FAMILY PRODUCTION AND ECONOMIC GROWTH

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ABSTRACT

The early stages of development in many economies are characterized by family-based production. Older family members own the production technology that is operated by younger family members. Both generations benefit; older members receive income to support retirement and younger members are guaranteed employment. However, this mode of production serves to impede economic growth by encouraging high rates of fertility and low levels of schooling and financial saving. We developed a life cycle model where the decline in family production is the central mechanism for growth. The model is applied to United States history and closely replicates the patterns of fertility, schooling, and economic growth from 1800 to 2000.

The family, and not the firm, was the predominant center for production in the United States during the nineteenth century (Ruggles (2001) and Carter, Ransom, and Sutch (2003)). The family was a multigenerational producer with capital and land provided by older generations and labor provided by younger generations. Goods were produced not only for home consumption but to sell and trade in the market as well. Family production was not limited to agricultural products; manufacturing goods (leather products, flour, furniture, tools) and services (retail sales) were also prominent.

The quantitative importance of the multigenerational family producer was striking. Ruggles (2001) provides data from the middle of the nineteenth century, showing that 80 percent of the elderly lived with their adult children. He further demonstrates that the property was owned by the elderly and that the children remained at home to provide the labor needed to operate the family farm. Family-based production was so prevalent that only about 45 percent of prime-aged white males were employed in wage and salary jobs at this time.

Carter et al (2003) argue that the family-owned, family operated farm economy impeded growth in living standards. Since the labor needed to operate the farm and provide old-age support came from family members, fertility was high. High fertility and guaranteed employment on the family farm made education, beyond the basic literacy needed to read the bible, expensive and unnecessary. Farm income financed the consumption of the elderly and reduced the need for financial saving.

In this paper we develop an overlapping generations model of family production that contains the features stressed by the historical analysis of Ruggles and Carter et al. Old households own an informal "family" production technology that can be operated with the labor input of their adult children and their grandchildren. Young households decide how many children to have and how much education they will receive with the knowledge that children may not only work on their grandparents farm but also on their farm when the family production technology is passed on or learned from their parents in the next period.

Adult children and grandchildren also have the option of supplying labor to a "firm," i.e. a production technology that is set up to employ workers from different families. Children are assumed not to be altruistic toward their parents, so older households employing their children in family production must pay an informal wage that matches the market wage offered by firms. Forces that drive up the market wage, beyond productivity gains in the family sector, will lead to the demise of the family production. This will generate a mechanism for growth by lowering fertility and shifting labor to the faster growing firm-sector.

We apply the model to United States history. The model is calibrated to have certain steady state properties and to match certain facts about fertility, schooling, and employment in the nineteenth century. Then a transition path for fertility, schooling, and labor productivity growth is simulated for the period 1800-2000. We find the model is able to closely match the trends in these three variables: a downward trend in fertility throughout, little change in schooling until the twentieth century, gradual increases in growth rates in nineteenth century, an acceleration in growth rates until the middle of the twentieth century and then a slowdown.

Section 2 explains how the family-production mechanism for demographic and economic transition differs from other mechanisms in the economics literature. Section 3 provides some historical background from the United States. Section 4 presents the technologies and preferences that determine the economic environment. Section 5 presents a model without family production and Section 6 adds family production. Section 7 calibrates the model to the United States and simulates historical transition paths. Section 8 contains concluding remarks.

2. Related Literature

The concept of *family* production is certainly related to the concept of *home* production that has been used by Benhabib, Rogerson, and Wright (1991), Parente, Rogerson, and Wright (2000), and Gollin, Rogerson, and Wright (2001) to explain various macroeconomic observations. However, there are two differences in emphasis. First, home production models are used to explain the allocation of labor across market (measured) and home (unmeasured) production sectors. In contrast, we assume that goods produced by the family farm can be used at home or sold in markets. Second, the home production literature has focused on adult labor inputs within a household containing a single generation. Our focus is on a mutigenerational household, where young adults and children supply labor to production technologies that are owned and managed by the old.

There are several papers that combine fertility and human capital accumulation in models of economic growth (e.g. Galor and Weil (2000), Greenwood and Seshadri (2002, 2003) and de la Croix and Doepke (2003)). The analysis by Greenwood and Seshadri (2002, 2003) is most similar to ours. They have two sectors of production, agriculture and manufacturing, allowing for the possibility of an e*conomic* transformation, as well as a *demographic* one. They also apply the model to the United States over the last two centuries and use calibration experiments to test predictions against historical data. However, our approach differs from theirs in several ways.

Extended Time Period—Greewood and Seshadri (2002, 2003 (section 3)) focus on the period 1800-1940. This is natural because the Baby Boom began around 1940.[1] We instead ignore the Baby Boom and focus on the downward trend in fertility over the entire twentieth century. We do this because, apart from fertility, we are interested in trying to explain the patterns of time investments in schooling and in labor productivity growth over the entire period from 1800 to 2000. It is important to include the period after 1940 for both these variables. Time investments in schooling did no change much over the nineteenth century and then trended upward from 1900 to 1970 before leveling off.[2] Growth rates in labor productivity slowly rose over the nineteenth century, accelerated until the mid-twentieth century and then leveled off and fell back somewhat.[3] These patterns are interesting in themselves and, because they are complex, they provide a challenging test for the model.

Agriculture versus Family Production—Most output through at least the Civil War was produced in family businesses. And, not withstanding small manufacturing and artisanal shops, the chief family business was farming. Thus, in the nineteenth century, measured growth rates in agricultural total factor productivity (TFP) were also good estimates of the growth in the TFP associated with family production. However, over the twentieth century the number of farms declined and the size of farms increased dramatically. During this century the link between family production and agricultural production was broken. Growth rates in agricultural TFP were no longer good indicators of the technological change affecting smaller family-based farm production.

The distinction between family production and agricultural production becomes particularly important after 1940. After 1940 measured growth rates in agricultural TFP were equal to or greater than those in manufacturing.[4] It seems unlikely that growth in TFP on family-based farms also outpaced those in manufacturing over this period (given the rapid growth in the size of farms over the period). This difference is important because the relative growth in TFP across the sectors play important roles in both Greenwood and Seshadri (2002, 2003) and in our model. In particular, the relative growth in TFP across sectors determines the growth in skills and in labor productivity, as we discuss below.

Schooling—Greenwood and Seshadri assume skilled labor is used exclusively in manufacturing and unskilled labor is used exclusively in agriculture. As we do, Greenwood and Seshadri interpret the skill investments in their models as investments in schooling. This interpretation creates a problem because the fraction of employment in manufacturing rose during the nineteenth century but average schooling investments did not (unless one includes the schooling of freed slaves after the Civil War). Also, as mentioned above, in their model the fraction of skilled workers is determined by relative TFP growth in manufacturing versus agriculture. This means their model predicts no further rise in schooling, or in the share of employment in manufacturing, after 1940. This is counterfactual. In our model these counterfactual links are broken; (1) a worker with any level of schooling may be employed in either the family or firm sector and (2) the growth in TFP, whether in manufacturing or agriculture, is not an important factor in explaining schooling.

Labor Productivity Growth—Greenwood and Seshadri do not focus on labor productivity growth. While we also do not calibrate any aspect of model with labor productivity growth in mind, we find the model's predictions on this variable to be an interesting test of the theory.

3. Historical Background

Since the start of the nineteenth century U.S. fertility has fallen 70 percent, years of schooling have more than doubled, and labor productivity has risen at least 10-fold. Important to these dramatic changes was the displacement of the pre-industrial, family production based economy by an integrated, dynamic market economy. Through the eighteenth century much of the non-South, inland colonial economy consisted of largely self-sufficient farmers. Employing a gender and age-based division of family labor, these 'little factories' produced on the farm much of what the family ultimately consumed, though marketable surpluses were necessary for the purchase of-as examples- axes and shovels. Due to the significant barrier posed by high transport costs, much production was rationalized along the lines of use values, rather than market values (cf. Sellers, 1991).

A system of intergenerational transfers provided sufficient incentives to ensure continuity across generations. In a learning-by-doing process the specific human capital needed to work the farm was transmitted to the young as they worked alongside their elders. These multi-genenerational families solved the problem of old-age support by having adult children and grandchildren provide services (such as the cutting of wood and fetching of water) for the elderly in exchange for the inheritance of a share of the family farm.

Carter et al argue that this system of intergenerational transfers impeded economic growth: Instead of financial savings for retirement, parents invested in children, keeping fertility high. The provision of child services to aging parents, in turn, kept low the demand for market goods and the supply of market labor. On the firm side, this state of affairs meant there was little incentive to supply goods or demand labor and capital. This insular organization of agricultural production generated only modest productivity gains.

Although we emphasize agriculture, family production was not limited to agricultural products; manufacturing goods (leather products, flour, furniture, tools) and services (retail sales) were also prominent. As the eminent historian of Jacksonian America Charles Sellers notes “Skills, tools, and shop gave master mechanics something of the security and independence that land gave farmers, as well as a similar patriarchal control over their families…(24)." Even as manufacturing firms increased in size -forming partnerships and later corporations- the extended family continued to be prominent. For as Lamoreaux notes, early "manufacturing firms had difficulty selling their stock to the general public because their ventures were perceived as risky. As a result, most of the stock issued by manufacturing corporations was closely held by people who were personally connected to the firm's promoters (p. 412, 2001)." A striking example of how deeply ingrained the institution of family production was in the early nineteenth century is that an important organizational form in the first American factories- the cotton mills of New England –was the Rhode Island system, under which entire families were hired (cf. Walton and Rockoff, p. 232, 2002).

Powerful forces led to the decline of family production. The transportation revolution in the Early Republic expanded markets while the dissemination of industrial knowledge from England encouraged production within firms.[5] Families were increasingly drawn into the market economy, selling ever-larger shares of their produce in exchange for market goods. Further, as productivity grew more rapidly in the firm than family sector, relative wages rose off the farm, making it more costly to purchase old-age support from sons. In combination, this produced what Carter et al have termed the 'life-cycle transition' during which parents increasingly switched to a strategy of accumulating financial assets to finance retirement. This reduced the demand for children. The schooling of children was externalized: No longer was teaching a child to farm at father's side the most efficient way to prepare him for adult life; formal schooling imparting general human capital became superior preparation for work in firms. Formalizing the arguments of Carter et al, we show how this revolution in intergenerational transfer mechanisms accelerated the process of economic growth by increasing the stocks of human and physical capital per worker.

Although there is a large literature examining fertility decline in the United States over specific periods, few studies model the entire 19th and 20th centuries. Caldwell (1982) argues that rapid fertility decline occurs in developing economies as the net present value of children changes from positive to negative. However, the applicability of his arguments to the United States is challenged by the findings of Craig (1993) who estimates that, despite high farm fertility, American farm children on the eve of the Civil War had a negative present value, even if one includes the value of any old age support the children may provide. In our model we acknowledge that children were net economic liabilities in the antebellum period, so that even the high fertility of that era relies on parental concern with child well-being. However, like Caldwell, we note that the demand for children declines with their contributions to family production (i.e., as their net costs increase).

Easterlin (cf. 1976) argues that regional variation in fertility patterns in Antebellum America were due to differences in land availability. In the 'western' states, land was more plentiful and this made it easier for parents to endow numerous children with a good start in life. In the East, only a smaller number of children could be appropriately established, and this accounted for the lower fertility observed there. Over time, as land availability declined nationwide, lower fertility would be predicted. However, Carter et al and Sundstom and David (1988) have demonstrated that once one controls for off-farm labor market opportunities, land availability is no longer a statistically significant determinant of fertility. This is important, because it means that long models of fertility need not address the complicated empirical and conceptual issues associated with changes in U.S. public land holdings and policy over the nineteenth century. What matters instead, they argue, are changes in the opportunities available to adult farm children, which determine how much they must be compensated to stay and work the family farm. The higher is the cost of family labor, the higher is the net cost of children, and the lower is fertility. This mechanism is central to our modeling below.

Theories of the demographic transition for most countries stress the importance of the preceding mortality decline. A decline in infant and child mortality rates reduce the number of live births demanded to achieve some desired final family size, particularly if parents have a precautionary childbearing motive (Kalemli-Ozcan 2002). The United States is interesting in that there was a pronounced decline in fertility in the several decades preceding the mortality transition of the late nineteenth century. Our modeling focuses on the forces relevant to that earlier period, and later. However, ignoring the mortality transition means that our model may miss some portion of the twentieth century fertility decline. Similarly, our model abstracts from the legalization of abortion and the advent of the Pill, two other huge shocks affecting fertility behavior (Goldin 2003). Nevertheless, our framework shows that the long decline in American fertility may be primarily a consequence of the displacement of family production to firms.

4. The Environment

Households reside in a small open economy where the internationally determined interest rate is *r* and the market rental rate paid to a unit of human capital is *w*. 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 earnings ($wh_{t?1}$) of all their children ($n_{t?1}$). Preferences are given by

$$\ln c_t^y \; ? \; ? \ln c_{t?1}^o \; ? ? \; \ln ? n_{t?1} w h_{t?1} ?$$

where $?$ and $?$ are preference parameters.

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 the 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 $?$ of the adult's first period wages.

Parents determine their children's schooling. Parents insist that all children possess basic literacy, perhaps in order to read the bible and to enable them to work effectively during the later years of childhood.[6] So each child invests at least $\bar{s}$ units of time into learning during the first portion of their childhood. This gives older children $?\bar{h}_t ? ?\bar{s}^?$ units of human capital that can be used in production during the later years of childhood, where 0< $?$ <1 is a parameter that gauges the effect of schooling on human capital accumulation and $0 ? ? ? 1$ 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 $h_{t?1} ? s_t^?$. A person is more productive in adulthood than in childhood because of greater strength and experience (1 > $?$) and additional schooling ($s_t ? \bar{s}$).

Final goods are produced in two sectors. In the first sector production takes place within standard neoclassical firms that combine physical capital (K_t) and human capital (H_t) to produce output from a Cobb-Douglas technology

(1) $$O_t ? K_t^? ?D_t H_t ?^{1??},$$

where D_t is the disembodied technology associated with production in firms. Firms operate in perfectly competitive factor and output markets. This implies the profit-maximizing factor mix must satisfy

(2a) $$r ? ? ? ? ? k_t^{? ?1}$$

(2b) $$w_t ? D_t ?1 ? ? ?k_t^?,$$

where $?$ is the rate of depreciation on physical capital and $k ? K/DH$.

A family sector also produces final goods. An old household owns a family production technology. The technology is informal and designed only for use with family members (no formal accounting, flexible hours, production is mixed with family consumption and care of younger children, some laws and regulations restricting firms are not followed). The family labor input available to an old household comes from their children and grandchildren.[7] Their children (young adults) may also supply labor time to firms (l_t). Their grandchildren spend some of their productive time in school and the fraction that they don't spend in school, may also be supplied to firms (m_t). The effective family labor supplied to an old household is then

$f_t = n_t h_t (1 - l_t) + \theta n_t n_{t+1} \bar{h} (T - s_t)(1 - m_t)$.[8] Output from family production is given by

(3) $$O_t^f = A_t f_t^{1-\alpha},$$

where A_t is the disembodied technological change associated with family production and $0 < \alpha < 1$ is a technology parameter.

The young workers "learn" the family production technology from their experience as workers. They thus "inherit" the family technology from their parents and operate it as old adults. While we do not explicitly model land as a productive input, one can think of land as being part of the family technology. The fact that land must be split across several children would work against technological innovations that increase family productivity and thus slow the growth of *A* over time.[9]

5. Fertility and Schooling without Family Production

In this section we discuss family choices in the absence of home production. This discussion will help highlight the changes that arise due to the presence of family production.[10]

Without family production, the model is similar to existing models that feature a trade-off between the quantity and quality of children. The household maximizes utility subject to the lifetime budget constraint,

$$c_t^y ? \frac{c_{t?1}^o}{1 ? r} ? n_{t?1} ? w_t h_t ? w_t h_t ? n_{t?1} w_t ? \bar{h} ? T ? s_t ?.$$

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

(4a) $$\frac{? ?}{s_t} ? ?_t n_{t?1} w_t ? \bar{h}$$

(4b) $$\frac{?}{n_{t?1}} ? ?_t ? ? w_t h_t ? ? T ? s_t ? w_t ? \bar{h} ?,$$

where $?_t$ is the Lagrange multiplier.

Equation (4a) 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. Equation (4b) 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, consistent with Craig's (1993) finding that farm children had a negative net present value in 1860.

Solving the model gives us the following demand functions for children and schooling, (5a) $n_{t?1} ? \dfrac{?1 ? ? ?}{?1 ? ? ? ? ? ?? ? ?T ?\bar{s}/s_{t?1} ? ?}$

(5b) $s_t ? \dfrac{? ?? ?s_{t?1}/\bar{s} ? ? ?T ?}{? ?1 ? ? ?}$.

These interior solutions require that $? ? ?T$ and, to prevent a corner solution for s_t, that

$? ?? ? ?T ?/? ?1 ? ? ? ? \bar{s}$. One can show that (5) converges to a unique steady state solution for *n* and *s*.

Greater schooling raises adult earnings relative to older children's earnings. This raises the net cost of having children, so fertility declines. Thus, the sole factor driving fertility down is the rise in schooling. This is problematic since fertility fell sharply during the 19th century, while schooling changed little.

In the next section, we introduce family production. Family production breaks the simple link between schooling and fertility over the 19th century. However, we assume that technological progress eventually causes the demise of family production, so that the model will converge to (5) over time.

6. Family Production

Family production creates a second period income flow for old households. Old households receive the portion of family production that is not informally paid to younger family workers. Younger family workers are not altruistic to their parents and must be paid the full opportunity cost, the formal market wage, for their work on the farm. The family wage bill is

$?_{t?1} ? w_{t?1}h_{t?1}n_{t?1} ?1 ? l_{t?1} ?? w_{t?1}\bar{h}?n_{t?1}n_{t?2} ?1 ? m_{t?1} ??T ? s_{t?1} ?$. Since younger family members are indifferent about where they work, the demand for labor by the old will determine family employment.

6.a. Static Microeconomics of Family Production

The generation-*t* household chooses $s_t, n_{t?1}, l_{t?1}, m_{t?1}$, and a life-cycle consumption path, to maximize utility subject to the lifetime budget constraint,

$c_t^y ? \frac{c_{t?1}^o}{1?r} ? n_{t?1}?w_t h_t ? w_t h_t ? n_{t?1} w_t ?\bar{h} ?T ? s_t ?? \frac{O_{t?1}^f ? ?_{t?1}}{1?r_{t?1}}$. In addition to first-order conditions that take the same form as (4), we also have

(6) $$?1 ? ??A_{t?1} f_{t?1}^{??} ? w_{t?1}.$$

Equation (6) states that the marginal product of family labor must be equated to the opportunity cost of their time, the market wage rate.

Solving the model for *n* and *s* gives

(7a) $$n_{t?1} ? \frac{?1 ? ? ?? ?1 ? \frac{?O_{t?1}}{w_t h_t ?1 ? r?} ?}{?1 ? ? ?? ?? ? ?T ?\bar{s}/s_{t?1}? ?}$$

(7b) $$s_t ? \frac{? ?? ?s_{t?1}/\bar{s}? ? ?T ?}{? ?1 ? ? ?}.$$

Comparing (7a) to (5a) reveals that family production introduces a new term, $?O_{t?1}/w_t h_t ?1 ? r?$, that raises fertility (other things constant). The numerator of this term is the share of family production that flows to older households ($?O_{t?1} ? O_{t?1} ? ?_{t?1}$). 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.

The expression for schooling (7b) is identical to (5b). Schooling continues to be determined by the value of forgone earnings from child labor. The value of forgone earnings is in turn determined by the ratio of fertility to consumption. Fertility determines the quantity of forgone earnings, and the level of parental consumption determines their value. Schooling is unaffected by family production because of offsetting substitution and income effects that keep the ratio of fertility to consumption constant when family production changes.. Family production raises fertility which raises the cost of schooling children (more children means greater forgone family earnings for any given schooling level). However, family production also raises wealth and consumption. This lowers the *value* of forgone earnings (the family can "afford" to forgo more income)

Using (6), the new term in (7a) can be written as

(8) $$\frac{?O_{t?1}}{w_t h_t ?1 ? r?} ? ?\frac{1}{s^{?}_{t?1}}??\frac{?}{1 ? ?}??\frac{1 ? d_{t?1}}{1 ? r}???\frac{1 ? ? ?A_{t?1}}{w_{t?1}}?^{\frac{1}{?}}.$$

Higher schooling raises the full wage and lowers the relative value of family production, offering a new dimension to the quality-quantity trade-off. More importantly, there is now a mechanism for lowering fertility that is independent of the level of schooling. The relative importance of family production falls if "family-based " technological progress (*A*) rises more slowly than the "firm-based" technological progress that determines the growth in the market rental rate on human capital (w). So, even if schooling is relatively constant, fertility will decline if technological progress in firms outpaces that in families.

6.b. Family Dynamics

Our focus is on three features of the 19th century United States: relatively constant schooling levels, declining fertility, and rising "paid" or "market" employment. Here we discuss the connection between these three features and how the model might explain them.

Schooling

As is evident from (7), the model is recursive in that schooling is determined independent from fertility and market employment.[11] If the model is to explain relatively constant schooling over the 19th century, it must come from the structure of (7b) alone. Equation (7b) is a transition equation that relates current schooling to past schooling. Past schooling raises the wages of parents relative to children. This increases the relative price of fertility compared to goods, and lowers the ratio of fertility to current consumption. A fall in this ratio lowers both the quantity and the value of forgone wages associated with educating children, and thereby raises current schooling.

Since the effect of schooling has a diminishing effect on human capital formation and wages, the transition equation would exhibit the standard properties of neoclassical growth if not for one additional feature. Children receive a minimum level of schooling or learning ($\bar{s}$). This creates a non-convexity in the transition equation, where the schooling during childhood must be greater than or equal to $\bar{s}$.

Figure 1 sketches the schooling transition equation. The vertical intercept of the graph is at ? ?*T*/(1 ? ?), rather than its usual position at the origin. This implies that the graph intersects the 45-degree line twice, at *A* and *B*. To guarantee that schooling increases over time, the minimum schooling level for young children must be to the right of *A*. Starting to the right of A will cause schooling to rise, but in relatively small increments. As the level of schooling rises, the increments in schooling across generations become larger, until the economy nears the stable steady state at *B* when the increments converge to zero. So the model predicts relatively small increments in schooling initially, an acceleration of schooling in the middle of the transition, and then a slow down as the steady state is approached. This fits the qualitative pattern observed over the last two centuries of United States history.

Fertility and Market Work

To match the data, the rise in schooling must be modest over the 19th century. This means that increases in child quality cannot be a significant factor in explaining the decline in the quantity of children over this period. The alternative explanation provided by the model is the decline in the value of family production (relative to market employment opportunities).

We identify the quantitative impact of family production on fertility using two types of observations. First we have estimates of the relative growth in total factor productivity (TFP) in the agricultural and nonagricultural sectors in the 19th century. As mentioned, since most farming was family based in the 19th century, there should be a close connection between TFP growth in agriculture and TFP growth in family-based production during this century. This information tells us how fast the expression in the square-bracket in (8) will decline over time. However, its impact on family production and fertility is also determined by the unobserved parameter ? . To help estimate ? , *without relying directly on fertility data*, we use estimates from Ruggles (2001) on the fraction of the work force in paid employment during the century. This approach leaves no free parameters to match the decline in 19th century fertility. The model's predictions on fertility over this period can then be interpreted as a measure of the impact of declining family production.

7. Applying the Model to the United States (1800-2000)

In this section we calibrate the model to the United States and then simulate values for s, n, and l over two centuries. Given these values, in combination with (1) and (3), we can also simulate the growth rate of labor productivity over the same period.

The Work of Children

We think of each period as lasting 20 years. Young adults aged 20-39 are endowed with one unit of time for work. Children aged 0-19 are endowed with one half that amount, i.e. $T = 0.5$. One way to interpret this assumption is that children aged 0-5 can't work at all, those aged 6-14 are only able to average half the hours of an adult, and those aged 15-19 can work as much as an adult.

Even with the same schooling as adults, children are not as productive in a given hour of work because they have less physical strength and experience. In the early 19th century estimates of the relative wage rate (?) of children less than 16 years old ranges from 0.20 to 0.37 (Lebergott (1964) and Goldin and Skoloff (1984)). We set ? ? 0.28. This implies that if a child works the full time endowment *T* that their contribution to family income is 14 percent of an adult's. This is close to the estimates of Craig for U.S. 1860 farm families. He found that children below age 6 depress farm output by about the same amount that those ages 6-12 increase it. The contribution of teenage males was just above a quarter that of adult males. Thus, over the entire period of dependency the average annual contribution would be around 10 percent (a number which excludes any off-farm earnings the child may receive). Similarly, Lindert (1976) estimates that children aged 10-18 contributed an average of 13 percent to family income in rural England at the end of the 18th century.

Schooling

Rangazas (2002) constructs estimates of the fraction of available time that children spent in school at the end of the 19th century. The estimates combine enrollments rates with attendance rates for those enrolled in school to get an average fraction of the year spent in school. He finds an average fraction of 0.10 with no trend from 1870 to 1900.

School enrollment rates did rise from the beginning of the 19th century to 1850 (Cremin (1980)), but then leveled off and showed no trend until the 20th century (Goldin (1999)). Indeed, in New York State in 1822 the average school year was already eight months and over ninety percent of those ages 5-16 attended (Randall 1871, p. 39). Basic literacy among the white adult population was already 90 percent by 1860 (Cremin (1980)), so many generations of children were evidently "schooled," either at home or in formal schools, at the beginning of the 19th century. The rise in formal schooling over the first half of the century was likely to have largely been a substitution of schooling away from the home and toward formal schools. For these reasons, we interpret $\bar{s}$ as the learning time necessary to obtain basic literacy and set it to 0.095, just a bit below the time investments observed at the end of the 19th century. We then interpret schooling over the 19th century as doing little more than establishing basic literacy and the rise in schooling over the 20th century as raising knowledge above basic literacy.

Technological Change

The driving causal force in the theory is the rate of technological change in family production relative to that in firm production. As discussed in section 2, there is a close association between family production and agricultural production in the 19th century. The annual rate of growth of TFP in agricultural during the 19th century was about 0.50 percent (Greenwood and Seshadri (2002)). The rate of technological change in family production and agricultural production were likely much different in the 20th century as size of farms increased and the number of farms decreased. This means we can no longer expect the growth in agricultural TFP to be a good proxy for technological change in family production. Over the 20th century, we simply assumed that the rate of technological change in family production remained at 0.50 percent.[12]

We assumed the annual rate of technological change in firms in the 19th century was equal to the rate of TFP growth in the nonagricultural sector during the 19th century, a value of 0.75 percent (Greenwood and Seshadri (2002)). We assumed the annual rate of technological change in firms in the 20th century and beyond was equal to the overall rate of TFP growth for the economy in the 20th century. Estimates of the rate of growth of TFP in the 20th century vary because approaches to measuring the growth in physical and human capital vary. We use the estimate from Rangazas (2002) because he attempts to account for the growth in the quantity and quality of education in a manner similar to the one we use here. He estimates the annual rate of TFP growth during the 20th to be about 1 percent.

Steady State Values

Since the rate of technological change in family production is assumed to be lower than the rate of technological change in firms, the importance of family production approaches zero over time. The steady state of the model with family production will then approach the steady state of the model without family production from section 2. There is also a closed-economy steady state expression for k implied by the saving behavior in the model. We assumed that the steady state k in the closed economy must be produce a closed economy interest rate equal to the 7 percent annual interest rate we assume in the open economy version of the model. We also set n = 1 (zero population growth) and s = 0.50 (no child labor) in the steady state. The annualized rate of depreciation of physical capital is assumed to be 10 percent.

Calibration based on Transition and Steady State Targets

The remaining calibration proceeds in two steps. First, ? and ? are set, using (7b), to match the steady value of s and to keep the initial choice of s close to $\bar{s}$. This is sufficient to generate the entire transition path of schooling.

Second, ?,? ,? , and the initial ratio of *A* relative to *D* are set, using (6), (7a), and the steady state equation for *k*, to match initial and steady state values of *n*, a value for *l* in 1860, and the steady state rate of return on capital. The fraction of men employed in wage and salary work in 1860 was 50 percent (Ruggles (2001)). Women had about 7 children in 1800 (Greenwood and Seshadri (2002a)), so we targeted *n*, the number of children per adult, to be 3.5.[13] The calibrated values for all parameters are given in Table I.

Table I Calibrated Parameter Values

?	0.28
T	0.50
?	0.18
?	0.40
?	0.33
?	0.19
?	0.27
?	0.25

Overidentifying Predictions

The calibrated model can now be simulated to produce historical predictions about key variables that were not targeted by the calibration itself. These predictions include the time paths of fertility (*n*), schooling (*s*), and labor productivity growth for two centuries.

In terms of the actual data, fertility declined over the two centuries, falling to a little under two children per adult in 1900 and to about one child per adult in 2000 (Caplow et al (2001)). Labor productivity grew less than one percent during the first half of the 19th century and then grew at around one percent until the 20th century (Greenwood and Yorukoglu (1997)). During the twentieth century growth rates rose until mid-century, leveled off, and then fell back somewhat in the last quarter of the century (Gordon (1999)). The average growth rate in labor productivity over the 20th century was about 1.7 percent. After little change over the 19th century, schooling investments rose significantly over the twentieth century until leveling off in the last quarter century. The rise in time spent in school was almost 4-fold over the century; *s* increased from 0.10 in 1900 to 0.38 in the last quarter century (Rangazas (2002)).

Simulated Time Paths

Table II gives the simulated time paths of fertility, schooling, and labor productivity growth rates from 1800 to 2000. The labor productivity growth rate presented for each time period is the annualized rate over the previous 20 years.

Table II.

Simulated Economic and Demographic Transition :1800-2000

1800	1820	1840	1860	1880	1900	1920	1940	1960	1980	2000

Schooling (*s*)

0.10	0.10	0.10	0.10	0.11	0.12	0.14	0.17	0.21	0.26	0.31

Non-family or Market Labor Supply (*l*)

0.15	0.15	0.34	0.50	0.62	0.70	0.84	0.92	0.96	0.98	0.99

Fertility (*n*)

3.5	3.3	3.1	2.9	2.6	2.3	2.1	1.8	1.6	1.4	1.3

Growth Rates *(annualized percent)*

	0.7	0.8	1.1	1.1	1.2	1.6	1.7	1.7	1.8	1.7

Schooling remains virtually constant throughout the 19th century and then begins its upward climb during the 20th century, but falling short of the observed value of 0.38 by century's end. The calibration targeted the values of *l* for 1860, but the value for 1900 is also very close to estimates from Ruggles. In addition, the initial values of *l* at the beginning of the century are close to the fraction of employment outside of agriculture at that time. Fertility declines somewhat slower than we observed over the two centuries; with values of 2.3 and 1.3 by 1900 and 2000 instead of 1.9 and 1.0 as observed.

The simulated values labor productivity growth are surprising good, given that not a single parameter was calibrated with growth rates in mind. Simulated growth rates were 1 percent or below for the 19th century and then trended upward until leveling off from 1940 to 1980 and then fell back slightly. The annualized growth rate over the 20th century exactly matched the observed average of 1.7 percent. The particular pattern for the growth rates is created by the combination of rising schooling investments and diminishing returns to schooling. Early on, schooling rose rapidly enough that diminishing return were offset by rising investment and growth rates increased. However, diminishing returns eventually dominated causing growth rates to level off and fall back despite further increases in schooling investments.

8. Conclusion

In this paper we modeled the role of family-based production in determining fertility and schooling of children. The model was calibrated to data from the United States over the period 1800-2000. Simulations show that the technologically driven decline in family production explains much of the decline in fertility and the rise in schooling over the period. It also generates aggregate labor productivity growth rates that closely match those observed in the United States over the two centuries. Our results suggest that family production is a potentially important determinant of fertility and schooling in agriculturally based economies.

Footnotes

1. Greenwood and Seshadri (2002b, section 2) address the entire period from 1800 to 2000 in a different model that helps explain both the baby bust and the baby boom. However, this model ignores schooling and the agricultural sector.
2. School enrollment rates for whites between the ages of 5 and 19 showed no trend from 1850 to 1910 (Goldin 1999, Figure 1). There was an upward trend for non-whites after the Civil War that pulled the over-all enrollment rates up after 1870. We ignored the increasing enrollment rates for nonwhites because our model does not address the larger plantation farms of the south that relied heavily on slavery, rather than family, for their labor input. This is interesting and important extension that is left for future work. The time investments, for enrolled students, within a given year did not increase from 1870 to 1880 and then increased until 1900 (Goldin 1999, Table A.6).
3. Data reported in Greenwood and Yorukoglu (1997, Figure 4) indicates a rise in labor productivity growth rates over the nineteenth century from about half a percent to a little over one percent. Gordon (1999) reports a hump-shaped pattern for labor productivity growth rates, with an average of about 1.6 percent, from 1870 to the end of the twentieth century that he refers to as the "Great Wave."
4. Caselli and Coleman (2001) argue that TFP may have grown faster in agriculture over the *entire* twentieth century.

5. Figure 9.1 in Walton and Rockoff, p. 181, 2002, shows a roughly 95 percent decline in upstream river rates per ton mile between 1790 and 1824, a 90 percent decline in canal rates by 1850, and a roughly 60 percent decline in railroad rates between 1830 and 1864. Simultaneously, the speed of transport also increased dramatically.
6. Alternatively, one could simply assume that children of sufficient age have a stock of human capital that is independent of any schooling. The important feature is for older children to be productive in work so that there is an opportunity cost to attending school. The fact that parents insist on a minimum amount of schooling is not binding (they will always choose at least the minimum) in our simulations.
7. Even if old farmers did not retire completely as in our framework, it is widely believed that the load for those old was greatly relieved by younger family members. As Caldwell (1982) notes, "(a) man with growing sons usually does less work than he claims to—especially if they are numerous. A woman with several daughters, and above all one with daughters-in law, will do less labourious work and instead spend her time in apparent organization."
8. We consider versions of the model where only a fraction of adult human capital was useful in family production. The fraction was calibrated and consistently came out very close to one, so this feature was dropped.

9. We also considered versions of the model with endogenous family capital. This added no further insight and little improvement in the model's ability to match the data.
10. Depending on the application, one may also wish to construct a version of the model with a mix of families; some with family production and some without. In application to the United States, we simplify the analysis by assuming that all households engaged in family production initially and then allowed its importance to gradually diminish over time. Assuming a small fraction of "urban" households without family production in 1800 does not change the results.
11. It should be noted that while (7b) is independent of the level of fertility, its particular form directly stems from the fact that parents consider the net cost or "price" of children when making fertility choices.
12. We experimented with other values for the growth rate of technology in family production in the 20th century. The results are not sensitive to the assumed value because by the beginning of the 20th century the relative importance of family production is relatively small. The reported value can also be defended by the fact that the simulated value for worker productivity growth in the 20th century is very close to the annualized average in the data.
13. By some accounts, fertility for married couples was somewhat higher at the beginning of the 19th century, closer to 8 children. We carried out calibrations where the initial fertility per adult was 4 instead of 3.5.

Simulation outcomes changed very little, with the exception of a slightly higher path of fertility.

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