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Wage Gaps and Development: Lessons from U.S. History

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Wage Gaps and Development: Lessons from U.S. History

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Abstract

During the course of development, wages and labor productivity are much higher in the nonfarm sectors of the economy than in agriculture. In this paper, we examine the sources and consequences of wage and productivity gaps in the U.S. from 1800 to 2000. We build a quantitative general equilibrium model that closely matches the two-century long paths of farm and non-farm labor productivity growth, schooling, and fertility in the U.S. The family farm emerges as an important institution that contributes to differences in wages and labor productivity. Income from farm ownership compensates farm workers for the relatively low labor productivity and wages earned in agriculture. Farm ownership, along with the higher cost of raising children off the farm, generated a two-fold gap in labor productivity across the farm and nonfarm sectors in the 19th century US. Consequently, the reallocation of labor from farming to industry raised the average annual growth rate of output per worker by about half a percentage point over the 19th century. The paper also draws some lessons from the quantitative analysis of U.S. economic history for currently developing countries.

JEL Classification Numbers: O11, O13, O14, O18, O40, O41, O51

Keywords: economic development, poverty, schooling, fertility, rural-urban wage gaps, structural transformation, calibrated dynamic general equilibrium models

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[1] We thank Bill Lord for comments.

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I. INTRODUCTION

The early stages of development are characterized by much higher wages and worker productivity in industry than in agriculture. For example, Caselli and Coleman (2001) estimate that wage income in industry was five times that in agriculture at the end of the 19th century in the US. In this paper, we examine the sources and consequences of wage and productivity gaps in the U.S. from 1800 to 2000. The historical literature on wage/productivity gaps is reviewed and then used to calibrate quantitative models of economic growth. The models attempt to explain the productivity gaps along with several other aspects of development including schooling, fertility, the growth rate of average worker productivity, and the economic transformation from agriculture to industry.

Our approach begins with the qualitative analysis of land markets by Drazen and Eckstein (1988). Drazen and Eckstein assume that if land markets are missing, then a traditional institution arises where land is simply passed down from one generation of a family to another.[2] We provide a twist on their traditional institution that serves to create a wage gap between agriculture and industry. We assume that the land, or the right to farm the land under a tenancy agreement, is only passed down if a child agrees to farm the land themselves—i.e. if the child agrees to keep the operation of the farm in the family. *Family farming* creates a link between land ownership and occupational choice that leads to a wage gap between sectors as in Rangazas (2006).[3]

We also consider *neoclassical farming* as an alternative to the *family farming* model. Here farms are neoclassical firms, a complete market for land exists, and there are no direct intergenerational linkages in farming. The only connection between generations is through transactions in the land market, where the old sell their land to the young each period.

We further extend the qualitative analysis of Drazen and Eckstein by embedding each of the farming models in a quantitative growth model of physical capital accumulation, schooling, fertility, and migration. We use this model to quantitatively examine the sources and consequences of wage gaps in conjunction with the other factors that simultaneously generate an economic transformation (the switch from traditional agriculture to industry) and a demographic transition (a fall in fertility) in developing economies.

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[2] Galor et al (2006) also make this assumption in their study of how land inequality affects human capital formation.

[3] The link between the farm and the family was surprisingly strong well into the 20th century. At the turn of the century, the farm in the US was still largely operated individually and organized around the family. Most of farm labor was provided within the family. Even by 1930 only 42 percent of all farms reported hiring labor outside the family (Ely and Werwein (1940, p.162)). As late as 1978, traditional family farms represented 88 percent of all farms accounting for 63 percent of total farm production (Gardner (2002, pp.56-57)).

The main findings from our historical and quantitative analysis are as follows.

- Much of the observed farm-nonfarm wage gap at the turn of the 19th century was due to unmeasured non-wage compensation of farm workers, cost-of living differences between rural and urban areas, and the reluctance of low-skilled labor in the South to migrate to the North after the Civil War. After these adjustments, real wages for nonfarm workers were about 2.5 times higher than for nonfarm workers, or half of the unadjusted 5.0-fold difference estimated by Caselli and Coleman (2001).

- The 2.5-fold wage gap in the 19th century was in a large part due to the shorter work year for agricultural workers. The gap in productivity per *hour worked* was not nearly as large. As suggested in David (2005), the "free lunch" that the economic transformation provides to average productivity growth comes mostly in the form of increased hours-worked rather than increased productivity per hour.

- Only a very small portion of the wage gap was due to differences in schooling. Most of the wage gap was due to the fact that workers who own or operate farms receive residual income from farm ownership that compensates for the lower wage income in agriculture.

- A model that assumes farming is an occupation that is passed from one generation to another within a family performs better in explaining the economic transformation and demographic transition of the US than does a model that assumes farms are strictly analogous to standard neoclassical firms. The *neoclassical farming* model cannot explain the wage gap and relies too heavily on rising schooling to explain the decline in fertility in the 19th century.

- The *family farm* model provides a reasonably close match to the two-century long trends in worker productivity growth, schooling per child, and fertility. Until the end of the 20th century, it also generates reasonable values for the wage gap across sectors. The *family farm* model over-predicts the wage gap late in the 20th century when agriculture was dominated by corporate farming. However, the model nevertheless provides a good approximation to other features of the economy because the fraction of labor in agriculture was very small by then, making the size of wage-gap of little consequence for the aggregate economy.

The share of the labor force in agriculture was 83 percent in 1800. Had this share remained constant over the 19th century, annual labor productivity growth in the US would have been lower by about half a percentage point.

II. Related Literature

The general equilibrium analysis of the economic transformation and demographic transition has expanded rapidly in the last ten years. Galor (2005) presents an excellent survey of this literature that he terms "unified theories of growth." One feature of developing economies that has not been fully integrated into a unified theory of growth is the presence of wage gaps across sectors. Some recent papers have introduced wage gaps based on differences in education requirements across sectors (Doepke (2004) and Greenwood and Seshadri (2002)). However, as we point out below, there are significant wage gaps across sectors for workers with the same level of education. To our knowledge no one has previously attempted to explain wage gaps, for given levels of education, in a two-sector growth model that also includes schooling, fertility, and the economic transformation.

Several complementary explanations for the wage gap currently exist in the broader economic literature. We offer a brief review of this literature to motivate our approach and place it in context. Each explanation likely plays some role in explaining the gap, but each also has its limitations. We attempt to contribute to the understanding of wage gaps by offering a complementary theory and by examining the quantitative importance of the theory in a unified growth model.

A. Urban unemployment

One way to explain a relatively low wage in agriculture is to assume that labor markets clear in rural areas, but that non-competitive wage setting occurs in urban labor markets, resulting in unemployment (Harris-Todaro (1970), Stiglitz (1974), and Calvo (1978)). The probability of being unemployed must be taken into account by those choosing an urban occupation. A worker would only consider seeking employment in the urban sector if the wage there were high enough to compensate for the probability of being unemployment for some period. Thus, a wage-gap between the urban and rural sector is necessary for equilibrium.

There are several difficulties with this theory. Unemployment in urban sectors of poor countries is not particularly high—certainly not high enough to explain large wage gaps (Rosenzweig (1988) and Caselli (2005)). There is also disguised or unmeasured unemployment in rural sectors (Stiglitz (1988)). Thus, there is less of an urban unemployment problem when viewed *relative* to the actual unemployment in the rural sector. We do not focus on the higher probability of facing unemployment in urban areas as a reason for the wage gap. However, we do add migration costs, as an extension to our model, and one interpretation of these costs is that it is hard for rural migrants to find steady employment in the city.

B. Education Gaps

The formal urban sector, which by definition uses relatively advanced technologies within a complex organizational structure, must also have relatively high payoffs to education. Caselli and Coleman (2001) explain the declining relative wage in non-agriculture for the US over the 20th century by assuming that education only payoffs "off the farm." They argue that at the beginning of the 20th century high costs of education kept workers from leaving the farm for industry jobs. This caused the supply of qualified workers in industry to be low, creating a large education wage-premium, which in their model also doubles as a large industry wage-premium. As the cost of education fell over the century, and the relative supply of workers in industry expanded, much of the wage gap was eliminated.

There is surely some truth in this story, but it is too extreme. While the payoffs to education are likely to be higher in industry, there is much evidence that they are also significant in agriculture—even in very informal agricultural settings (see footnote nine below for some supporting references). Some of the empirical literature on the wage gap first adjusts for experience and education differences and then seeks to explain why any remaining wage gap exists. For example, Jenkins and Knight (2005, Table 4.6) find large wage gaps across rural and urban sectors in Zimbabwe for workers with the *same* years of schooling. We find that only a small portion of the wage gap in U.S. history is due to schooling differences.

C. Unmeasured Home Production

At least a portion of the wage gap between industry and agriculture is due to measurement error and non-traded goods. Workers in rural areas spend a larger portion of their work day producing unmeasured goods that are consumed at home. Mueller (1984) finds that agricultural workers in Botswana devote less than one hour per day to wage labor and the trading, vending, and processing of goods. If these workers are measured as a full unit of labor and their output is measured based only on market transactions, then their measured productivity is much less than their actual productivity. Our reading of U.S. history and case studies from currently developing countries also suggests that measurement error is an important explanation for observed productivity gaps.

Gollin, Parente, and Rogerson (2004) build a theory that accounts for measurement error due to home production. They make two reasonable assumptions about home production—(i) it is relatively labor intensive and (ii) it has a relatively high total factor productivity in rural, versus urban, areas. These two features cause countries with a high relative price for capital goods, and thus low productivity in the market sector, to allocate relatively large portions of their work force toward home production in rural areas.

While this part of the story seems reasonable, other features raise questions about its implications. They assume that manufacturing, rather than agricultural, goods are produced at home. The small fraction of workers in urban areas, where market-based manufacturing takes place, and the large fraction of workers producing substitutes for manufacturing goods at home combine to lower the *market* supply of manufacturing goods. The relatively small supply of manufacturing goods in the market causes the price of manufacturing goods to be relatively high, five times the price of agricultural goods.

Additionally, while time devoted to market activity is 3.5 times higher for a manufacturing worker (which drives the measured productivity gap up), the relative productivity of workers in the capital-intensive manufacturing sector is lowered by the high relative price of capital goods (which drives the productivity gap down). Thus, the productivity gap measured at *international prices* is not particularly large. Most of the large productivity gap in developing countries, when measured at *local prices*, is explained by the low relative price for agricultural goods predicted by the model.

This conclusion is problematic because it is unclear that the relative price of agricultural goods is lower in developing countries than in developed countries. For example, Restuccia, Yang, and Zhu (2004) find no systematic difference in the relative producer price for agricultural goods across rich and poor countries. Consistent with this finding, the low relative price of agriculture in the Gollin et al model causes their predictions about the share of agricultural production in total output to be lower than what is observed. Thus, while the measured output of workers in agriculture is likely below the actual output, it is unclear how large the measurement error is and how much it impacts the productivity gap. We do not incorporate a theory of unmeasured home production in our model, although this would clearly be a worthwhile extension.

D. Migration Costs

Workers migrating to the urban formal sector are likely to face many costs not found in the rural sector including taxes, discriminatory housing costs, union fees and the one-time cost of moving to the city. These migration costs require a higher gross wage for workers to be willing to choose occupations in the formal sector.

Restuccia et al (2004) and Vandenbrouke (2003, 2004) assume that migration costs are the sole reason for the productivity gap between sectors. This approach is problematic when the productivity gap between sectors is large. Restuccia et al (2004) focus on the productivity gap between agricultural and non-agricultural workers in currently developing countries. According to their estimates, nonagricultural workers in poor countries are 6.7 times as productive as workers in agriculture. To explain a 6.7-fold wage gap requires migration costs to be equivalent to an implicit tax on wages in the formal sector of 85 percent! The necessary "tax rate" on nonagricultural workers would have to be even higher if one accounts for the fact that (i) marketed agricultural goods are also often taxed, (ii) the relevant tax rate should be *net* of any transfers or services generated from the tax revenue and (iii) shared tenancy arrangements in agriculture carry implicit marginal tax rates as well.

Vandenbrouke focuses on the wage gap between the eastern and western regions of the U.S. in the 19th century. The gap in earnings between these sectors is rather small, in part because this is not a strict comparison between workers on and off the farm. In this setting appealing to migration costs as the sole source of the wage gap is reasonable. As mentioned, we do supplement our model with migration costs to help match the observed wage gaps between farm and non-farm workers. However, we find that migration costs play a relatively minor role.

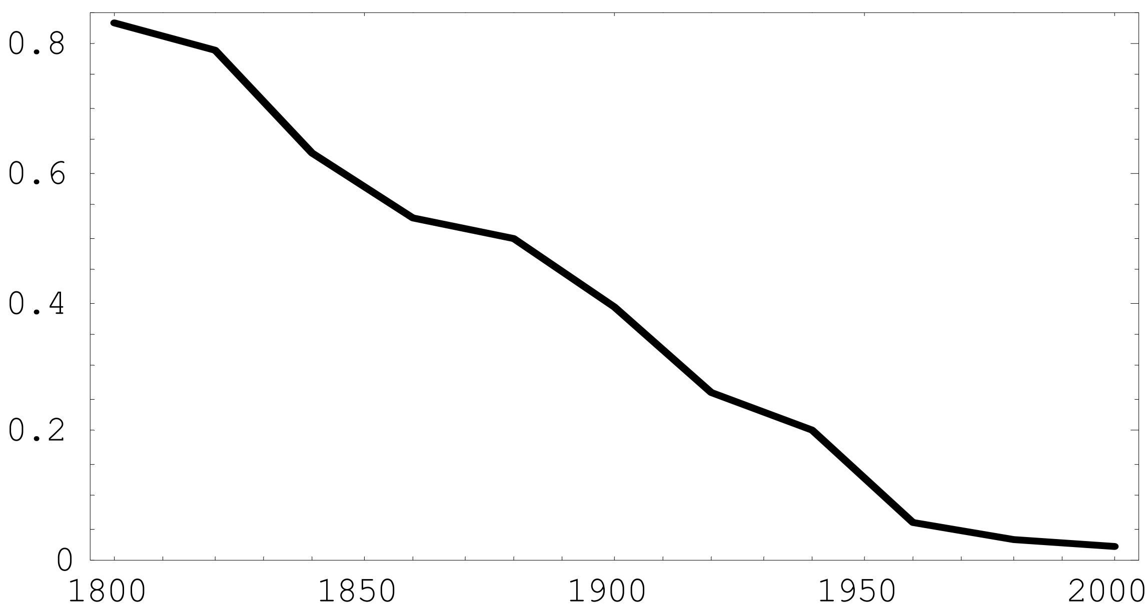
III. Economic Transformation and Demographic Transition in the US

This section presents a historical overview of the economic development of the U.S. from 1800 to 2000. The data presented here will either serve as targets to calibrate theoretical models or as observations used to test the models' predictions.

A. Sectoral Allocation of Labor

As in nearly all countries of the world, the economic transformation of the U.S. involved a sectoral shift of labor out of agriculture and into "industry"—which we use here to denote all nonagricultural production. The U.S. began as a predominately agricultural economy in 1800 and then transformed gradually into a predominately industrial economy. Figure 1 presents the share of the labor force employed in agriculture, starting at over 80 percent in 1800 and falling steadily over the two centuries to 2 percent in 2000.

Figure 1. Share of Labor in Agriculture



Sources: 1800-1860 from David (2005, Table 2.2, column 2), 1880-1980 from Caselli and Coleman (2001, Table 1), 2000 from *Economic Report of the President 2006* (Table B-35)

B. Productivity/Wage Gap

One of the puzzles of economic development is why so many workers remain in agriculture when their productivity and wages are potentially much higher in industry. Table 1 presents the relative annual output per worker (for 1840) and annual wage earnings per worker (from 1880 to 1980) in industry compared to agriculture. The wage gaps in U.S. history were quite large. However, they must be interpreted with care because there are a number of difficulties in comparing annual farm and nonfarm wages. The difficulties include non-money wages paid to farm workers (e.g., room and board), the cost of living in rural versus urban areas, differences in hours worked over the year across the two sectors, and the willingness to accept lower wages for purely cultural reasons. Accounting for these factors serves to reduce the size of the effective gap as it relates to the incentive to migrate across sectors.

Table 1. Relative Productivity/Wage of Industrial Workers

1840	2.5
1880	5.0
1900	4.8
1920	3.1
1940	2.9
1960	2.0
1980	1.4

Sources: 1840 from David (2005, p.5), 1880 to 1980 from Caselli and Coleman (2001, Table 1).

To begin, Table 1 reveals a large difference between the productivity ratio for 1840, measured by David (2005), and the wage income ratios for 1880 and 1900, measured by Caselli and Coleman (2001).[4] There are at least two reasons for this. First, the wage ratios do not include non-cash compensation, a relatively large portion of the compensation paid to farm workers. Second, there is no adjustment for the fact that farm workers lived in rural areas where the cost of living was lower. The literature shows that it is important to account for these two factors (Alston and Hatton (1991)). They find that in 1940 monthly cash earnings in manufacturing were 3.3 times those in agriculture, even greater than the Caselli and Coleman estimate of a 2.9-fold wage gap for that year. However, after adjusting for non-cash payments and cost-of-living differences, Alston and Hatton find that the gap shrinks to a 1.8-fold difference. Thus, assuming that real wages reflect productivity, the productivity gap in 1940 was actually considerably *less* than that in 1840.

A third reason why differences in relative wages were larger after 1860 was the Civil War. There is evidence that *low-skilled* workers in the South were willing to accept substantially lower pay rather than migrate to the North. Wright (1986, Table 3.3) shows that daily wages paid to *farm* labor in North was the 1.5 to 2 times greater than that in the South from 1866 to 1946. Wright (1986, Table 3.8) also provides evidence that the wage gap favoring Northern farmers appeared only after 1860. In addition, he argues that only small North-South gaps appeared for more *skilled* labor such as weavers, bakers, bricklayers, carpenters, painters, and machinists (Wright (1986, p.67)). Since the proportion of labor in agriculture was much higher in the South than in the nation as a whole, the willingness of unskilled labor to accept significantly lower wages to remain in the South, would be one factor contributing to lower relative farm wages in the economy as a whole after 1860.

[4] Caselli and Coleman use census data on wages and incomes. David measures GDP by sectors.

In summary, once accounting for the non-cash payment, cost-of-living differences, and differences in wages due to purely cultural factors, the remaining real farm-nonfarm wage differences after 1860, *due to general economic fundamentals*, were likely similar to the productivity differences in 1840. It is also clear that real wage differences, adjusted for these factors, fell far below the 1840 productivity differences sometime before the middle of the 20th century.

One final difficulty in interpretation remains. David (2005) argues that recorded agricultural workers spent much fewer *hours* generating measured agricultural output than did workers in industry (due to a shorter work-year and more part-time employment). For 1840, David estimates that, over the course of a year, the average agricultural worker spends about half the hours producing that the average worker in industry does. Thus, the gap in output per *worker* across the two sectors will be much larger than the gap in output per *hour worked*. A 25 percent productivity advantage in non-agricultural occupations would suffice to explain a 2.5-fold gap in output per worker if hours worked were twice as high in industry.[5] A significant role for differences in hours worked across sectors is also consistent with the data on labor productivity growth presented in the next section.

C. Labor Productivity Growth

The assessment of the productivity/wage gaps by David (2005) suggests that there could be a significant difference between the growth in labor productivity depending on whether it is measured per *worker* or per *hour-worked*. If there were actually significant differences in worker productivity per *hour-worked*, then as workers moved from agriculture to industry, there should have been a significant increase in the average productivity of an hour worked in the economy as a whole. On the other hand, if the sector-productivity gap was largely due to differences in hours spent producing measured output, then as labor migrated to industry, the growth in productivity per hour-worked would not show much rise. However, measured productivity *per worker* would rise significantly, but mostly due to an increase in hours-worked per worker.

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[5] This is consistent with Margo's(2000) finding of relatively small gaps in hourly wages in favor of non-farm workers in the antebellum period. David (2005) goes as far as to argue that farm workers (i) were actually *more* productive than nonfarm workers, once accounting for unmeasured home production and land improvements, and (ii) received *higher* annual income, once accounting for entrepreneurial or residual income from farm ownership. It is difficult to say that farmers were more productive per hour since there was certainly unmeasured hours of work that generated the unmeasured home production and land improvements. During the 19th century, Primack (1969) estimates that farmers spent about 20 percent of their annual work hours in activities such as improving land, constructing farm buildings, and fencing property. In addition, if farm incomes were actually higher for the same hours of work, why then was there a steady flow of labor *out* of agriculture? We assume that land improvements and maintenance are captured in farm TFP. We also assume that such activities did *not* increase the net flow of income to the current generation, but did increase the quantity of effective land bequeathed to the next generation. Finally, we assume that the entrepreneurial income received by farm owners compensated for much of the gap in real *wage* income, but did not create a *consumption* gap in the *opposite* direction.

Tables 2 and 3 present the U.S. economy's growth rate in output per worker and the growth rate in output per hour-worked. For the 19th century, there are large differences in the growth rates across the two tables. The annualized growth rate for output per worker was 1.36 percent over the 19th century compared to 0.65 percent for output per hour-worked. The average growth rate in output per worker was double that of output per hour-worked, supporting the claim that the main cause for lower output per worker in agriculture was fewer hours worked. As farm workers migrated to industry over the century, output per worker expanded significantly due to an increase in hours worked per worker. Output per hour worked did not increase as much because farm workers hourly productivity was not much different from that of nonfarm labor.

Table 2. Growth Rate in Output per Worker

1820	0.31
1840	1.82
1860	1.32
1880	1.84
1900	1.53
1920	1.40
1940	1.72
1960	2.45
1980	1.58
2000	1.62

Notes: Growth rate at each date is the annualized growth rate over the previous 20 year period. Growth rates are presented as percentage points. *Sources:* 1800-1840 from David (2005, Table 6, Column 1 and Table 2.1, Column 3), 1840 to 1900 from Broadberry and Irwin (2006, Tables A1 and A2), 1900-1940 from Kendrick (1961, Table A XXII), 1940-1960 from Kendrick (1973, Table A 19) and 1960-2000 from *Economic Report of the President* (2006, Table B 2 and Table B 36)

Table 3. Growth Rate in Output per Hour-Worked

1800-1855	0.39
1855-1890	1.06
1890-1927	2.01
1929-1966	2.52
1966-1989	1.23

Notes: Growth rate is the annualized growth rate over the previous 20-year period. Growth rates are presented as percentage points. *Sources:* Abramovitz and David (2001, Table 1 II).

D. Land Expansion

Fertility is generally high on the farm. In 1800, farm families averaged more than seven children, compared to less than five for urban families (Greenwood and Seshadri (2002)). With such a high rate of population growth, land used in farming must expand or the productivity of farm labor would decline rapidly (especially when technological change is limited).

Land did expand rapidly in the 19th century U.S., during the "cheap land" era, where land could be acquired at no or little cost (Benedict (1953, pp.12-22) and Saloutos (1962)). Gallman (1992) estimated that the stock of improved land increased about 10-fold over this century. While land used in farming continued to expand until 1950 (Gardner (2002, Figure 1.1)), it slowed considerably after 1900 when it became difficult to obtain good land cheaply or improve it without great effort (Garner (2002, p.3), Benedict (1953, p. 112) and Saloutos (1962, p.449-450)).

The expansion and improvement of land helped keep output per worker in agriculture growing at a relatively fast pace in the 19th century. Using sector-data from 1840 to 1900 from Broadberry and Irwin (2006, Tables A1 and A2), we computed a growth rate in output per worker of 1.29 percent in agriculture, 1.47 percent in industry, and 1.42 percent in services. The growth rates in the industrial and service sectors probably benefited disproportionately from growth in physical capital (excluding land) and human capital. This suggests that, in terms of the effect on labor productivity, the combined effect of technical change in agriculture and land expansion was roughly comparable to technical change off the farm.[6]

E. Fertility

In 1800, the average U.S. household had seven children (Haines 2000). As mentioned above fertility also differed across sectors of the economy, with significantly higher fertility for families working in the agricultural sector. In the spirit of Galor's (2005) suggestion that theories of economic growth be "unified" to include as many of the stylized features of development as possible, we will attempt to match the demographic transition along with the economic transformation.

Figure 2 presents the U.S. fertility data. Over the 19th century, the average rate of fertility fell almost in half, from 7 to 3.6. Over the 20th century, fertility continued to trend

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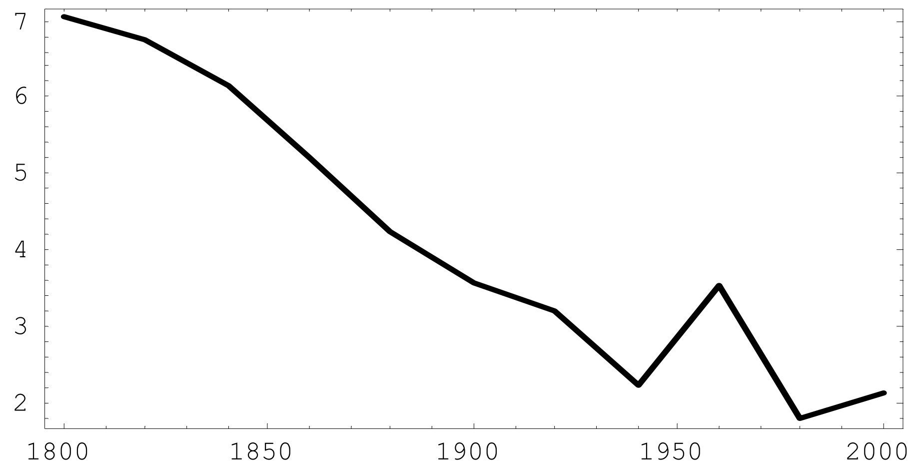
[6] Direct quantitative estimates of TFP growth in agriculture and nonagricultural sectors over this periods can be found in Atack, Bateman, and Parker (2000) and Greenwood and Seshadri (2002). Unfortunately these estimates are flawed because Atack et al interpreted Weiss's (1993) *labor productivity* estimates as *TFP* estimates (see also Mundlak (2005, footnote 30)). Greenwood and Seshadri based their calculations on Atack et al's interpretation, so their estimates suffer from the same problem. Beyond this error, any attempt to calculate TFP growth over this period faces the difficulty of measuring physical and human capital accumulation during the 19th century.

downward, with the notable interruption of the "baby boom" after WWII, reaching a level of two children by 2000.

Figure 2. U.S. Fertility 1800 to 2000



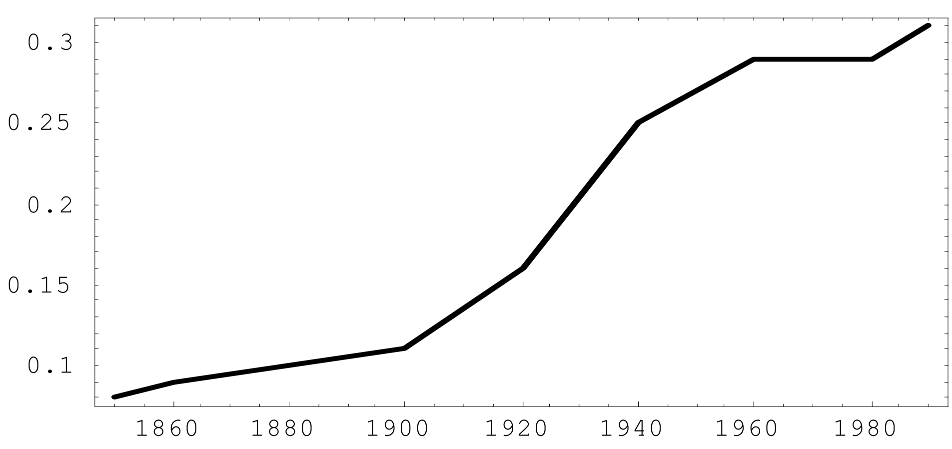
Source: Haines (2000, Table 4).

F. Schooling

Many studies have established a close link between economic growth, fertility, and schooling (see Galor (2005) for an excellent survey). In addition, Caselli and Coleman (2001) rely on schooling to explain the wage gap between agriculture and industry.

To quantify schooling over the development of the U.S., we use a measure from Lord and Rangazas (2006). They estimate the time spent in school by 0-19 year-old children using data on white enrollment rates for 5-19 year olds and data on days attending school per enrolled student, both found in Goldin (1999). The average time spent in schooling, as a fraction of the total available days, is presented in Figure 3.

Figure 3. U.S. Schooling 1850 to 2000



Source: Lord and Rangazas (2006, Table 2).

Note that time spent in school changed very little from 1850 to 1900 and then expands very rapidly in the 20th century. While the data does not go back to 1800, Lord and Rangazas (2006) use a historical analysis to conclude that schooling, and more importantly learning (including learning at home) and literacy, rose only moderately from 1800 to 1850.

IV. Model

This section extends the neoclassical growth model of Mourmouras and Rangazas (2007) to a two sector setting, with rural agriculture and urban industry. The analysis is conducted under two different assumptions about the way agricultural land is passed on from one generation to the next. Under one institutional arrangement, the children of farmers inherit the rights to operate a family farm and/or the farmland itself from their parents. The approach is similar to Drazen and Eckstein (1988), who assume that in the absence of formal land markets, farm land itself, or the right to farm the land under a tribal or tenancy agreement, is simply passed from one generation of farmers to the next. Our approach differs from theirs because we assume the land is passed *only if* the children agree to farm it themselves—this ties the inheritance/management of land to occupational choice.[7]

The second arrangement is one with a neoclassical market for land and no direct intergenerational transfers of specific human capital or land. Land is like any other asset that can be purchased in a perfectly competitive market and then rented to farmers. In this case, "farms" are standard neoclassical firms, a general blueprint is available to operate the farm, and no specific or local managerial expertise is required. We call the first institutional arrangement "family farming" and the second "neoclassical farming."

We also follow Drazen and Eckstein by abstracting from "demand side" differences between agricultural goods and industrial goods. We assume that agricultural goods and manufacturing goods are perfect substitutes in consumption. Household utility is simply a function of the total consumption of the two goods. Fixing the relative price of agricultural goods in terms of manufactures eliminates any changes in the agricultural

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[7] As suggested in the introduction, our approach is consistent with the strong tradition of family farming that persists even today in the US. Intergenerational links to farming seem to be a common feature of many developing countries for a variety of reasons. Hayashi and Prescott (2006) claim that Japan's development was slowed by a social convention of passing the farm along within the family. The paper includes a passage (p.40), suggested by Andrew Foster, arguing that the social convention may be strong enough to operate even in the presence of a land market. "First, the heir could sell the inherited farmland and live in the city to collect the higher urban income. However, to prevent this, the father could require the son to remain on the farm until he inherits the land. By the time his son inherits the estate, it may be too late for him to start a career in the city." Collier, Radwan, and Wange (1986) find that those individuals who indefinitely migrate away from farms in Tanzania tend to lose their land entitlement. In China, explicit migration rules cause migrants to the city to give up ownership claims to land and small businesses in rural areas (Au and Henderson (2006)).

sector that might arise from differences in price or income elasticities for the two goods.[8] Alternatively, one can think of the distinction between sectors as rural-informal production and urban-formal production with the same good produced in each sector with different technologies.

A. Industry

1. Technology

Producers in the industrial sector are neoclassical firms with the standard Cobb-Douglas production function

$$Y_t = K_t^{\alpha}\left(D_t H_t\right)^{1-\alpha}, \tag{1}$$

where *Y* denotes output, *K* is the physical capital stock, *DH* is the effective labor supply, and α is the capital share parameter. The effective labor supply is comprised of a labor-augmenting level of technology, *D*, and the stock of human capital allocated to industry, *H*. The level and growth of *D* is exogenously determined, with a constant growth rate of *d*. The supply of *H* is determined endogenously determined by fertility, the fraction of the working population in industry, and the schooling of children.

The firms operate in perfectly competitive markets and the standard profit-maximizing factor-price equations for the rental rates on human and physical capital are

$$W_t = \left(1-\alpha\right) D_t k_t^{\alpha} \tag{2a}$$

$$r_t + \delta = \alpha k_t^{\alpha-1}, \tag{2b}$$

where *r* is the net return to capital, δ is the rate of depreciation of physical capital, and $k \equiv K / DH$.

2. Households Working in the Industrial Sector

All households live for three periods; one period of childhood and two periods of adulthood. Households value their consumption over the two periods of adulthood (c_t^y, c_{t+1}^o) and the adult human capital (h_{t+1}) of all their children (n_{t+1}). Preferences are identical across households, regardless of occupational choice, and are given by

$$U_t = \ln c_t^y + \beta \ln c_{t+1}^o + \psi \ln\left(n_{t+1} h_{t+1}\right),$$

where $0 < \beta < 1$ and $\psi > 0$ are preference parameters. This preference specification is a simple way of capturing the idea that parents value both the quantity and the quality of children. It has been use extensively in the literature on fertility and growth (e.g., Galor

[8] Caselli and Coleman (2001) find little trend in the relative price of farm goods from 1880 to 1980.

and Weil (2000), Greenwood and Seshadri (2002), Hazan and Berdugo (2002), and Moav (2005)).

Adults inelastically supply one unit of labor when young and zero units when old. Children have an endowment of $T<1$ units of time that they can use to attend school (s_t) or work ($T-s_t$). Children have less than one unit of time to spend productively because in the very beginning years of childhood they are too young to either attend school or to work, and in their middle years they do not have the mental or physical endurance to school or work as long as an adult.

While children may work as they become older, they are also expensive to care for and feed. To raise each child requires a loss of adult consumption equal to a fixed fraction τ of the adult's first period wages.[9]

The government decrees that younger children receive some education during their early years. So each child invests at least $\bar{s}$ units of time into learning during the first portion of their childhood.[10] This gives older children $\gamma\bar{h}_t = \gamma\bar{s}^{\theta}$ units of human capital that can be used in production during the later years of childhood, where $0 < \theta < 1$ is a parameter that gauges the effect of schooling on human capital accumulation and $0<\gamma<1$ reflects the fact that children lack relative physical strength or experience in applying knowledge to production compared to an adult. Adult human capital of the same person in the next period is $h_{t+1} = s_t^{\theta}$. Thus, a person is more productive in adulthood than in childhood because of greater strength and experience ($1 > \gamma$) and additional schooling ($s_t \geq \bar{s}$).

The household maximizes utility subject to the lifetime budget constraint,

$$c_t^y + \frac{c_{t+1}^o}{1+r_{t+1}} + n_{t+1}\tau w_t h_t = w_t h_t + n_{t+1} w_t \gamma\bar{h}\left(T - s_t\right).$$

In addition to the standard first order conditions for life-cycle consumption, the choices of n_{t+1} and s_t yield

$$\frac{\psi\theta}{s_t} \leq \lambda_t n_{t+1} w_t \gamma\bar{h} \tag{3a}$$

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[9] One can interpret the loss in consumption as forgone wages from time taken to rear children or the payment for good and services provided to children. In the latter case, the costs of goods and services are interpreted to rise with adult labor costs (e.g. primary schooling) or one can simply assume that young parents offer children a share of their earnings for consumption.

[10] Alternatively, $\bar{S}$ may be interpreted as a minimum amount of schooling (learning) needed for the child to be productive.

$$\frac{\psi}{n_{t+1}} = \lambda_t \left[\tau w_t h_t - (T - s_t) w_t \gamma \bar{h} \right], \tag{3b}$$

where λ_t is the Lagrange multiplier.

Equation (3) summarizes the parents' decisions regarding the quantity and quality (human capital) of children. Equation (3a) says the marginal utility of additional child quality must be equated to the marginal value of consumption lost from allowing children of working age to attend school. The strict inequality holds when the marginal cost of educating children beyond the schooling received in their early years, $\bar{s}$, exceeds the marginal benefit. In this case, parents are content to set $s_t = \bar{s}$.

Equation (3b) says the marginal utility of additional children must be equated to the marginal value of lost consumption. Consumption is lost from having additional children because we assume the cost of children exceeds the earnings that older children bring to the household.

Solving the model gives us the following demand functions for children and schooling

$$n_{t+1} = \frac{\psi}{(1 + \beta + \psi)\left(\tau - \gamma (T - s_t)(\bar{s}/s_{t-1})^{\theta}\right)} \tag{4a}$$

$$s_t = \max\left[\frac{\theta\left(\tau (s_{t-1}/\bar{s})^{\theta} - \gamma T\right)}{\gamma (1 - \theta)}, \bar{s} \right]. \tag{4b}$$

Assuming that s_{t-1} is sufficiently high, an assumption that we make throughout, a dynamic results that causes economic growth and a demographic transition.[11] Greater schooling raises adult earnings relative to older children's earnings. This raises the net cost of having children, so fertility declines. Lower fertility and greater consumption lowers both the quantity and the value of forgone earnings from schooling children, so schooling rises further. Thus, the sole factor driving fertility down is the rise in schooling.

B. Agriculture

The agricultural sector differs from the industrial sector because of differences in the production technology and, under one of our extreme assumptions, because the technology is directly owned and operated by a family—creating entrepreneurial or residual income for the family head.

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[11] Mourmouras and Rangazas (2007) examine a "poverty trap" outcome with $s_t = \bar{s}$ for all *t*.

1. Technology

Agricultural output is produced using the following Cobb-Douglas technology

$$O_t = A_t l_t^{\rho} f_t^{1-\rho}, \tag{5}$$

where O is agricultural output, A is agricultural TFP, l is land per farm, f is farm labor, and $0 < \rho < 1$ is a technology parameter. This technology differs from that use in industry because land is an input rather than physical capital.[12] In general, TFP and the labor-share parameter may also differ across sectors.

2. Households Working in the Agricultural Sector

In the case of *family farming*, we assume that the young household inherits the skills and land needed to operate a farm from their parents. Operating a family farm will, in addition to the wages earned from working on the farm, generate residual income for the family. The presence of this residual income and the fact that the rental rate on human capital earned in agriculture ($\tilde{W}$) will in general differ from those in industry are the fundamental differences between farming and working in industry. We also consider the possibility that schooling for those in the agricultural sector may lag behind those in the industrial sector (simply because schooling became available in urban areas before rural ones, causing schooling to lag behind, via the dynamics of (4b), for every subsequent generation). These three differences then potentially cause all farm choice variables to differ from those chosen in the industrial sector.

The lifetime budget constraint for a household choosing to follow their parents and work in agriculture is

$$\tilde{c}_t^y + \frac{\tilde{c}_{t+1}^o}{1+r_{t+1}} + \tilde{n}_{t+1}\tau\tilde{W}_t\tilde{h}_t = \tilde{W}_t\tilde{h}_t + \tilde{n}_{t+1}\tilde{W}_t\gamma\tilde{h}\left(T-\tilde{s}_t\right) + \left[O_t - \tilde{W}_t f_t\right], \tag{6}$$

where $\left[O_t - \tilde{W}_t f_t\right]$ is the residual income from farming.[13] Thus, the farm is passed to the next generation when the farmer retires. This means the residual income from farm ownership is received in the first period of adulthood. An alternative approach would be to assume that parents retain ownership and manage the farm during their "retirement"

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[12] Of course, physical capital also contributes to agricultural production, although less than in industry. For simplicity, we assume no role for physical capital in agriculture, a more dramatic difference between sectors than is present in reality. In our empirical application we do not allow for endogenous changes in physical capital intensity, for reasons that are discussed below. So changes in physical capital intensity, and their differential effect across sectors, are captured in changes in relative TFP across sectors.

[13] Unlike some approaches, we follow Schultz (1964) and assume that human capital is productive on the farm. There is a good deal of evidence supporting this stance (e.g. Jamison and Lau (1982), Lucas (1985), Foster and Rosenzweig (1996), Goldin and Katz (2000), Duflo (2001), and Jenkins and Knight (2005)).

period. In this case the farm is not passed to children until the parent dies. The children, who worked on the family farm during their first two periods of life, then receive residual income in their third or retirement period.

Assuming that residual income accrues in the third period captures the idea that the family farm provided a source of retirement income that substituted for retirement saving, a potentially important factor in slowing physical capital accumulation in the early stages of development (see Carter and Sutch (2002)). However, taking this approach, in a two sector-model, results in indeterminate transitional growth paths for the agricultural wage (Rangazas (2006)). The focus of this paper is wage gaps during transitional development, so we assume the farm is passed to the children during their working period. In what follows, the deficiencies of our assumption as it relates to saving and physical capital formation will be minimized by making a small open-economy assumption.

Maximizing utility subject to (5) and (6) yields demands for children, schooling, and farm labor

$$\tilde{n}_{t+1} = \left(\frac{\psi}{1+\beta+\psi}\right)\frac{\left(1+\left(\rho/(1-\rho)\right)\left(f_t/\tilde{h}_t\right)\right)}{\tau-\gamma\left(T-\tilde{s}_t\right)\left(\overline{s}/\tilde{s}_{t-1}\right)^{\theta}} \tag{7a}$$

$$\tilde{s}_t = \max\left[\frac{\theta\left(\tau\left(\tilde{s}_{t-1}/\overline{s}\right)-\gamma T\right)}{\gamma(1-\theta)}, \overline{s}\right] \tag{7b}$$

$$f_t = \left[\frac{(1-\rho)A_t l_t^{\rho}}{\tilde{W}_t}\right]^{\frac{1}{\rho}} \tag{7c}$$

Contrasting (7a) to (4a), reveals that production on the family farm introduces a new term in the fertility demand function, $\rho f_t / (1-\rho)\tilde{h}_t$, that raises fertility (other things constant). The numerator of this term is the after-tax share of family production that flows to older households. The denominator is the potential "full" wage that can be earned as a young adult, which determines the opportunity cost of having children. The more important family production is, relative to the opportunity cost of children, the stronger is the demand for children. This is not a pure wealth effect, but rather is an effect that arises when one form of wealth (that does *not* affect the net cost of children), the ownership of family production, changes relative to another form of wealth (that *does* affect the net cost of children), the flow of adult earnings. A shift in the composition of family wealth away from family production and toward adult labor income causes the net cost of children to rise, for a given level of family wealth, and the demand of children falls.

The demand for schooling takes the same form as in (4b), although there may be different initial conditions for households living in rural areas. There is no effect of family production on schooling because of two offsetting effects. To see these effects, first note that fertility raises the cost of schooling children (more children means greater forgone consumption of parents as schooling rises and child labor income falls). Second, note that the level of parental consumption determines the marginal *value* of forgone consumption associated with greater schooling (higher parental consumption levels means parents can better "afford" the lost consumption associated with more schooling). Family production raises *both* fertility and parental consumption, other things constant. As just mentioned, higher fertility lowers the incentive to school children, but a higher consumption level raises the incentive to school children. With our functional forms for preferences and human capital production, these two effects always exactly offset.

The demand for labor in (7c) results from the farm owner hiring labor to equate the marginal product of effective labor to the agricultural rental rate on human capital, perfectly analogous to the demand for labor by neoclassical firms in competitive factor markets. Note that we allow the demand for labor at an individual farm to be is less than or greater than the supply of labor coming from the household owning the farm. From the perspective of individual farms, some of the household labor may have to be supplied to neighboring farms or, alternatively, farm "hands" may have to be hired to supplement family labor supply.

In the case of *neoclassical farms* with a land market, the farm is not passed down across generations. Instead land is strictly analogous to physical capital; an asset purchased by young households, from old households, that can generate rental income and retirement savings. For this case, the agricultural sector is comprised of neoclassical firms, and not family producers, that rent land and hire labor from households.

In the presence of a land market, the rate of return on land must equal the interest rate if both land and capital are held in equilibrium. An implication of the equality of rates of return on land and physical capital is that the *lifetime* budget constraint is unaffected by the presence of land and would take the same form as the constraint in the absence of family production. In this case, the numerator of (7a) would contain no family production terms and fertility would be determined solely by schooling as in (4a). Thus, the presence of land/farming does not affect fertility. Furthermore, we also show below that wages (more accurately, rental rates on human capital) across the two sectors must now be equated. Thus, other than possible differences in the schooling of their initial generations, households in the two sectors are identical under the neoclassical farming assumption.

C. Equilibrium

As discussed above, we begin by making a small open-economy assumption.[14] The interest rate and rate of return to physical capital must equal the exogenous international

[14] Assuming that the residual income from farm ownership is received in the first period has the advantage of pinning a unique transition path for the farm wage—a primary focus of the paper. However, it comes at the cost of generating too much saving to finance physical capital accumulation in the relatively small industrial sector. The open economy assumption minimizes this problem.

interest rate, *r*. Equating r_{t+1} to *r* in (2b), allows one to solve for the equilibrium value *k*. Equation (2a) can then be used solve for the equilibrium W_t.

Next we turn to the labor market where the equilibrium allocation across sectors is determined. The determination of labor market equilibrium is tied to our institutional assumptions about farming and the market for land.

1. Family Farming

Occupational Choice and the Equilibrium Gap in Rental Rates

A young household born into the rural sector has the option of staying there (receiving land and then farming it) or of moving to the city and working in industry. Those who were born in the urban sector must stay there because they have no possibility of obtaining land. As discussed, fertility is higher in agriculture, so there must be some movement of the population from agriculture to industry, or the fraction of workers in industry would *fall* over time (contradicting the economic transformation associated with development). For there to be some movement, but not a *complete* shift of the population to industry, the rental-rate gap between the two sectors much be such that a worker born into the rural sector is indifferent about staying there. Calculating the indirect utility function of the household under each option and then equating them, gives an expression for the equilibrium rental-rate gap

$$\frac{W_t}{\tilde{W}_t} = \left[1 + \frac{\rho f_t}{(1-\rho)\tilde{h}_t}\right]^{1+\frac{\psi}{1+\beta}}. \qquad (8)$$

The term in the square-bracket on the right-hand-side exceeds one due to the residual income received from operating a family farm. Rental rates in industry must exceed those in agriculture to compensate for giving up the farm and its additional source of income. [15]

The equilibrium rental-rate gap is further widened by the fact that the exponent on the term in square bracket exceeds one. With endogenous fertility, being indifferent about working in the two sectors requires more than the equality of lifetime resources. The higher wages in industry increase the opportunity cost of time spent away from work or raise the direct costs of providing consumption goods to children. Thus, working in the industry raises the cost of having and raising children relative to working in agriculture. This results in fewer children for nonfarm households. Given that parents like children

[15] Note that the rental rate on human capital applies to the entire working life. Thus, the rental rate gap across sectors incorporates both differences in hours worked across sectors and differences in productivity per hour worked.

(ψ > 0), they must receive a rental-rate premium in industry that compensates them for the fewer children they will have.

Labor Market Clearing

Let $\tilde{N}_t$ denote the number of young households choosing the rural sector. The aggregate demand for farm labor is then $\tilde{N}_t f_t$. Each household supplies their own labor and that of their children to the market for farm labor.[16] The aggregate supply of effective labor to the rural sector is then $\tilde{N}_t \tilde{h}_t \left[1 + \tilde{n}_{t+1} \gamma \frac{\bar{h}}{\tilde{h}_t} (T - \tilde{s}_t) \right]$. All households that remain in the agricultural sector are identical, thus in equilibrium each household must demand enough labor to absorb the quantity of labor they supply,

$$f_t = \tilde{h}_t \left[1 + \tilde{n}_{t+1} \gamma \frac{\bar{h}}{\tilde{h}_t} (T - \tilde{s}_t) \right]. \qquad (9)$$

Land per Farmer and the Allocation of Labor

The aggregate quantity of raw land is fixed at *L*. The quantity of land per farmer is then $l_t = L / \tilde{N}_t$. Thus, l_t falls over time as long as the population of farming households increases over time. However, the *effective* land per farmer may stay constant or grow if farm technology and land development increase over time at a sufficiently fast pace. Technological progress in agriculture and land improvements are treated exogenously and are captured in A_t.[17]

Given the path of A_t, (7)-(9) determine the equilibrium paths of $\tilde{s}_t, \tilde{n}_{t+1}, \tilde{W}_t, f_t$, and $\tilde{N}_t$. In particular, using (7c) and (9), the number of farm operators is given by

$$\tilde{N}_t = \frac{L\left[(1-\rho) A_t\right]^{\frac{1}{\rho}}}{f_t \tilde{W}_t^{1/\rho}}.$$

The number of farm owners is increasing in A_t (a better technology or a higher effective supply of land increases farm productivity). The number of farmers is decreasing in both

[16] The labor supply of farm households depends on how one interprets the costs of raising children. We considered the costs to be either pure time costs (that reduce parents' labor supply) or pure goods costs (that reduce parents' consumption directly). We found that the "goods-costs" interpretation lead to a more plausible calibration of the model. In the pure "time-cost" interpretation, the calibrated values of τ and γ were too high to be consistent with empirical estimates.

[17] For an interesting and detailed first attempt to make land improvements endogenous see Vandenbrouke (2003, 2004).

$\tilde{W}$ (the cost of farm labor) and the effective supply of farm labor from a farm family (to absorb a larger effective supply of family workers, more land per farmer is needed to generate a rise in labor productivity and a greater demand for labor).

It should be noted that the supply of *potential* farmers in period-*t* includes the entire population of children of the previous generation of farmers, $\tilde{n}_t\tilde{N}_{t-1}$. In equilibrium we must have $\tilde{N}_t \le \tilde{n}_t\tilde{N}_{t-1}$. Along a transitional growth path, we will have $\tilde{N}_t < \tilde{n}_t\tilde{N}_{t-1}$, so that a fraction of the potential farmers leave for the industrial sector each period. This implies that there are actually three types of households: (i) the original dynastic line of industrial workers, (ii) industrial workers that have migrated from the agricultural sector, and (iii) households remaining in the agricultural sector. In general, the initial schooling of types (i) and (ii) will differ, causing the schooling of *all* households in each of their dynastic lines to differ during the transition. The schooling difference causes fertility of the migrant households to be different from a household whose dynastic line originated in an urban area. The migrant household's fertility is given by

$$\hat{n}_{t+1} = \left(\frac{\psi}{1+\beta+\psi}\right)\frac{1}{\tau-\gamma\left(T-\tilde{s}_t\right)\left(\bar{s}/\tilde{s}_{t-1}\right)}. \tag{10}$$

Thus, the industrial sector will contain two distinct types—both of which differ from the household remaining in the agricultural sector, along at least one dimension.

Summary

Given the international interest rate *r*, the exogenously determined paths of D_t and A_t, and initial conditions for s_t and $\tilde{s}_t$, the equilibrium transition paths for $W_t, \tilde{W}_t, s_t, \tilde{s}_t, n_{t+1}, \tilde{n}_{t+1}, \hat{n}_{t+1}, f_t, \tilde{N}_t$, under the *family farming* arrangement, are determined by (2), (4), and (7)-(10).

2. Neoclassical Farming

Occupational Choice

In the absence of any intergenerational transfer of skills/land, land is purchased as any other asset and then rented to neoclassical farms. Occupational choice is not tied to the ownership of land, and therefore the rental rate paid in each sector must be equal,

$$\tilde{W}_t = W_t. \tag{11}$$

Factor Market Equilibrium in Agriculture

The neoclassical farms take the competitive rental rates on labor and land, W_t and r_t^L, as given and choose labor and land inputs to maximize profits. The corresponding factor-price equations are

$$\rho O_t = r_t^L l_t \tag{12a}$$

$$\left(1-\rho\right) O_t = W_t f_t \, . \tag{12b}$$

Equation (12b) can be used to solve for the optimal input mix in agriculture,

$$\frac{f_t}{l_t} = \left[\frac{(1-\rho)A_t}{W_t} \right]^{\frac{1}{\rho}} . \tag{13}$$

In the aggregate, the supply of land is *L* and the supply of labor to the agricultural sector is $\tilde{N}_t \tilde{h}_t \left(1 + \tilde{n}_{t+1} \gamma \frac{\bar{h}}{h_t} \left(T - \tilde{s}_t\right)\right)$. Thus, market clearing in the factor markets implies

$$\tilde{N}_t \tilde{h}_t \left(1 + \tilde{n}_{t+1} \gamma \frac{\bar{h}}{h_t} \left(T - \tilde{s}_t\right)\right) = \left[\frac{(1-\rho)A_t}{W_t} \right]^{\frac{1}{\rho}} L \, . \tag{14}$$

As above, we consider transitional growth paths with the property that $\tilde{N}_t < \tilde{n}_t \tilde{N}_{t-1}$, so that each period there is migration from agriculture to industry.

Land Prices

Young households buy land at the market price P_t and then rent it to agriculture firms. In the next period, land owners receive the rental rate on their land holdings and then sell land to the next generation of land households. In equilibrium where land and physical capital are both held, the returns on the two assets must be equal,

$$\frac{P_{t+1}}{P_t} + \frac{r_{t+1}^L}{P_t} = 1 + r \, . \tag{15}$$

Summary

Given the international interest rate *r*, the exogenously determined paths of D_t and A_t, and initial conditions for s_t and $\tilde{s}_t$, the equilibrium transition paths for $W_t, r_t^L, s_t, \tilde{s}_t, n_{t+1}, \hat{n}_{t+1}, f_t, \tilde{N}_t, P_t$, under the *neoclassical farming* arrangement, are determined by (2), (5), (7b), (10), (11), (12a) and (13)-(15). Note that because there is no residual income from family farming that the fertility of all households with dynasties originating in the agricultural sector is $\hat{n}_{t+1}$, as given by (10).

V. CALIBRATION AND TESTING

In this section we calibrate the parameters of the models under our two extreme assumptions and then test the resulting quantitative models against the remaining observations not used in the calibration.

A. Calibration

The time periods are interpreted to last 20 years. The physical capital share in the industrial sector, α , is set to the standard value of 1/3. Since the aggregate labor share does not vary systematically with a country's state of development (Gollin (2002)), we also set ρ to a value of 1/3. The productive time endowment of children for work or school, *T*, is set to 0.5 (one half the time endowment of a young adult). One can think of the child has having no capability for productive activity from ages 0 to 4, half that of an adult from ages 5 to 14, and the same capabilities for productive effort as an adult from ages 15 to 19. We assume that the steady state is characterized by full-time schooling, $s = \tilde{s} = T$, and a fertility rate of one child per parent in urban households, $n = 1$. The remaining calibrations are specific to our assumptions about farming.

1. Family Farming

As in Mourmouras and Rangazas (2007), we set the schooling level of young children, $\bar{s}$, to be 0.08. We know from Lord and Rangazas (2006) that time spent in school was in the range 0.08 to 0.10 during the second half of the 19th century, and increased only modestly before then. The parameters θ, τ, γ , and $\varphi \equiv \frac{\psi}{1+\beta}$, the initial conditions for s_t and $\tilde{s}_t$ (schooling in 1780, which determine the initial human capital stocks for parents in 1800) and the fraction of rural households that migrant to industry in 1800, were then set to match seven targets. The targets include (i) an average economy-wide fertility of 3.5 in 1800, (ii) the average time spent in school in 1880, 0.10 (the earliest year with both complete data and a sufficient distance in time from the Civil War), (iii) n =1, (iv) $\tilde{n}_{1800} = 3.6$, (v) $n_{1800} = 2.4$, (vi) $\bar{s}$ = 0.08, and (vii) s = 0.5.

The time series for $a_t \equiv \frac{A_t}{D_t}$ is set to match the fraction of the workforce in agriculture in each period. This is possible since (7c) and (9) determine *l*, the land per farmer, needed to generate the demand for labor that is just sufficient to clear the labor market. By choosing a_t , we can use (9) to determine the value of $\tilde{N}_t$ that matches the observed fraction of the aggregate workforce in agriculture. The resulting growth in a_t over time can be interpreted as a prediction of how fast effective land (determined by cultivation of new and improved land, and by technology change in agriculture) grew relative to technological change in industry.

Finally, the exogenous growth rate of labor-augmenting technological change in industry, *d*, was set to match the average growth in labor productivity during the 20th century. The first column of Table 4 summarizes the parameter settings under the *family farming* assumption.

Table 4. Calibrated Parameter Values

Parameter	Family Farming	Neoclassical Farming
γ	0.2729	0.2729
τ	0.1704	0.1641
θ	0.3910	0.3766
$\alpha = \rho$	0.3333	0.3333
φ	0.2054	0.1963
d (annualized)	0.0085	0.0093
$\overline{s}$	0.08	0.06
s_{1800}	0.0950	0.0825
$\tilde{s}_{1800}$	0.0807	0.0620

2. Neoclassical Farming

Under the neoclassical farming assumption, fertility is determined solely by schooling because inherited residual income from operating a family farm is absent. In order to match fertility levels early in the 19th century, the level of schooling must be lower than under family farming. We set $\overline{s}$ in order to allow schooling to be set sufficiently low in 1800 to generate 3.5 children per parent. The other aspects of the calibration are similar to the calibration under family farming. The second column of Table 4 summarizes the parameter settings under the *neoclassical farming* assumption.

B. Testing

The calibrated models can now be used to simulate the economic development of the U.S. from 1800 to 2000. The predictions of the models can be compared to actual data not used in the calibration. The data free for testing includes (i) the path of schooling during the 20th century, (ii) the pattern of the fertility decline over both centuries, (iii) the average rate of growth of worker productivity during the 19th century, (iv) the pattern of worker productivity growth over both centuries (v) the wage gap over both centuries, and (vi) the relative growth in farm technology/land improvement over both centuries.

C. Schooling

Figure 4 compares the predicted schooling from both models to actual schooling. The *family-farming* model matches schooling almost exactly until 1920. In the middle of the 20th century, the predicted schooling does not rise as fast as actual schooling, although it matches actual schooling well by century's end. The failure to match the rapid rise in schooling in the middle of the century was in part due to government's expanding subsidy of schooling during the high school movement and then after WWII through programs such as the GI Bill and Pell Grants, elements missing from the model.

The neoclassical model predicts a rise in schooling that exceeds actual schooling from 1880 on. Although predicted and actual schooling are close in the middle of the 20th century, predicted schooling is significantly above actual schooling by century's end. The reason for the divergence in the predictions of the two models is that the *neoclassical-farming* model must start with significantly lower schooling levels at the beginning of the 19th century to order to match the fertility observations. Starting with lower levels of schooling, it must generate a more rapid increase in schooling to match the target level of schooling in 1880. The rapid rise in schooling causes the level of schooling to rise too fast over the 20th century.

Figure 4a. Schooling with Family Farming

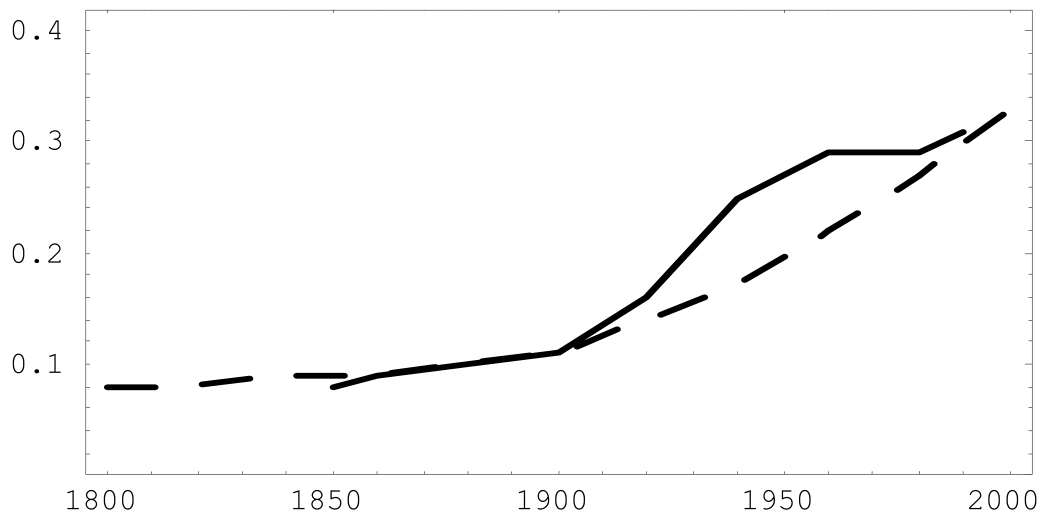
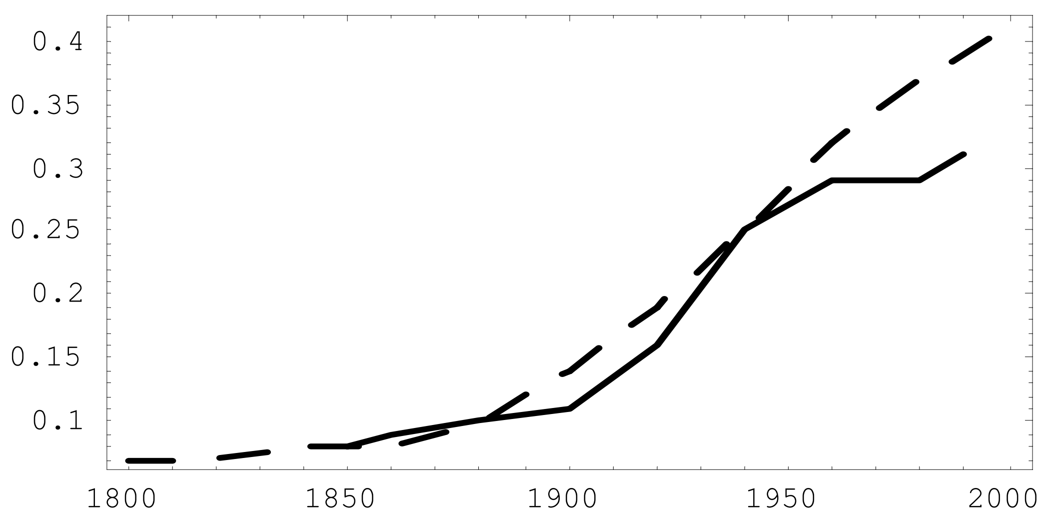


Figure 4b. Schooling with Neoclassical Farming



1. Fertility

As seen in Figure 5, both models match the fertility levels at the end of the 20th century, but fail to fully explain the decline during the 19th century. The neoclassical farming model does better in matching fertility levels by 1900, but this is largely due to its over-prediction of schooling levels in 1900. While the models explain a significant portion of the fertility decline, there are certainly some missing factors that accelerated the fertility decline at the end of the 19th and beginning of the 20th century (for example, declines in child mortality).

Figure 5a. Fertility with Family Farming

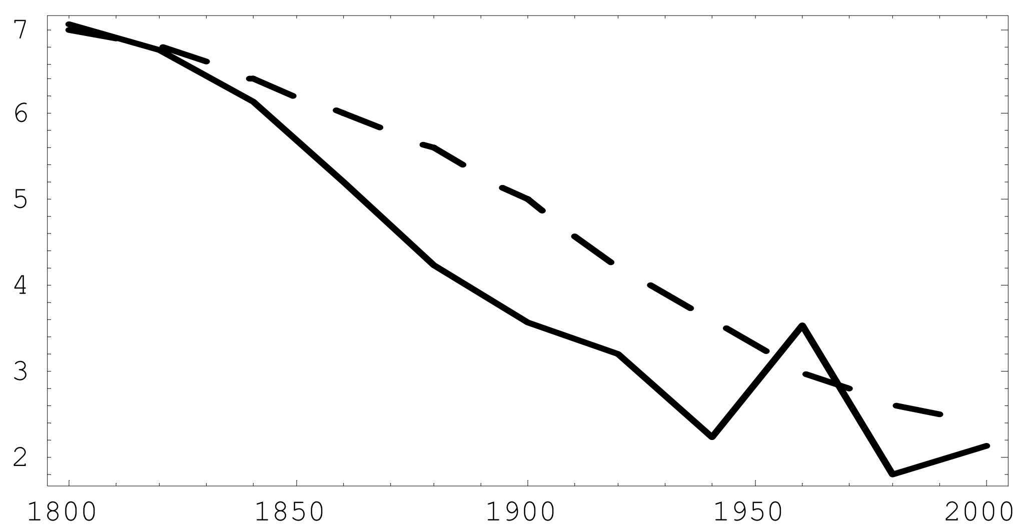
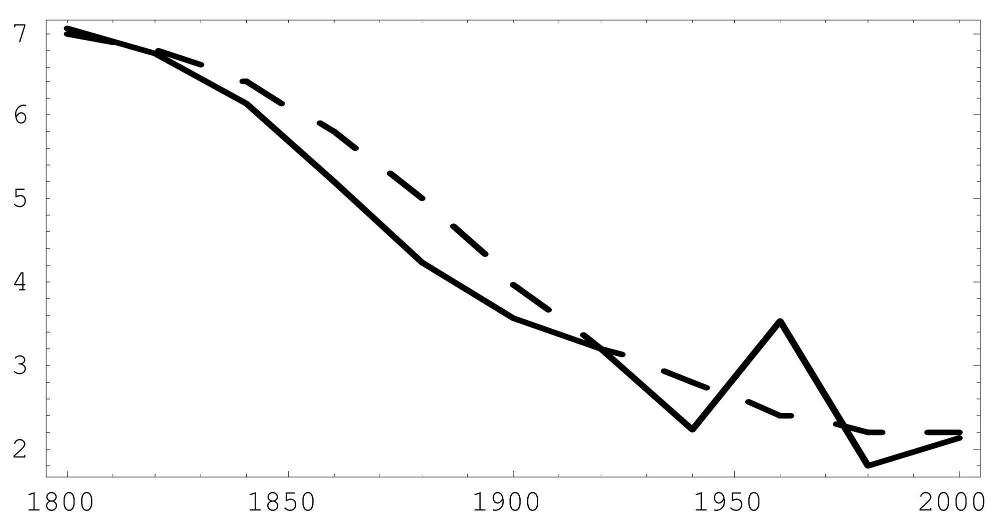


Figure 5b. Fertility with Neoclassical Farming



2. Wage Gap

The *family farming* model explains wage gaps on the basis of three factors: (i) residual income that accrues to owners of the family farm (ii) the higher opportunity cost of raising children as a worker in industry and (iii) differences in the initial schooling levels for family dynasties that found themselves in rural versus urban communities in 1800. The *neoclassical farming* model explains the wage gap solely on the last of these factors. The human capital differences suggest differences in productivity per hour worked, but the first two factors could explain differences in lifetime wages due to productivity per hour worked or differences in hours worked per year.

As discussed above in the historical background section, the pre-Civil War value for annual output per worker is a reasonable measure of the productivity gap based on real economic fundamentals. In 1840, output per worker was 2.5 times higher in industry than in agriculture. The estimates of relative annual wages at the end of the 20th century should also be reasonably tight upper-bounds for the real differences in annual productivity based on economic fundamentals. Complicating factors, such as The Civil War effect on North-South wages and non-wage payments, were likely to be quantitatively unimportant by this time. However, the estimates are still likely to be a somewhat high due to cost-of-living differences between urban and rural areas. The wage gap for 1980 was 1.4.

The *family farming* model predicts a wage gap of 2.06 in 1840 and 1.68 in 1980. The decline in the predicted wage gap is due to a decline in the importance of family farming (as labor shifts to industry and fertility falls, the family farm generates less residual income per farmer) and a convergence in human capital across the two sectors. The *neoclassical farming* model predicts a wage gap of 1.14 in 1840 and 1.00 in 1980, based on schooling differences across sectors that are consistent with the other targets of the model (in particular the average level of schooling, the average level of fertility, and the difference in fertility across rural and urban families). The small wage gap predicted by the *neoclassical farming* model suggests that schooling differences had little to do with the wage gap.[18]

Both models under-predict the gap in 1840, but the *family farming* model explains about 80 percent of it. The family farming model, however, over-predicts the gap in 1980. This is not surprising; the extreme assumption of *family farming* is certainly less accurate at the end of the 20th century than in the middle of the 19th century.

[18] This is in contrast to Caselli and Coleman (2001). They explain a large wage gap based solely on differences in schooling across sectors. However, as in our model, schooling differences across sectors have never been very large. Based on the 1915 Iowa census, Goldin and Katz (1999) find the average years of schooling in white collar occupations was 10.8 years, while in blue collar occupations and farming it was 7.8. Using the 1960 US census, Murphy and Welch found the average years of schooling were 13.4 in white collar occupation, 9.8 in blue collar occupations, and 9.1 in farming.

3. Worker Productivity

Figure 6 compares the actual growth rates in output per worker to those predicted by the models. The rate of technological change was calibrated to match the average growth rate in worker productivity during the 20th century. No parameter was calibrated to match the average growth rate in the 19th century. The actual average growth rate of output per worker in the 19th century was 1.36 percent. The *family farming* model predicts an average growth rate of 1.35 percent and the *neoclassical farming* model predicts an average growth rate of 1.29 percent. In comparison to the *neoclassical farming* model, the *family farming* model has a smaller rate of technological change (0.85 percent versus 0.93 percent) because the larger wage gap in the *family farming* model increases the endogenous component of growth as labor is reallocated to industry.

The *family farming* model preformed better in generating the pattern of growth. At only three of the ten data points did the *neoclassical farming* model come closer to the actual growth rate. Over the entire sample, the average absolute deviation of the predicted value from the actual value was over 40 percent higher when using the *neoclassical farming* model.

Figure 6a. Worker Productivity Growth with Family Farming

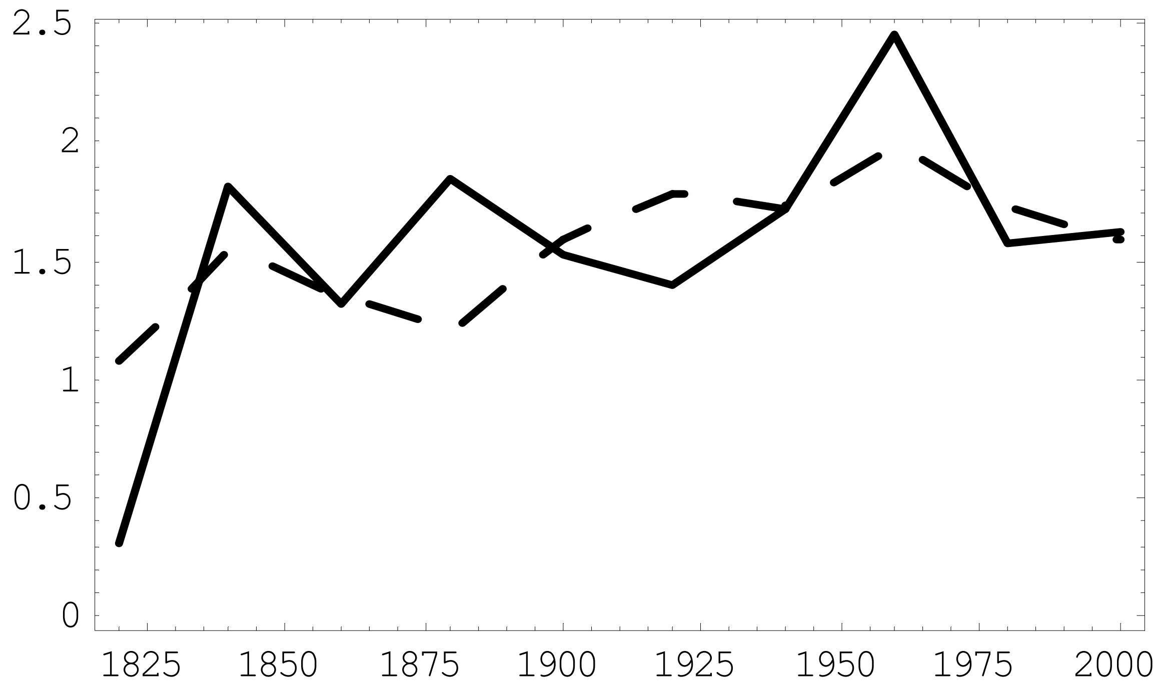
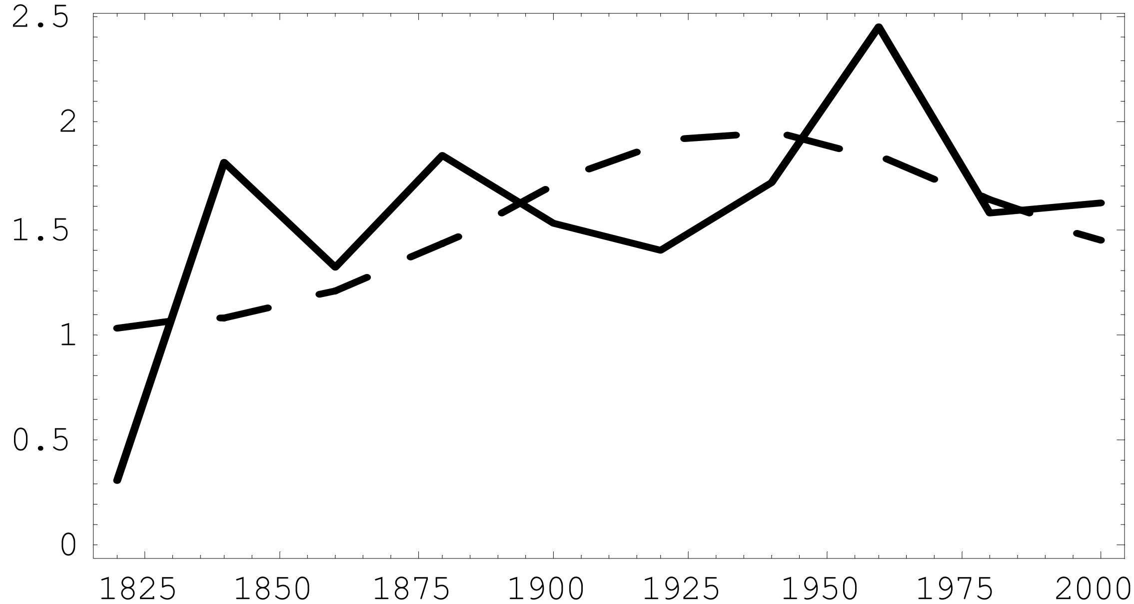


Figure 6b. Worker Productivity Growth with Neoclassical Farming



4. Farm Technology/Land Improvement

We computed the growth in relative farm technology and farm land per farmer, captured by the growth in A_t, that was required to match the fraction of the work force in agriculture. Under both models, the predicted growth in farm technology and farm land per farmer was approximately equal to predicted technological change off the farm during the 19th century. This feature seems reasonable given the observed behavior of labor productivity growth across sectors in the 19th century. Recall that labor productivity off the farm grew only 0.13 percentage points faster in services and 0.18 percentage points faster in industry, than in agriculture. Thus, the growth in TFP in the two sectors was probably quite similar.[19]

In the 20th century both models predicted a slight rise in the relative farm technology and land per farmer (about 0.2% per year). This was necessary to raise farm productivity in the presence of a rising relative wage in agriculture and an increase in effective labor

[19] The small open economy assumption does not allow for endogenous changes in physical capital intensity. Historical interest rate data (see Wallis (2000)) suggests an increase in physical capital intensity occurred from 1870 to 1900, as interest rates fell. Increased physical capital intensity over this period increased the relative wage in industry and encouraged migration out of farming, other things constant. Since we do not account for the rise in physical capital intensity on migration, our estimated growth in the relative TFP in agriculture underestimates what is needed to match the data over this period—i.e. in face of a rise in physical capital intensity, the growth in relative TFP in agriculture would have to be higher from 1870 to 1900.

supply per farm operator. This is consistent with Caselli and Coleman (2001) who conclude that TFP growth on the farm was faster than that off the farm from 1880 to 1990 (see their Appendix D).

5. Summary

The *family farming* model does a better job of explaining the U.S. economic transformation from 1800 to 2000. The residual income from operating a farm helps explain the high rate of fertility in the 19th century. This means that schooling levels do not have to set as low in 1800, preventing the counterfactually large rise in schooling during the 20th century that is predicted by the *neoclassical farming* model. The residual income from operating a family farm also helps explain the 19th century wage gap, which in turn helps explain the growth rate in worker productivity during the 19th century. The pattern of growth rates across time is also more accurately explained by the *family farming* model.

The main weakness of making the family farming assumption is that it over-predicts the wage gap at the end of the 20th century. However, this problem is greatly mitigated by the fact the fraction of labor in agriculture was very small by then.

To understand why migration out of farming occurs in the models, recall the discussion from section IV.C.1. The number of farmers is increasing in farm TFP (A_t), decreasing in the farm rental rate on human capital ($\tilde{W}_t$), and decreasing in the effective labor supply that each farmer must employ (f_t). Both models explain the transition of labor out of agriculture in the 19th century based on insufficient growth in A_t . Rising wages across the economy and a growing population both imply that A_t must grow to maintain a constant fraction of the population in farming. Insufficient growth in A_t causes the fraction of the population in agriculture to fall, until effective land per farmer rises enough to make farming profitable.

In the 19th century, the effect of a rising *relative* wage rate in agriculture (i.e. a shrinking wage gap) on the decline in the number of farms and farm operators is almost exactly offset by a decline in f_t . The farm labor that must be absorbed per farm fell due to the decline in fertility over the century. Since less land is needed to productively employ fewer farm workers, this latter effect causes a *rise* in the number of farms and farm operators, an effect that offset decrease in farm operators due to the rising relative wage of farm workers.

Over the 20th century, the relative wage in agriculture and the supply of effective labor rose together to further reduce the number of farms and farm operators. The supply of effective labor that had to be absorbed per farm rose because schooling and human capital rose faster over this century than fertility fell.

VI. Reallocation of Labor and Productivity Growth

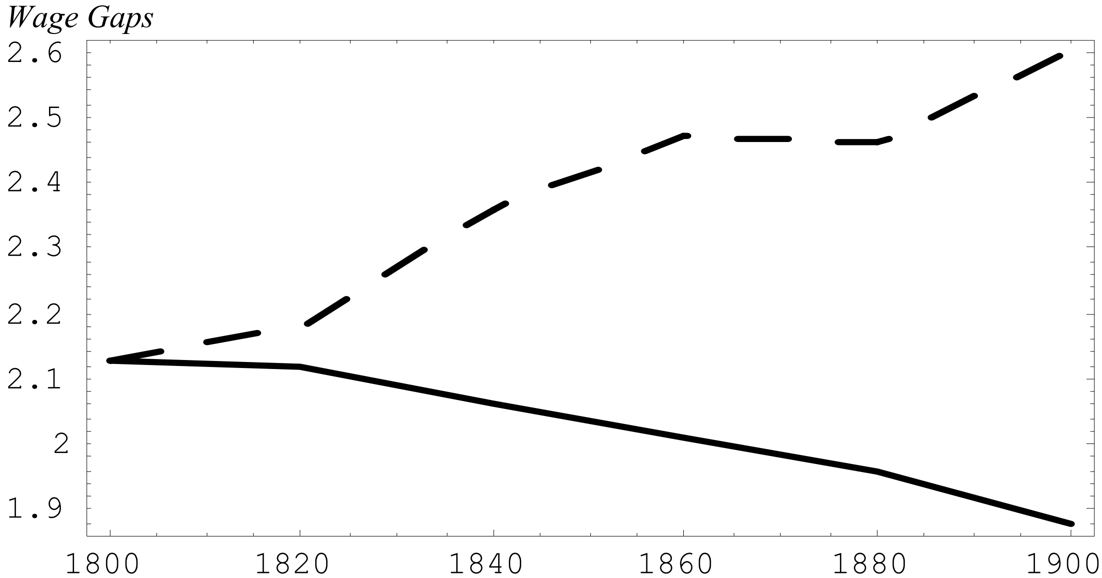
In this section we conduct two experiments designed to identify the growth effects of reallocating labor away from agriculture and toward industry. In both experiments we compute labor productivity growth over the 19th century, assuming that the share of labor in agriculture remains constant at its value of 83 percent in 1800. Both experiments are conducted under the *family farming* assumption.

In Experiment #1 we adjust TFP growth in agriculture so as to generate the constant share of labor in agriculture as an *equilibrium outcome*. To absorb the greater number of agricultural households under the constant labor-share counterfactual, technological progress and land improvements must grow at a faster pace than what was estimated with the declining labor share observed in U.S. history. In this experiment, the equilibrium wage gap will be the same as in the experiment that matched the historical labor shares. To see this, note that in equilibrium each household in agriculture must be indifferent about their choice to remain in farming. As a result, equation (8) must be satisfied. Note further that schooling and fertility will be the same as in the experiment that matched historical labor shares (see the Appendix where the recursive nature of the model is discussed). This causes f_t (from (9)) and $\tilde{h}_t$ to remain the same as well. Thus, all determinants of the human capital rental rate ratio in (8) remain constant. The difference is simply that there will be more farming households in Experiment #1, causing the land to farmer ratio to be smaller. However, this negative effect on farm productivity is offset by the increased pace of agricultural technology and land improvements (by construction).

In Experiment #2 we think of the constant labor share as a *constrained outcome*—as if there were barriers that prevented the equilibrium migration from occurring. In this experiment, farm households would prefer to migrate off the farm and equation (8) is not satisfied. Instead, $\tilde{W}_t$ is determined directly from the marginal product of labor condition in (7c). The value of technological change and land improvements in agriculture will be the same as those estimated from the historical data. The land to farmer ratio will decline, forcing the marginal product of labor and $\tilde{W}_t$ below the values simulated in the experiment that matched historical labor shares. This generates a wider wage gap between sectors.

In Experiment #1, the simulated 19th century growth rate in average worker productivity falls to 1.06 percent, 0.3 percentage points below the historical value of 1.36 percent that was successfully matched when using the historical labor shares. In Experiment #2, the simulated average growth rate drops further because the economy becomes increasingly less efficient over time—as revealed in an increasing wage gap. Figure 7 plots the 19th century wage gaps when the historical shares are matched versus those with a constant labor share. In the historical experiment, the wage gap falls over time (as the value of residual income falls and more households migrate). In Experiment #2, the wage gap widens over time as the marginal product of labor on the farm falls. The 19th century growth rate of average labor productivity in Experiment #2 is only 0.84 percent, more than half a percentage point lower than the historical growth rate.

Figure 7. Simulated 19th Century Wage Gaps



Notes: Solid line is the equilibrium wage gap and dashed line is wage gap when the employment share in agriculture is kept constant.

VII. Migration Costs

Migration from rural to urban areas is certainly associated with some transitional, and perhaps even longer-lasting, costs. For a variety of reasons, migrants may have difficulty finding steady employment and affordable, safe housing in the city. Migration costs, in particular those associated with urban unemployment, are at the heart of the standard Harris-Todaro (1970) models of migration and the wage gap. Carrington, Detragiache, and Viswanath (1996) focus on the role of social networks for migration to the city. They extend the standard Harris-Todaro model by positing that migration costs will be the greatest when the number of recent migrants living in the city, people who may provide assistance to new migrants, is small. They argue that migration costs of new migrants are decreasing in the stock of migrants living in the city.[20]

We introduce migration costs in the spirit of Carrington et al as a way of widening the wage gap. We assume that the migrant is only able to consume a fraction, Φ_t, of the wages received by the urban household because (i) migrants only work a fraction of the work-life of a fully-employed urban household or (ii) migrants face wage and price discrimination—receiving lower wages and paying higher prices for housing and other

[20] See Munshi (2003) for recent evidence supporting the importance of social network for migrants.

goods than do urban households. Following Carrington et al (1996), we assume that Φ_t is an increasing function of the fraction of the workforce in the urban area (a variable that is increasing in the fraction of the urban force that has migrated from rural areas).

In the presence of migration costs, the equilibrium rental-rate gap equations for family farming and neoclassical farming models become

$$\frac{W_t}{\tilde{W}_t} = \frac{1}{\Phi_t}\left[1 + \frac{\rho f_t}{(1-\rho)\tilde{h}_t}\right]^{1+\frac{\psi}{1+\beta}} \tag{8'}$$

and

$$\tilde{W}_t = \frac{1}{\Phi_t} W_t . \tag{11'}$$

In each model, migration costs will decrease $\tilde{W}_t$ and the marginal product of labor in rural areas. However, it is important to note that schooling and fertility are independent of rental rates on human capital. Thus, migration costs will not alter the equilibrium paths of these two variables in both rural and urban areas. In particular, the counterfactually rapid rise in schooling predicted by the neoclassical farming model cannot be rectified by introducing migration costs.

The primary effect of introducing migration costs is to increase the gap between the productivity of labor across sectors. This implies that as labor moves from rural to urban areas, the positive effect on average productivity is magnified in the presence of migration costs. Thus, the endogenous component of economic growth will increase when migration costs are present. The precise nature of the productivity effect depends on the interpretation of the migration costs. If migration costs are reflected in lost employment for the migrant, then average productivity rises over time because the amount of lost employment decreases as the migrant population in the city increases. If migration costs are reflected in discriminatory wages and prices, then average productivity rises simply because the migrant's output, if not consumption, is higher in the city.

The function Φ_t is assumed to take the form

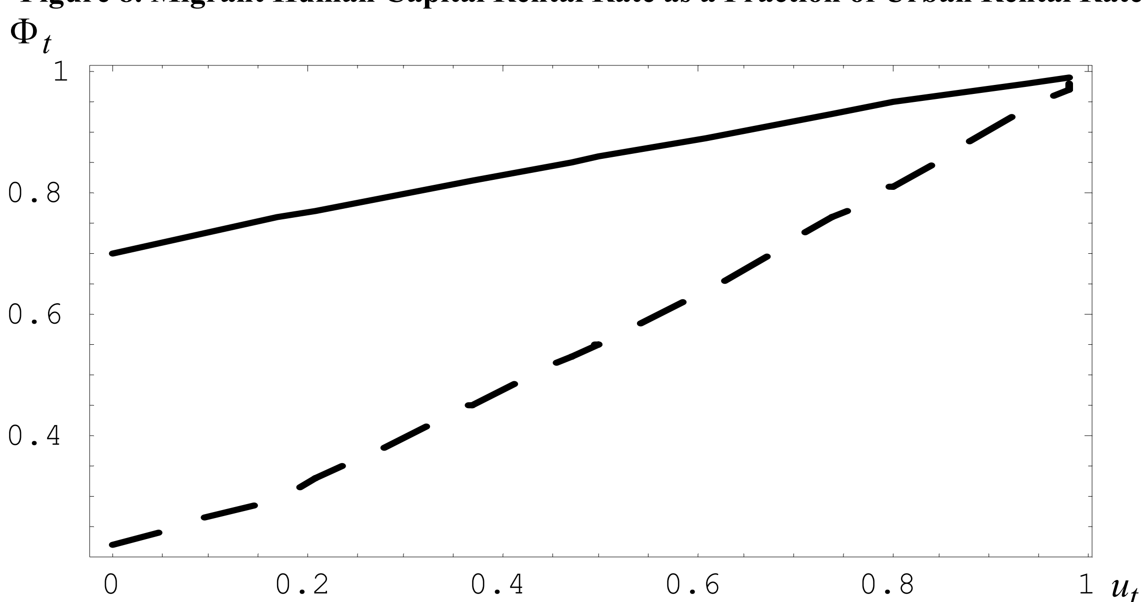
$$\Phi_t = \varepsilon_0 + \varepsilon_1 u_t^{\varepsilon_2} , \tag{16}$$

where u is the fraction of the work force in urban areas. To calibrate Φ_t we first assume that when $u = 1$, the economy is completely assimilated and $\Phi_t = 1$. This assumption implies that $\varepsilon_0 = 1 - \varepsilon_1$. Next, we calibrate ε_1 and ε_2 to match two targets: (i) a real wage and productivity gap of 2.5 in 1840 and (ii) an average annual growth rate of productivity in the 19th century of 1.37 percent. Note that because positive and decreasing migration costs will increase the economy's growth rate as migration occurs, the exogenous rate of technological change needed to target the average growth rate of worker productivity in the 20th century will be lowered.

We calibrated the model under both interpretations of the migration costs. The two interpretations led to cost functions with different shapes, but the difference in the predicted pattern of average productivity growth was small. As result, we will only report the results for the employment-loss interpretation.[21]

Figure 8 plots the calibrated function for Φ_t against the fraction of the workforce in urban industry for the *family* and *neoclassical* farming models. To match the 2.5-fold wag gap in 1840, the migration cost must be much larger in the *neoclassical* farming model. Under the *neoclassical* farming model, the migrant's wages are only 30 percent of the urban household's wages in 1800, when $u_t = 0.17$, compared to 76 percent in the *family* farming model. In the *neoclassical* farming model, the migrant's wages do not reach 76 percent of the urban household's wages until 1900, when $u_t = 0.61$. Given that the shortfall in wages is for the *entire* work-life, the migration costs in the neoclassical model seem excessive.

Figure 8. Migrant Human Capital Rental Rate as a Fraction of Urban Rental Rate



Notes: Solid line is for the *family farming* model and dashed line is for the *neoclassical farming* model

As mentioned, introducing migration costs introduces another element of endogenous growth that lowers the exogenous technological change needed to explain the observed

[21] The employment-loss interpretation also has a cleaner interpretation in our model since we do not model the discrimination against migrants that lowers their wage and raises their cost of living, nor do we model any rent that urban employers or landowners may capture from the migrant. Under the employment-loss interpretation, there are no missing "rents" to urban households that go unaccounted for.

growth rate in worker productivity. With migration costs, the exogenous rate of technological change falls to 0.75 percent in the *family* farming model and to 0.51 percent in the *neoclassical* model. One can also examine how introducing migration costs affects the *pattern* of growth rates predicted by the models for each twenty year period. In the family farming model, migration costs do not altered the absolute deviation between predicted and actual growth rates across twenty-year periods. In the neoclassical model, the absolute deviations are slightly *larger* with migration costs.

In summary, the migration costs needed to match the productivity/wage gap with the neoclassical farming are too high. Furthermore, the introduction of migration costs does not alter the clear advantage of the family farming model in matching the rise in schooling and the pattern of growth rates across periods.

VIII. THE PRODUCTIVITY GAP IN CURRENTLY DEVELOPING COUNTRIES

Recently it has been pointed out that the productivity gap across industry and agriculture is very large for currently developing countries, reaching double-digits for several of the poorest countries (Gollin et al (2004) and Restuccia et al (2004)). Double digit productivity gaps, far in excess of those from U.S. history, imply a large growth dividend from migration out of agriculture. However, labor productivity is probably dramatically underestimated in the agricultural sector of poor countries because marketed agricultural output is a small fraction of total agricultural output.

The underestimate of agricultural production is evident from countries where available data on wage earnings and survey information on household consumption can be compared to worker productivity estimates based on GDP accounting. Consider Zimbabwe, a country where, according to 1985 GDP calculations, industry workers are 9 times as productive as agricultural workers (Restuccia et al (2004, Figure 5). Zimbabwe collects regular data on wages and conducts occasional household surveys that record family consumption. The information from wage data and household surveys is nicely summarized and analyzed by Jenkins and Knight (2002).

Begin by considering the wage data. From 1979 to1990 real earnings for nonagricultural workers were about 5 times higher than for workers in *commercial* farming—only a little more than half the GDP productivity gap (Jenkins and Knight (2002, Table 8.8)). How can the wage data be reconciled with the worker productivity estimates? About two-thirds of the population of Zimbabwe lives on *communal* farm lands. On communal farms, 80 percent of production is consumed by the farmers themselves—only 5 to 7 percent of the country's *marketed* agricultural goods are produced from communal lands (Jenkins and Knight (2002, p. 79)). Many of the workers on communal lands are likely counted in the workforce despite their small contribution to measured GDP, which explains the very low worker productivity measure based on GDP calculations.

The Zimbabwe government carries out occasional national surveys of households. These surveys measure regular monthly consumption expenditures. According to the survey conducted in 1990/91, the adult-equivalent consumption ratio for nonagricultural workers compared to commercial farmers was 1.5 and compared to communal farmers was 2.6

(Jenkins and Knight (2002, Table 4.1)). These consumption ratios do underestimate real income differences because the surveys exclude expenditures that do not occur regularly such as clothing, schooling and health expenditures. Nevertheless, the consumption ratios clearly indicate that even the 5-fold earnings gap overestimates actual productivity differences across sectors.

Finally, the survey also indicates that the consumption gaps between urban and rural households are largely independent of schooling differences. For workers with 10 years of schooling or less, a 2-fold consumption gap exists across sectors, holding years of schooling constant (Jenkins and Knight (2002, Table 4.6)).

In summary, the wage and survey information from Zimbabwe suggests the following. First wage differences are much less than worker productivity differences based on GDP accounting. Jamal and Weeks (1993) confirm that the urban-rural wage differences for several African countries are similar or less than those in Zimbabwe. For example, in 1985, Kenya had the same 9-fold productivity gap across sectors as Zimbabwe (Restuccia at al (2004, Table 5)). However, Jamal and Weeks (1993, Table 4.7) report that an urban-to-rural wage ratio of only 2 for Kenya in 1983. Second, urban-rural consumption and real income differences are even smaller than wage differences suggesting that there are significant sources of non-wage income on the farm. Third, there are 2-fold real income differences across sectors that are independent of schooling. These differences may be due, in part, to migration costs. Overall, the actual productivity gap in countries such as Kenya and Zimbabwe are between 1.5 and 5, larger than those found in U.S. history, but as dramatically difference as the 9-fold labor productivity measure suggests.

IX. Conclusion

What are the general lessons for development that one can draw from our historical and quantitative examination of the U.S. experience? First, measured labor *productivity* gaps in developing countries significantly overstate differences in productivity *per worker* because many of the workers sell little of their output in the market. This is part of the reason that the *wage* gap between nonfarm workers and farm workers, employed on commercial farms, is much less than the sector productivity gap. However, as in U.S. history, even wage gaps overestimate actual productivity differences because they miss unmeasured forms of compensation paid to farm workers and a lower cost-of-living in rural areas. In the 19^{th} century U.S., a worker in industry was 2 to 3 times more productive, over the course of the year, than a worker in agriculture. The labor productivity gaps that have recently been measured for many currently developing countries are significantly larger than the historical gap from the U.S. However, the measured gaps appear to be significantly overstated. Household consumption surveys indicate that actual gaps are much closer to those observed in U.S. history.

Second, family farming is an important feature of early development that helps explain large differences in fertility and wage income across rural and urban sectors. Residual income from farming raises fertility and lowers wage income in rural areas. This mechanism alone can explain about a 2-fold gap in wages and annual worker productivity across sectors.

Third, the family farm, or the rights to farm under tribal or tenancy agreements, may be passed down across generations, in part, because of imperfect land markets. In this case, an imperfect land market creates an inefficient allocation of labor. Too many workers remain in agriculture because their claim on the farm revenue is contingent on choosing farming as an occupation. Reallocating workers to industry would result in greater productivity per hour worked and more hours worked over the year.

Fourth, the quantitative effect on output growth from reallocating farm labor to nonfarm production is potentially significant. In the US, we estimate that the movement of labor away from farming raised the average annual growth rate of output per worker by about half a percentage point over the 19^{th} century.

Finally, quantitative exercises indicate that the primary cause of the 19^{th} century economic transformation in the U.S. was insufficient growth in the relative TFP in agriculture. The pace of technological change in agriculture and the improvements in land were not sufficient to allow the number of farmers to expand as fast as the economy-wide labor force was growing. In the absence of explicit migration restrictions, the growth in relative TFP across sectors is also likely to be an important determinant of the speed of economic transformation in today's developing countries.

Appendix

This appendix gives a more detailed description of the recursive structure and solution of the model. The description will be for the *family* farming model. The *neoclassical* farming model's structure is similar.

The schooling paths may be solved for first. Schooling for urban and rural households (including migrants) is given by (4b) and (7b), where the only difference is the initial level of schooling (the schooling of the initial generation of parents).

Given the paths of schooling, the paths of fertility can be found. Urban and migrants fertility are given by (4a) and (10)—the only difference being the difference in schooling. The fertility of rural households has a different structure. Substituting (9) into (7a) and solving gives rural fertility as a function of schooling

$$\tilde{n}_{t+1} = \frac{1}{1 - \frac{\gamma}{\tau}\frac{\bar{h}}{h_t}\left(T - \tilde{s}_t\right)\left(1 + \frac{\tau\rho}{1-\rho}\right)}.$$

Compared to the fertility of migrants given by (10), note the extra term in the denominator (due to family farm production), $1 + \frac{\tau\rho}{1-\rho}$, raises fertility for any given level of schooling.

Given the paths of schooling and fertility, (9) can be used to solve for f_t, the quantity of effective farm labor per family. With f_t, equation (8) gives the equilibrium gap in rental rates. Using (2a), the farm rental rate, $\tilde{W}_t$, can be found.

Next, (7c) is used to compute the relative TFP in agriculture, $a_t \equiv \frac{A_t}{D_t}$, that matches the fraction of the workforce in agriculture that is observed in the data. More precisely,

$$a_t = \frac{\tilde{w}_t}{1-\rho}\left(\frac{\mu_t \times Workforce \times f_t}{L}\right)^{\rho},$$

where μ is the observed fraction of the workforce in agriculture, L is the fixed initial stock of raw land, and the size of the *workforce* is determined by aggregating the size of the rural, migrant, and urban populations.

Keeping track of the size of each group (rural, migrant, and urban) allows the average values of schooling and fertility to be solved. The wage gap is determined by the gap in the rental rate on human capital, the gap between rural schooling and the average of migrant and urban schooling, and the gap in rural child labor and the average of urban and migrant child labor.

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