evidence we summarized above in Section 2 indicates that non-agriculture has been the relatively capital intensive sector, and this fact alone would lead us to conclude that the differential capital deepening effect would have actually slowed the reallocation of labor out of agriculture in this historical episode. However, such a conclusion would be inaccurate because differential sectoral productivity growth rates may contribute in important ways to differential sectoral capital-to-effective labor ratios; see the last term in Eq. (12). As such, differential capital intensities would amplify the Baumol effect—an interaction between the two supply-side effects that is often overlooked in the theoretical literature. Therefore, the historical process we consider in this paper reflects the *combined* influences of the Baumol and capital deepening effects.[21]

Eq. (8) is analogous to Solow growth accounting. It links the data on agricultural consumption per worker, the investment-to-non-agricultural output ratio, and the allocation of capital across sectors to the four proximate determinants of the sectoral allocation of labor described above. Structural change accounting, as measured by changing employment shares, immediately follows from this accounting expression.

4. Accounting for U.S. structural change

4.1. Data

We rely on numerous data sources to account for the U.S. structural change in the nineteenth and twentieth centuries. See Table 1 for a description of variables and data sources, and Dennis and İşcan (2008) for the details. Our nineteenth century data set builds on the meticulous work of numerous economic historians affiliated with the NBER, and the twentieth century data come mostly from official sources. Not surprisingly, our desire to use both nineteenth and twentieth century data faces

[21] In fact, quantitative simulations show that structural change driven by differential capital deepening *alone* is painstakingly slow even when agriculture is the more capital intensive sector. Even at the early stages of transformation, reallocating 20% of the labor force toward the labor intensive sector takes about 1000 years! This speed of labor reallocation is clearly too slow to match the U.S. data. Thus, even if future research concludes that agriculture has always been the more capital intensive sector, there is reason to be skeptical about the strength of differential capital intensities alone as a significant source of structural change for the U.S. industrialization.

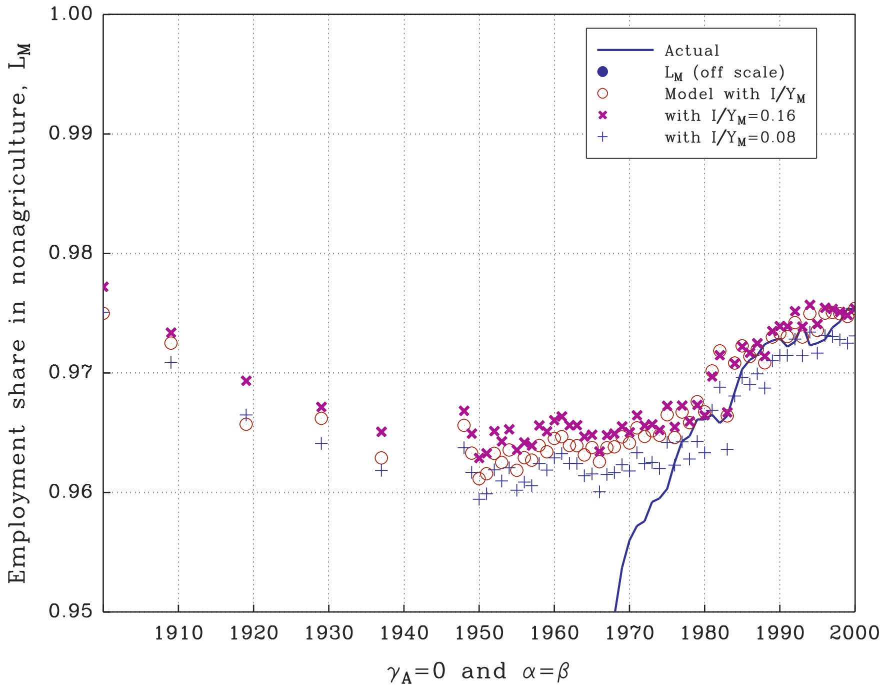

Fig. 5. Employment share of non-farm sector: baseline model. *Source*: For actual series (solid line), see sources to Fig. 1. *Notes*: The calibrated series are computed using the relative productivity values (b and z) calibrated to match L_M in 2000 and using the measured relative productivity growth, as discussed in the text. The parameter values are $\nu = 0.1$ and $\eta = 0.85$. Circles (O) cover the period 1900–2000 and are based on Kendrick's (1961) and BEA's I/Y_M series (which are not directly comparable). The figure also shows two alternative calibrated series using "high" value for $I/Y_M = 0.162$ (×; its value in 2000) and a "low" value for $I/Y_M = 0.081$ (+).

important data constraints. We encounter many instances in which data from different sources using different methodologies need to be parsed (over time). There are also instances in which we have to choose among alternative estimates (covering roughly the same period). In those cases, we consult different sources and historical accounts to determine whether the broader tendencies we detect in our parsed data series coincide with those detected by previous researchers and economic historians. These are discussed extensively in Dennis and İşcan (2008).[22] When we are unwilling to parse two time series, we bracket our estimates based on alternative scenarios. This "sensitivity" analysis is the best we can do given our current knowledge.

4.2. Quantitative results

To illustrate the forces at work, we use a series of figures to demonstrate how well each source of structural change can track the actual share of non-agricultural employment, L_M, over time. In the figures and discussion that follows, we use the term "model-based series" to refer to the portion of L_M for which the framework can account using the different sources of structural change identified above. The difference between the actual and model-based L_M series is analogous to the Solow residual in growth accounting. The accounting framework allows for three key sources of the reallocation of labor out of agriculture in the U.S., and we will progressively introduce each of these drivers to illustrate their relative contribution.

4.2.1. Baumol and capital accumulation effects

We begin by considering a "baseline scenario" in which only the Baumol and capital accumulation effects drive structural change. We thus turn off both the Engel effect, by setting $\gamma_A = 0$, and the differential capital deepening effect, by setting $\alpha = \beta$. To carry out the structural change accounting, we still need values for two preference parameters: the elasticity of substitution between farm and non-farm goods, ν, which we set equal to 0.1 (gross complementarity), and the weight on the non-farm good in the consumption aggregator, η, which we set equal to 0.85 (to match the long-run expenditure shares).

Fig. 5 demonstrates the results of the baseline scenario for the twentieth century. Accounting only for Baumol and capital accumulation effects leaves a considerable residual, especially before about 1960, despite an acceleration of the farm productivity growth rate starting in the late 1930s. The results are especially disappointing for the beginning of the century,

[22] Mundlak (2005) also uses two centuries of U.S. data in his analysis of technological change in the U.S. agriculture. However, he does not use data on the rest of the economy and his data sources are slightly different from those we use.

when relative productivity growth favors the non-farm sector and the model-based series imply that agriculture's share of total employment should have increased. Aside from grossly missing the broader trends in the early part of the century, the combined influences of the Baumol and capital accumulation effects are also economically small. The best the baseline scenario can account for is about a 2% points increase in the employment share of the non-farm sector through the twentieth century relative to the actual change of about 30% points.

Fig. 5 also shows that the baseline scenario is not sensitive to substantial variations in the investment–non-farm output ratio. We consider two examples in which the investment–output ratio is kept constant: a "high" ratio corresponds to the investment–output ratio in the year 2000 when the investment boom in the United States reached one of its historic peaks (according to the BEA data), and a "low" ratio, which is taken as half of that peak, but still above the post-WWII mean.[23] While these alternative estimates help bracket the model-based series, they have no substantial influence on our conclusions.[24]

Inspection of Eq. (8) shows why the joint influences of relative productivity and capital accumulation are unlikely to account for the structural change in the United States even after the 1930s when relative productivity growth on average favored agriculture. On the right-handside of Eq. (8), we have the inverse of the relative productivity term, $p(z)$, multiplied by one minus the investment–output ratio (with $s_A = 0$ and $s_k = 1$). Although relative productivity growth $(\dot{z}_t/z_t)$ favors the farm sector at least in the second half of the twentieth century, changes in $p(z)$ do not sufficiently amplify the changes in relative productivity. Alternatively, to have an upward trend on the right-handside of Eq. (8), we need a strong trend in the ratio of investment to non-farm output. But, at least over the twentieth century, this ratio moved little.

In order for the Baumol effect to account for structural change, we would need a consistent 2% per annum TFP farm–non-farm differential in favor of the farm sector (absent capital accumulation effects) in order to bring the employment share of agriculture in the model from its actual value of 33% in 1910 to about 6.2% by 2000 (the actual growth rate of L_M is 2.4%). As shown above, however, the TFP growth differential was much less than 2% per year during the twentieth century, and typically favored non-agriculture during the nineteenth century.[25]

Overall, the results show that combined Baumol and capital accumulation effects can account for a significant fraction of the U.S. structural change only since the mid-1960s, and they leave a considerable unexplained residual in the employment share of the non-farm sector (especially in the nineteenth century data). In the next section we introduce the Engel effect, $\gamma_A \neq 0$, into the analysis and examine its quantitative contribution to structural change in the United States.

4.2.2. Engel effect

To incorporate the Engel effect into the analysis, we use data on food consumption C_A and need to calibrate the subsistence consumption parameter γ_A. We set $C_A = Y_A$—of course, in practice food consumption is not equal to food production because of spoilage, cooking losses, waste, and other losses. Our measure of C_A includes processed foods. With the rise of the share of processed foods in total consumption expenditures on food, this measure would overstate the expenditures on farm goods, and thereby lead us to understate the contribution of Engel effect to the reallocation of labor out of agriculture.

For γ_A, one approach is to treat this as a constant. However, it may not be plausible to treat γ_A as constant in a study that covers two centuries of rapid physiological, as well as structural change. As we noted above, minimum requirements for caloric intake might have changed over time with the increase in the average height and weight of adults. Also, as incomes and social norms change, preferences that determine the subsistence consumption bundle may also change over time—for instance, more weight on meat and fruits, which are relatively more expensive, and less weight on cereals and potatoes, which are relatively inexpensive. As such, there may be a subjective component to this parameter. We thus pursue several alternative approaches.

In the first approach, we fix γ_A using a benchmark year estimate of the ratio of subsistence food consumption to per capita food consumption $C_A = Y_A$. Specifically, we set $\gamma_A/C_A = 0.95$ for 1919, and let this ratio fluctuate over time with the fluctuations in per capita consumption.[26] Aside from the fact that this approach fixes the subsistence consumption requirements for the entire sample period, it is also only feasible for the twentieth century, because we lack food consumption data for the nineteenth century.

The second approach we pursue makes assumptions about the evolution of γ_A/C_A without necessarily assuming that γ_A remains constant throughout. Thus, annual variations in the values of C_A no longer translate automatically into fluctuations in the γ_A/C_A ratio. This more flexible and indirect approach also allows us to extend the analysis to the nineteenth century. Within this approach we again consider two alternatives: (i) a constant γ_A/C_A ratio at 0.90 from 1800 until 1950, and (ii) a

[23] Gordon's (2004, Fig. 2.9) estimates also show that since 1870 capital–output ratio in the United States has been roughly constant.

[24] We do not present the model-based series for the nineteenth century because, as we discussed above, relative productivity growth was much higher in the non-farm sector during much of this century. This alone implies an increasing employment share of farm employment which is counter to the actual record and which therefore widens the gap between the baseline scenario and the data.

[25] Even during the golden years of agricultural productivity growth from 1948 to 2000, this differential was only about 0.7% per annum. Furthermore, even if we (incorrectly) used relative price inflation to gauge relative TFP trends, the average relative price deflation was 1.6% for 1946–2000, significantly below the figures needed to account for U.S. structural change by the Baumol effect alone.

[26] Specifically, our data in Fig. 2a suggests that real per capita food consumption was particularly low in this year—clearly due to the rising price of food during WWI. So, for that year, we pick a high ratio of the value of subsistence to actual food consumption. We then use the γ_A value corresponding to that benchmark (1330 in 2000 dollars) and the actual data on per capita consumption expenditures on food to determine the γ_A/C_{At} series.

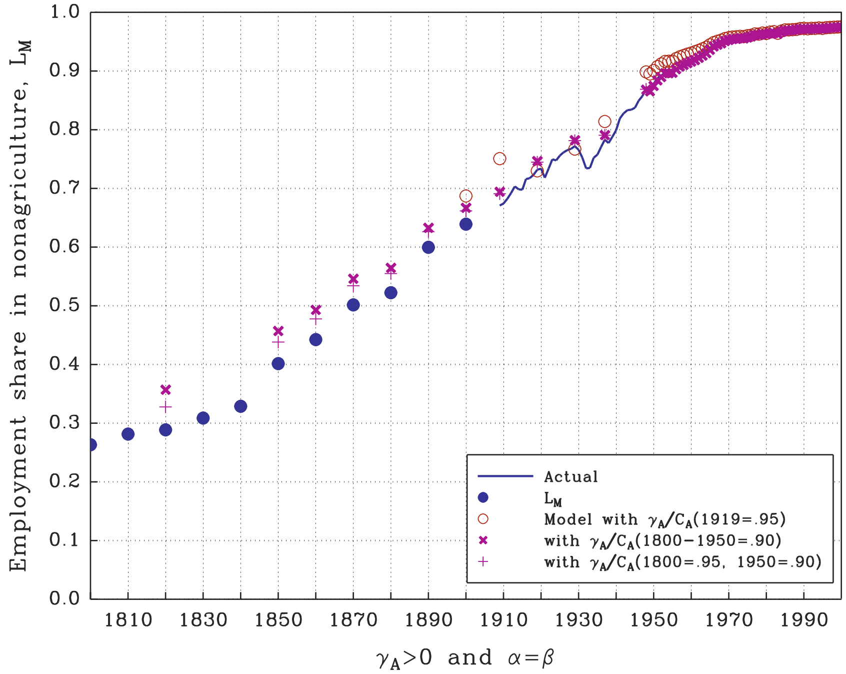

Fig. 6. Employment share of non-farm sector: the extended model. *Source*: For actual series, see sources to Fig. 1. *Notes*: See text for details. Other parameter values are $v = 0.1$ and $\eta = 0.85$.

trending γ_A/C_A ratio from 1800 until 1950 with $\gamma_A/C_A(1800) = 0.95$ and $\gamma_A/C_A(1950) = 0.90$. In both cases, after 1950 we let γ_A/C_A vary as in our first approach.

At first blush, assuming an almost constant γ_A/C_A ratio for a period of 150 years appears extreme. However, we base our decision to use flat γ_A/C_A profiles on several observations. First, we construct an index of farm output per U.S. worker from 1800 to 2000 using the value of farm output and total employment.[27] Remarkably we find that this index is practically flat from 1800 until about 1950. Although there is uncertainty about the exact turning point, after about 1960 these data exhibit an upward trend.[28] This suggests that a flat γ_A/C_{At} profile is not inconsistent with the production data at least until the early 1950s.

A relatively flat γ_A/C_A profile is also consistent with the U.S. Department of Agriculture's estimates of total food supply measured in calories per person per day. For instance, Putnam et al. (2002, Fig. 1) show that per capita food consumption remained practically constant from 1910 (the earliest year for which there is reliable data) until 1965, and has since been *increasing*.

Fig. 6 presents the actual share of employment in non-agriculture, as well as the model-based series calculated using the three alternative approaches to calibrating γ_A/C_A. In all cases, we allow for the relative productivity and capital accumulation effects.[29] First, consider the scenario in which we set $\gamma_A/C_A = 0.95$ for 1919. Compared to the baseline scenario, the model with Engel effect yields much more significant reallocation of labor from agriculture to non-agriculture, and it matches the employment share of the non-farm sector closely in 1919 and 1929. More specifically, the extended framework that includes a low income elasticity of demand for farm goods accounts for the long-run trend reallocation after 1919 reasonably well. These results forcefully underscore the importance of the demand-side factors in accounting for the U.S. structural change.

There are, however, some important discrepancies between the data and what the framework can account for. In particular, the accounting framework leads to an unrealistically high employment share in the non-farm sector at the turn of the twentieth century. Given that this approach fixes γ_A, these high values of L_M in 1900 and 1909 are largely due to the *slightly* higher per capita food consumption (hence lower γ_A/C_A ratio) in those years relative to that of 1919. Our emphasis on

[27] In particular, we constructed a farm output index (2000 = 1) by relying on three sources: for 1800–1900 we used Towne and Rasmussen (1960) estimates of the value of agricultural output entering gross product as revised by Weiss (1993), for 1900–1929, farm gross private domestic product by Kendrick (1961), and for 1929–2000, farm business GDP by BEA. We also construct a total employment index (2000 = 1) by relying on Weiss (1992, 1993) for the nineteenth century and the U.S. Department of Commerce for the twentieth century. We then took the ratio of the farm output index and the total employment index. This index is admittedly noisy at the beginning of our sample.

[28] The per capita consumption data in Fig. 2 also show a distinct upward trend after the early 1960s. Consumption data before that date are relatively more volatile because they are more heavily influenced by on-farm consumption of food and food transfers during the Great Depression.

[29] For the nineteenth century, we set I/Y_M equal to its value in 2000. We experimented with alternative (and plausible) values of I/Y_M, and the results were not sensitive to the specific values of this ratio.

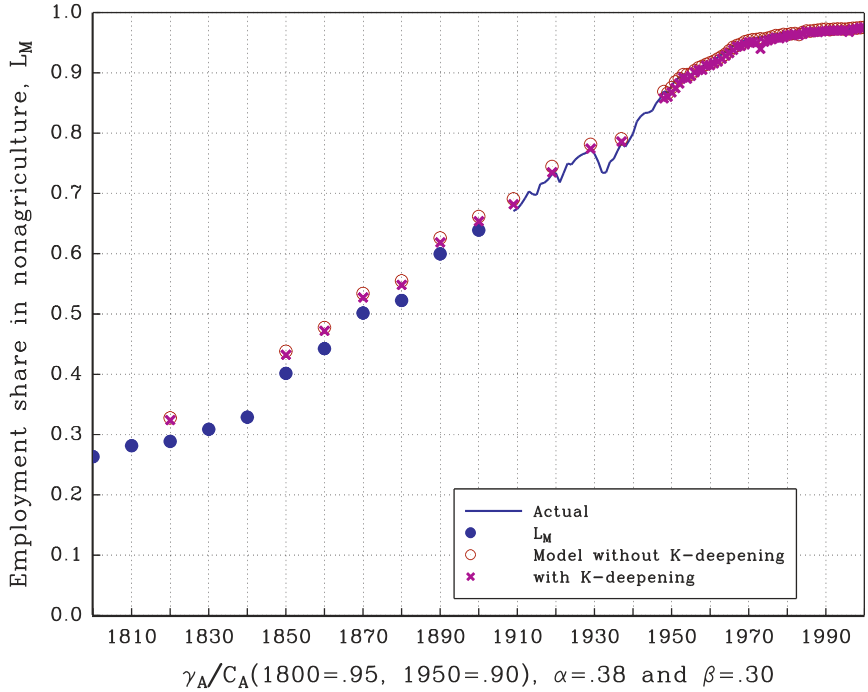

Fig. 7. Employment share of non-farm sector: full model. *Source*: For actual series, see sources to Fig. 1. *Notes*: See text for details. Other parameter values are $\nu = 0.1$ and $\eta = 0.85$.

slightly is warranted, because in the model even minor variations in the γ_A/C_A series have a substantial effect on the sectoral allocation of labor.

When we consider the alternative and more flexible approaches to measuring γ_A/C_A ratio, the model-based L_M series coincide with the actual data remarkably well (Fig. 6, series labeled by + and $\times$; note that these series coincide after 1950 by construction). Overall, the case in which we allow γ_A/C_A ratio to decrease gently from 0.95 in 1800 to 0.90 in 1950 accounts for the U.S. structural change experience considerably better than the other two cases. We thus find that the Engel effect is the dominant driving force of structural change in the United States from the beginning of the nineteenth century well into the mid-twentieth century. This complements the baseline scenario, whereby Baumol and capital accumulation effects jointly provided a good accounting of U.S. structural change beginning in the mid-1960s.

4.2.3. *Differential capital deepening effect*

The third driver of structural change that the accounting framework can accommodate is the differential capital deepening effect. This effect is only present when $\alpha \neq \beta$. As we discussed in Section 2, there is no agreement on the parameter estimates of the sectoral capital intensities, α and β, but those that find sharp differences typically suggest a larger capital intensity in non-agriculture. To make the contrast between the previous scenarios as sharp as possible, we use the estimates of Jorgenson, Gallop and Fraumeni (1987) and set the share of capital in agriculture at 0.30 and the share in non-agriculture at 0.38.

To incorporate the differential capital deepening effect into the analysis, we need data on the sectoral capital stock per effective worker, k_A, k_M. Since there are no estimates available for k_A, k_M, we calculate the s_k series from the data using Eq. (6), which links s_k to information on relative prices, factor shares, and relative productivity levels, b and z—and this is where the interaction between the capital deepening effect and Baumol effect becomes important.

Fig. 7 shows the model-based L_M when we consider both $\alpha = \beta$ and $\alpha > \beta$, the latter of which incorporates all three key theoretical drivers of structural change. Because the results when the subsistence consumption effect operates through the gently upward sloping γ_A/C_A profile from 1800 until 1950 (i.e., $\gamma_A/C_A(1800) = 0.95$ and $\gamma_A/C_A(1950) = 0.90$) provide a better fit for the nineteenth century, we present this scenario. Visually, the model-based series with $\alpha = \beta$ (no differential capital deepening) are practically indistinguishable from the model-based L_M with the differential capital deepening effect.[30]

[30] In a recent paper, Young (2006) argues that, in the U.S., share of labor in agriculture has not remained constant between 1958 and 1996. More importantly, his estimates suggest a switch in relative factor shares with agriculture becoming more capital intensive relative to the rest of the economy, especially after 1965. According to these estimates, the capital deepening effect alone would have contributed relatively more to structural change after 1965, but quantitatively the results are very similar to those we report in the paper.

Table 2
Decomposition of structural change.

	[1] Baumol effect	[2] Engel effect	[3] $\alpha > \beta$	[4] Total	[5] Actual	[6] Difference
(a) *Changes over a period*						
1820–1900						
$\%\Delta L_M$ due to:	−1.2	103.4	−0.0	102.2	121.1	−19.0
% contribution:	−1.1	101.2	−0.0	100.0		
1900–1950						
$\%\Delta L_M$ due to:	−1.4	33.7	0.4	32.6	37.5	−4.9
% contribution:	−4.3	103.3	1.1	100.0		
1950–2000						
$\%\Delta L_M$ due to:	1.5	9.9	1.0	12.4	11.0	1.4
% contribution:	12.0	80.1	8.0	100.0		
1980–1990						
$\%\Delta L_M$ due to:	0.7	0.3	−0.2	0.7	0.7	0.0
% contribution:	90.7	38.6	−29.4	100.0		
1990–2000						
$\%\Delta L_M$ due to:	0.2	0.1	0.3	0.6	0.3	0.3
% contribution:	37.8	14.8	47.4	100.0		
(b) *Average annualized* $\% \Delta L_M$						
1820–1900	−0.015	0.891	−0.000	0.884	0.997	−0.113
1900–1950	−0.029	0.583	0.007	0.567	0.639	−0.072
1950–2000	0.029	0.189	0.020	0.234	0.209	0.025

Note: Column 1 only allows for differential relative productivity growth (Baumol effect) with $\gamma_A = 0$ and $\alpha = \beta$. Column 2 adds the subsistence consumption (Engel) effect with an upward sloping γ_A/C_A profile from 1800 until 1950 (i.e., $\gamma_A/C_A(1800) = 0.95$ and $\gamma_A/C_A(1950) = 0.90$) while maintaining $\alpha = \beta$, and column 3 adds the differential capital deepening effect with $\alpha = .38$, and $\beta = .30$. The (marginal) contributions reported in the table correspond to the differences in the model-based L_M across each of these successive outcomes, *given* unique underlying relative productivity data.

4.3. Putting things together

Table 2 shows the contribution of each of the three sources of structural change for three periods: 1820–1900, 1900–1950, and 1950–2000. For each of these periods, we show the annualized percentage changes in the model-based L_M series due to each of the three sources (columns 1–3), and their combined effect on the share of non-farm labor (column 4). For the periods 1820–1900 and 1900–1950, the three sources explain from 84% to 87% of actual structural change. However, for the period 1950–2000, these sources imply a higher level of structural change than actually occurred (a difference of 13%).

The results show that the Engel and Baumol effects account for the bulk of U.S. structural transformation in the last two centuries. Of these sources, the Engel effect is dominant in all three periods, and constitutes 80% or more of the reallocation of labor out of agriculture. As anticipated by our earlier discussion, relative productivity growth slows down the reallocation of labor out of agriculture in the periods 1820–1900 and 1900–1950. This tendency, however, reverses in the period 1950–2000, when the Baumol effect accounts for approximately 12% of the model-based structural change. Differential capital deepening also provides a (minimal) headwind, which slows down reallocation of labor out of agriculture from 1820 to 1900. However, this force reverses direction in the final two periods with differential capital deepening contributing 8% to model-based structural change in the period 1950–2000. The key to this result is the relatively higher productivity growth in the farm sector, which has fueled relatively more rapid capital deepening in this sector, and thus has been responsible for the further release of labor out of agriculture—this despite the fact that absent these relative productivity growth effects, $\alpha > \beta$ would have slowed reallocation. In fact, the contribution of relative productivity effect increases from 12% in the decade 1950–1960 (not shown) to 38% in 1990–2000, while the contribution of subsistence consumption decreases from 80% to 15%.[31]

5. Extensions

5.1. International trade

How does openness to international trade affect our understanding of this historical process? After all the U.S. has historically been a net exporter of farm goods, and historians have long argued that in the absence of foreign demand for United States farm goods, the reallocation of labor out of agriculture would have been faster, especially in the nineteenth century (Gallman, 2000).

To account for the impact of international trade on the reallocation of labor out of agriculture, we start by modifying the market clearing conditions for farm and non-farm goods, and denote the ratio of farm net exports to farm output by $1 - \tau_A$

[31] The contribution of relative productivity when $\alpha > \beta$ increases even faster: from 20% in 1950–1960 to 85% in 1990–2000.

(where τ_A is the ratio of consumption of farm goods to farm output), and similarly, denote the ratio of non-farm net exports to non-farm output by $1 - \tau_M$:

$$C_A = \tau_A Y_A, \tag{13}$$

$$I = \tau_M Y_M - C_M. \tag{14}$$

We denote the *domestic* relative price of farm goods in terms of non-farm goods by P_A^{open}. Setting this (exogenous) relative price equal to relative factor intensities and using the market clearing equations, we obtain an expression for what we term the *relative price* effect

$$p^{\text{open}} = \left(\frac{1-\eta}{\eta}\right)(P_A^{\text{open}})^{1-\nu}. \tag{15}$$

The resulting sectoral allocation of labor L_M is given by

$$L_M = \frac{\tau_A - s_A}{\tau_A + (\tau_M - s_M)p^{\text{open}}\left(\frac{1-\beta}{1-\alpha}\right)}. \tag{16}$$

The Engel and capital accumulation effects (s_A and s_M) are similar to those in the closed economy. In the case of the open economy, however, we have the relative price effect, p^{open}—although differential capital intensities still matter and in fact amplify the relative price effect.

Table 3 presents the decomposition results for the open economy. Data limitations force us to begin this decomposition from 1938. Once again, the Engel effect dominates, accounting for 97% of model-based structural change for the period 1938–2000, while the relative price effect accounts for the remaining 3%. Allowing for differential capital shares does not affect the results. However, these results are based on a small open-economy assumption in which the relative price is exogenous. For the United States, we suspect that the closed economy framework conforms more closely with reality.

5.2. Complementary sources of structural change

Of course, the sources of structural change we have considered in this paper do not constitute an exhaustive list, and here we mention those *potential* sources of structural change that are left out of the analysis.

One complementary explanation suggests that observed structural change is simply an artifact of increased specialization within each sector (Johnston and Kilby, 1975). For example, much of the home manufacturing and repairs undertaken by farmers in the nineteenth century is now carried out by specialized non-farm firms, thereby giving the impression of labor reallocation out of agriculture. While data limitations do not permit us to present a thorough assessment of these effects of specialization, our nineteenth century data set does allow us to account for the declining significance of home manufacturing on farms, and we find its impact relatively insignificant for the balance of U.S. structural change.

Also, in a seminal study, Schultz (1945) argued that barriers to labor mobility in the United States were a significant determinant of employment in agriculture, and predicted that the removal of these barriers over time would be an additional source of structural change. Dennis and İşcan (2007) consider a framework that allows for endogenously determined partial labor mobility and, using twentieth century data, find that while the contribution of increased labor mobility to structural change was not negligible, it was transitory and relatively small in comparison to the other forces that we consider in this paper.

We should also note that our emphasis on the decline of the agricultural sector is not meant to downplay the rise of the service sector. At least in the United States, the patterns of structural change associated with the service sector are considerably more complex. In the second half of the twentieth century, the decline in the employment share of the farm sector coincided with the well-documented increase in the employment share of the service sector. Yet, in the nineteenth century, the decline in the employment and output shares of the farm sector mostly translated into parallel increases in the employment and output shares of manufacturing.[32] In fact, after documenting the non-negligible increase in the service sector's share in overall output (from 38 to 47% between 1840 and 1900), Gallman and Weiss (1969, Table 2, p. 291 and p. 304) also conclude that this increase in the share of the service sector "is not such a marked change when compared with the structural shifts that occurred within the commodity [agriculture, manufacturing, mining and construction] producing sector" and especially from agriculture to manufacturing.[33] Furthermore, the fact that the reallocation of labor out of agriculture accelerated in the twentieth century makes our focus particularly relevant. Accounting for the secular structural change that has taken place in the United States since 1800 is thus an exercise in accounting for the relative decline of agriculture. Nonetheless, the method used here of accounting for sources of structural change could in principle be extended to address services as a third sector.

[32] Fuchs (1968) is the classic study on the growth of the service sector.

[33] Another vexing issue is the lack of consistent productivity, price and output estimates for the service sector before the 1920s.

Table 3
Decomposition of structural change: open-economy.

	[1] Relative price	[2] Engel effect	[3] $\alpha > \beta$	[4] Total	[5] Actual	[6] Difference
(a) *Changes over a period*						
1938–2000						
$\%\Delta L_M$ due to:	0.5	19.2	0.0	19.7	23.8	−4.1
% contribution:	2.6	97.4	0.0		100.0	
(b) *Average annualized* % ΔL_M						
1938–2000	0.010	0.352	0.000	0.360	0.428	−0.068

Note: Column 1 only allows for the relative price effect, i.e., $\gamma_A = 0$ and $\alpha = \beta$. Column 2 adds the subsistence consumption (Engel) effect with an upward sloping γ_A/C_A profile from 1800 until 1950 (i.e., $\gamma_A/C_A(1800) = 0.95$ and $\gamma_A/C_A(1950) = 0.90$) while maintaining $\alpha = \beta$, and column 3 adds the differential capital deepening effect with $\alpha = .38$, and $\beta = .30$. The (marginal) contributions reported in the table correspond to the differences in the model-based L_M across each of these successive outcomes, *given* unique underlying relative price data.

6. Concluding remarks

The structural transformation of the U.S. economy from an agricultural to an industrial base was a rapid and striking event. Surprisingly, very few attempts have been made to quantitatively account for this phenomenon. In this paper, we propose an accounting framework to decompose the reallocation of labor out of agriculture into three of its well-studied sources. We find that the low income elasticity of demand for agricultural goods accounts for much of the labor reallocation until the 1950s, after which differential sectoral productivity growth also becomes a key determinant. Our framework provides a unified account of long-run structural change, and demonstrates that historical interpretations and theoretical models that emphasize only one dimension of this process cannot adequately account for the dramatic trends in the United States.

Our accounting exercise does not, of course, explain the sources of technological progress in the farm and non-farm sectors. However, the evidence provided through this exercise opens some interesting avenues for future research, both historical and theoretical. The sectoral TFP and relative price data strongly suggest a reversal of relative TFP rates in the twentieth century. Was the twentieth century universally a golden age of agricultural productivity? Mundlak's (2000, Fig. 1.11) cross-country data suggest so. Was the nineteenth century universally different?

Sectoral productivity growth reversals also pose theoretical challenges. Directed technological change models would predict a faster rate of labor saving technological progress in the sector with the higher labor intensity (since labor is the scarce, non-reproducible factor). As long as agriculture is the more labor intensive sector, this explains the facts well—but only after the 1930s. Why doesn't the same explanation hold in the nineteenth century? There is no theoretical model of which we are aware that can endogenously account for this reversal of technological progress. We think that isolating the key drivers of sectoral technological progress would constitute a worthy contribution to the literature.

References

Acemoglu, Daron, Guerrieri, Veronica, 2008. Capital deepening and nonbalanced economic growth. Journal of Political Economy 116, 467–498.
Atack, Jeremy, Bateman, Fred, Margo, Robert A., 2005. Capital deepening and the rise of the factory: the American experience during the nineteenth century. Economic History Review 58, 586–595.
Atack, Jeremy, Bateman, Fred, Parker, William N., 2000. The farm, the farmer, and the market. In: Engerman, Stanley L., Gallman, Robert E. (Eds.), Cambridge Economic History of the U.S., vol. 2. Cambridge University Press, Cambridge, UK.
Baumol, William J., 1967. Macroeconomics of unbalanced growth: the anatomy of urban crisis. American Economic Review 57, 415–426.
Francesco, Caselli, Coleman II, Wilbur John, 2001. The U.S. structural transformation and regional convergence: a reinterpretation. Journal of Political Economy 109, 584–616.
Crafts, Nicholas, 1980. Income elasticities of demand and the release of labor by agriculture during the British industrial revolution: a further reappraisal. Journal of European Economic History 9, 153–163.
Craig, Lee A., Weiss, Thomas J., 2000. Hours at work and total factor productivity growth in 19th century U.S. agriculture. Advances in Agricultural Economic History 1, 1–30.
Dennis, Benjamin N., İşcan, Talan B., 2007. Productivity growth and agricultural out-migration in the United States. Structural Change and Economic Dynamics 18, 52–74.
Dennis, Benjamin N., İşcan Talan B., 2008. Data appendix to Engel versus Baumol: accounting for structural change using two centuries of U.S. data. Available from: <http://myweb.dal.ca/tiscan/>.
Engerman, Stanley L., Sokoloff, Kenneth L., 2000. Technology and industrialization, 1790–1914. In: Engerman, Stanley L., Gallman, Robert E. (Eds.), Long-Term Factors in American Economic Growth. NBER Studies in Income and Wealth, vol. 51. University of Chicago Press for NBER, Chicago and London, pp. 367–401.
Echevarria, Cristina, 1997. Changes in sectoral composition associated with economic growth. International Economic Review 38, 431–452.
Fogel, Robert W., 2004. The Escape from Hunger and Premature Death, 1700–2100: Europe, America and the Third World. Cambridge University Press, Cambridge.
Fuchs, Victor R., 1968. The Service Economy. Columbia University Press for NBER, New York.
Gallman, Robert E., 1960. Commodity output 1839–1899. Trends in the American Economy in the Nineteenth Century, Studies in Income and Wealth, vol. 24. Princeton University Press for NBER, Princeton.
Gallman, Robert E., 1972. Changes in total U.S. agricultural factor productivity in the nineteenth century. In: Kelsey, Darwin P. (Ed.), Farming in the New Nation: Interpreting American Agriculture 1970–1840. Agricultural History Society, Washington, DC.
Gallman, Robert E., 1986. The United States capital stock in the nineteenth century. In: Engerman, Stanley L., Gallman, Robert E. (Eds.), Long-Term Factors in American Economic Growth. NBER Studies in Income and Wealth, vol. 51. University of Chicago Press for NBER, Chicago and London, pp. 165–213.

Gallman, Robert E., 2000. Economic growth and structural change in the long nineteenth century. In: Engerman, Stanley L., Gallman, Robert E. (Eds.), Cambridge Economic History of the U.S., vol. 2. Cambridge University Press, Cambridge, UK.
Gallman, Robert E., Weiss, Thomas J., 1969. The service industries in the nineteenth century. In: Fuchs, Victor R. (Ed.), Production and Productivity in the Service Industries Studies in Income and Wealth, vol. 34. Columbia University Press for NBER, New York.
Gardner, Bruce, 2002. American Agriculture in the Twentieth Century. Harvard University Press, Cambridge, Mass.
Gordon, Robert J., 2004. Productivity Growth, Inflation, and Unemployment. Cambridge University Press, Cambridge, UK.
Hanes, Christopher, 1998. Consistent wholesale price series for the United States, 1860–1990. In: Dick, Trevor J.O. (Ed.), Business Cycles since 1820: New International Perspectives from Historical Evidence. Edward Elgar, Cheltenham, UK and Northampton, MA, USA.
Houthakker, Hendrik S., 1987. Engel's law. In: Eatwell, John, Milgate, Murray, Newman, Peter (Eds.), The New Palgrave: A Dictionary of Economics, vol. 2. Stockton Press, New York.
Johnson, D. Gale, 2002. Comment on The U.S. structural transformation and regional convergence: a reinterpretation. Journal of Political Economy 110, 1414–1418.
Johnston, Bruce F., Kilby, Peter, 1975. Agriculture and Structural Transformation. Oxford University Press, New York, London.
Jorgenson, Dale W., Gallop, Frank, 1992. Productivity growth in U.S. agriculture: a postwar perspective. American Journal of Agricultural Economics 74 (August), 745–750.
Jorgenson, Dale W., Gallop, Frank, Fraumeni, Barbara, 1987. Productivity and U.S. Economic Growth. Amsterdam, North-Holland.
Kendrick, John, 1961. Productivity Trends in the United States. Princeton University Press for NBER, Princeton, NJ.
Kongsamut, Piyabha, Sergio, Rebelo, Danyang, Xie, 2001. Beyond balanced growth. Review of Economic Studies 68, 869–882.
Lebergott, Stanley, 1996. Consumption Expenditures: Old Motives and New Measures. Princeton University Press, Princeton, NJ.
Meiburg, Charles O., Brandt, Karl, 1962. Agricultural productivity in the United States: 1870–1960. Food Research Institute Studies 3 (May), 63–85.
McClelland, Peter D., 1997. Sowing Modernity: America's First Agricultural Revolution. Cornell University Press, Ithaca, NY, and London.
Mundlak, Yair, 2000. Agriculture and Economic Growth. Harvard University Press, Cambridge, Mass.
Mundlak, Yair., 2005. Economic growth: lessons from two centuries of American agriculture. Journal of Economic Literature 43, 989–1024.
Ngai, Rachel L., Pissarides, Christopher A., 2007. Structural change in a multi-sector model of growth. American Economic Review 97, 429–443.
North, Douglas, 1966. Industrialization in the United States. In: Habakkuk, H.J., Postan, H. (Eds.), The Cambridge Economic History of Europe, vol. 6. Cambridge University Press, Cambridge, pp. 673–705. pt. 2.
Perez, Stephen J., Siegler, Mark V., 2003. Inflationary expectations and the Fisher effect prior to World War I. Journal of Money, Credit, and Banking 35, 947–965.
Putnam, Judy, Allshouse, Jane, Kantor, Linda Scott, 2002. U.S. per capita food supply trends: more calories, refined carbohydrates, and fats. Food Review (Winter), 1–15.
Schultz, Theodore W., 1945. Agriculture in an Unstable Economy. McGraw-Hill, New York and London.
Sokoloff, Kenneth L., 1986. Productivity growth in manufacturing during early industrialization: evidence from the American Northeast, 1820–1860. In: Engerman, Stanley L., Gallman, Robert E. (Eds.), Long-Term Factors in American Economic Growth. Studies in Income and Wealth, vol. 51. University of Chicago Press for NBER, Chicago.
Solow, Robert M., 1957. Technical change and the aggregate production function. Review of Economics and Statistics 39, 312–320.
Towne, Marvin W., Rasmussen, Wayne D., 1960. Farm gross product and gross investment in the nineteenth century. Trends in the American Economy in the Nineteenth Century, Studies in Income and Wealth, vol. 24. Princeton University Press for NBER, Princeton.
U.S. Department of Commerce, 1975. Historical Statistics of the United States: from Colonial Times to the Present (1970). Bureau of the Census. U.S. Government Printing Office, Washington, DC.
U.S. Department of Commerce, 2006. National Economic Accounts, Private Fixed Assets by Type. Bureau of Economic Analysis, Available from: <http://www.bea.gov/bea>.
Weiss, Thomas., 1992. U.S. labor force estimates and economic growth, 1800–1860. In: Robert E. Gallman, John J. Wallis (Ed.), American Economic Growth and Standards of Living before the Civil War. University of Chicago Press for NBER, Chicago.
Weiss, Thomas., 1993. Long-term changes in U.S. agricultural output per worker, 1800–1900. Economic History Review 46 (May), 324–341.
Williamson, Jeffrey G., 1986. Comment: Productivity Growth in Manufacturing during Early Industrialization: Evidence from the American Northeast, 1820–1860. In: Engerman, Stanley L., Gallman, Robert E. (Eds.), Long-Term Factors in American Economic Growth. Studies in Income and Wealth, vol. 51. University of Chicago Press for NBER, Chicago, pp. 729–733.
Young, Andrew T., 2006. One of the things we know that ain't so: is U.S. labor's share relatively stable? Unpublished Working Paper. University of Mississippi, MS.