Revista de Análisis Económico, Vol. 8, Nº 2, pp. 3-18 (Noviembre 1993)

ENDOGENOUS FERTILITY IN MODELS OF GROWTH*

COSTAS AZARIADIS**
University of Pennsylvania
University of California at Los Angeles

ALLAN DRAZEN
University of Maryland
National Bureau of Economic Research

Abstract:

Most theories of economic growth ignore determinants of growth in population. The common assumption of constant population growth is strikingly inconsistent with the data, which reveals a logistic pattern of population growth, the acceleration often coinciding with industrialization. After surveying existing theories of endogenous population, we propose a model in which the family replaces the market in a "traditional" sector. Children are both the primary source of labor and the sole means of saving in this sector, with output divided between generations via bargaining. Industrialization improves the opportunities of children outside the rural sector. It thus leads not only to higher outmigration, but also, by increasing children's bargaining power and hence their share of output, lowers the incentive to bear children. The model can thus explain observed changes in both overall population growth and its sectoral composition.

1. Introduction

Any theory of economic growth is necessarily incomplete if it concentrates on growth in output but ignores determinants of growth in population. Yet neither the standard one-sector model nor most new endogenous growth models treat population as an important endogenous variable –they assume a constant, exogenous rate of population growth. The description of the development process these models provide is

* This paper was prepared for and published in the special growth issue of *Revista de Análisis Económico* corresponding to June 1993 (v. 8, Nº 1). Due to an unexcusable mistake, the publication did not include two figures. For the sake of completeness, we reproduce here the whole original version.

** The authors gratefully acknowledge support from the National Science Foundation, Grant SES-8910980, and the IRIS Project at the University of Maryland.

therefore incomplete. They cannot explain the typical process in which many successful developing economies pass from an early period of extensive growth to a later intensive period, with the development process dominated at first by expanding population and later by a rise in the standard of living [Table 1]. The assumption of a constant rate of population growth is in fact strikingly inconsistent with the data. We observe a logistic pattern of population growth, rather than a constant growth rate, in many parts of Europe and Asia over the last four hundred years –a long period of slow population growth gives way to an acceleration of population growth and a subsequent levelling off [see Figure 1, and Kuznets (1965) for a discussion of this and other related observations]. Population growth within sectors reflects a further regularity ignored by standard growth models, namely the movement of population across sectors. The process of development is marked by persistent labor migration to hired non-agricultural work in urban areas; as a result, we observe a large shift in the sectoral composition of population over time [Table 2].

The pervasiveness of these demographic patterns across developing economies, as well as the fact that some of these demographic shifts coincide with industrialization in many economies, suggests that population dynamics reflect and partially result from economic changes. An endogenous growth model should therefore endogenize population dynamics as well, and should do so in a way which explains how the size and the sectoral composition of population responds to industrialization or economic development. The purpose of this paper is to summarize briefly the approach most often taken in the literature and to suggest an alternative approach.

In the next section of the paper, we document the empirical regularities set out above by considering the European and American demographic experience of the 18th and 19th centuries and more recent events in the third world. Section 3 considers how fertility has been treated in the literature and suggests an approach which focusses on the family as a production unit. After considering some conceptual issues about the economic role of the family in them, we argue that part of the decline in population growth rates in developed economies over the last century or so may well be a by-product of the diminished importance of the family in economic life. As technological progress in manufacturing drives up relative urban wages, people migrate from farm to factory, family labor yields to hired work, and social security takes care of the elderly.

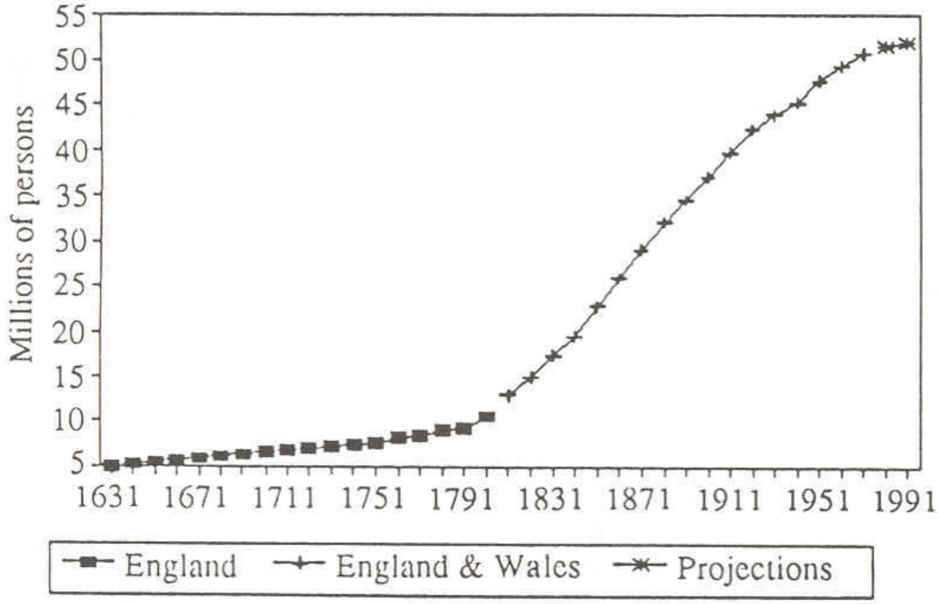
TABLE 1

EXTENSIVE AND INTENSIVE GROWTH IN THE UNITED KINGDOM

Year	Level (1751=100)		Percent Growth		Ratio of Ext. to Int. Growth
	(Population)	(Per cap. GNP)	Pop.	PCGNP	
1701	93	81	–	–	–
1751	100	100	7.5	23.4	.38
1791	131	117	31.0	17.0	1.82
1831	222	192	70.0	64.1	1.09
1871	354	301	60.0	56.7	1.06
1911	554	455	57.0	51.2	1.11
1985	765	1,238	38.0	172.1	.22

FIGURE 1 (a)

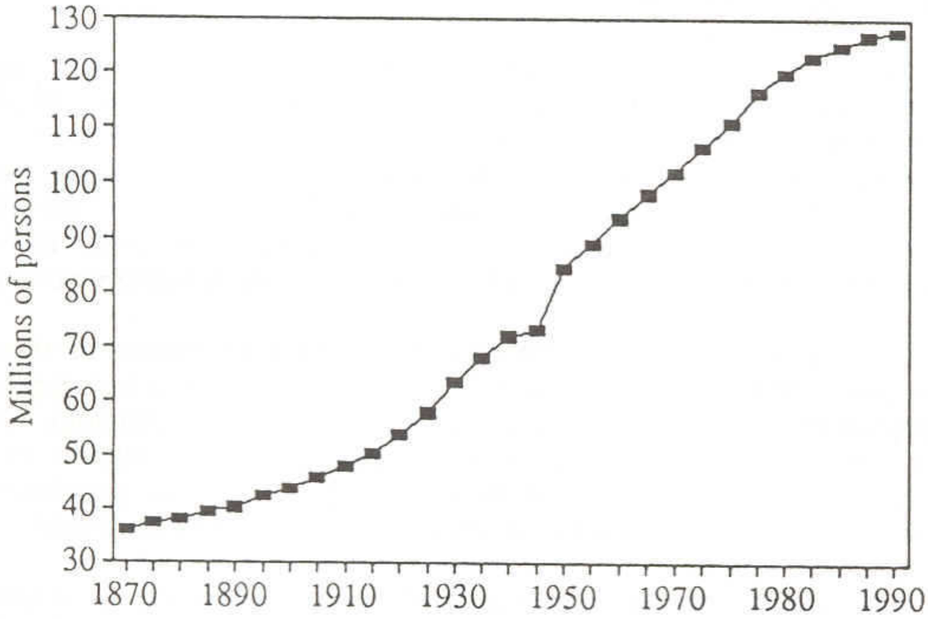
THE POPULATION HISTORY OF ENGLAND



Sources: Wrigley and Solofield (1981) for 1631-1801.
Mitchell (1978) for 1801-1971.
WDR (1984) for projections.

FIGURE 1 (b)

THE POPULATION HISTORY OF JAPON



Sources: Olkawa and Shirohara (1979) for 1872-1940.
Bank of Japan (1988) for 1940-1990.

TABLE 2

PERCENT SHARE OF AGRICULTURE IN NATIONAL INCOME

	1870	1970
Britain	15	3
France	45	6
US	30	3
Japan	63	7
Sweden	43	4

Source: Cipolla (1974).

Section 4 proposes an extension of the Diamond growth model that describes population dynamics and migration under laissez faire. Endogenous fertility is the by-product of intrafamily bargaining between an older generation of parents who own the means of production (land, farming "know-how") and a younger generation of offspring who control the labor input. We analyze how fertility and population movements of the type demographers identified long ago depend on the ratio of labor productivity in the traditional sector to that in the urban sector. We further investigate migration, that is, how a growing population would distribute itself in a dual economy. In the final section we compare the facts of section 2 to the theoretical predictions of the model in section 4.

2. The Empirical Regularities

Most Western European countries exhibited slow population growth throughout their histories until the 17th-18th centuries; experienced an acceleration of population growth approximately coinciding with the beginning of industrialization; and then saw high population growth rates return to levels consistent with moderate population growth. The population of Britain, for example, rose by 55% over the eighteenth century, by 247% in the nineteenth, and by some 56% so far (1900-1985) this century.[1] Similar upward spurts in population growth seems to have occurred in several countries during the eighteenth century.

The experience of Europe illuminates the underlying causes of this logistic population curve.[2] In pre-industrial Europe, moderate fertility rates balanced mortality to keep population growth close to zero; given the level of technology, traditional economies could not support any significant expansion in the population. Changes in fertility induced changes in mortality in the same direction, keeping population growth close to zero. Similarly, a decrease in mortality led to reduced fertility via later marriages and fewer children.

With industrialization, life expectancy shot up in response to scientific and technological advances; both mortality and fertility declined. However, the decline in fertility occurred only with a lag, so that population growth rates initially increased sharply in Western Europe with the improvement in medical techniques. As fertility continued to decline in Europe and North America, the slowdown in life expectancy increases after 1900 implied that net population growth rates began to decline, yielding the observed flattening of the population logistic curve.

The eighteenth century saw the beginning of rapid changes not only in the size of national populations but also in their distributions across sectors. The expansion of industry and services attracted millions away from farming in small relatively isolated communities to work in urban centers (see Tables 2 and 3). The sectoral shift strengthens the overall fertility decline outline above. To the extent that rural fertility systematically exceeds urban fertility, migration to the cities will lower average fertility through a composition effect, in addition to causing rural fertility to fall directly.

TABLE 3

AGRICULTURAL POPULATION IN BRITAIN
(Millions)

	(1) Total Population	(2) Urban Population	(3) Rural Population	(4) Proportion of Rural Population in Agriculture	(5) Rural Agricultural Population (3) x (4)
1520	2.40	0.13	2.27	0.80	1.82
1600	4.11	0.34	3.77	0.76	2.87
1670	4.98	0.68	4.30	0.70	3.01
1700	5.06	0.85	4.21	0.66	2.78
1750	5.77	1.22	4.55	0.58	2.64
1801	8.66	2.38	6.28	0.50	3.14

PERCENTAGES OF TOTAL POPULATION IN MAJOR CATEGORIES

	(1) Urban	(2) Rural Agricultural	(3) Rural Non-Agricultural	(4) Total
1520	5.5	76.0	18.5	100
1600	8.0	70.0	22.0	100
1670	13.5	60.5	26.0	100
1700	17.0	55.0	28.0	100
1750	21.0	46.0	33.0	100
1801	27.5	36.25	36.25	100

Source: Wrigley (1986)

3. Basic Models of Endogenous Fertility

The approach to endogenizing fertility seen most often in the literature basically considers children as a consumption good [Becker and Barro (1988), Tamura (1988), and others]. The quantity and quality of children is an argument in the utility function, implying that economic variables which affect household optimization will affect decisions on family size. We agree with many of the basic insights of this approach (and in fact include a utility value of children as one motivating factor in our model), but we think that focussing simply on the consumption side misses a some crucial characteristics of population decisions in the development process. We view children, in less developed societies, primarily as a factor of production and store of value (e.g., laborers for the family farm, a social security system for parents) and only to a lesser extent as a consumption good. We therefore focus on the changing economic role of the family as economies come to depend less on self-contained family units and more on organized large-scale markets.

Dual economy models suggest a number of differences between the primitive, agricultural sector and the more developed, manufacturing sector. The standard difference stressed in the literature [Dixit (1973)] is in product specialization, with the agricultural sector producing only consumption goods and the manufacturing sector producing both consumption and investment goods. Another difference is in factor inputs, with the more primitive agricultural sector exhibiting low capital-labor ratios and heavy reliance on land as an input, while the more advanced manufacturing sector is highly capital intensive.

A more basic distinction in our opinion is in the modes of economic organization, specifically how output is produced and distributed. A "modern" sector is one that relies on markets for the hiring of factors of production, the distribution of output, and the accumulation of assets. In contrast, these markets are often absent or poorly functioning in a "traditional" sector.[3] Our primary argument here is that the key facts about population dynamics during a demographic transition may come from the relative absence of organized markets in the traditional rural sector.

Specifically, we assume that the urban sector has well-functioning, competitive labor and credit markets. Neither market exists in the rural, agricultural sector. What takes the place of missing markets? We assume that all exchanges are made within the family-these are no *interfamily* exchanges of dated consumption goods or labor. The complete absence of markets in the agricultural sector implies that rural workers "save" by bearing children and consuming in old age part of what their children produce. Here the family is a crucial economic unit in providing labor, the distribution of output, and the intertemporal smoothing of consumption. In contrast, the development of labor and credit markets in the urban sector erodes the economic function of the family.

Our argument about the economic role of the family is broader than "the old age security hypothesis", which postulates that individuals bear children as a means of saving for old age when standard asset markets are nonexistent (see, for example, Neher [1971]). As indicated above, the family in the agricultural sector is crucial not only in saving decisions, but also in the provision of inputs and the distribution of farm product. This view of the family implies that endogenous fertility decisions will be influenced by a host of variables which would have no effect in simpler models of fertility. For example, since farm output is split between parents and children via bargaining, improved employment opportunities in the urban sector, by increasing the children's bargaining power, will also increase their share and hence reduce the incentive to bear children. The effect of higher urban wages in reducing rural fertility is consistent with empirically observed fertility movements during industrialization, but is absent in models which treat children as a consumption good. A very similar model has been proposed by Sundstrom and David (1988). We will discuss their model further in section 5.

More generally, the process of development is marked by a decline in traditional modes of family organization. Better opportunities in the city not only imply smaller rural families, but also induce migration to urban areas where markets perform many of the functions reserved for families in agriculture. Improved exchange opportunities in the rural sector will further weaken the role of the family. Understanding the family as a provider of economic services is central, we feel, to understanding demographic transitions and perhaps the entire development process.

4. The Model

We propose here a model of the rural sector that brings out the role of "traditional" families and explores the implications of such a structure. The model is designed to focus on the deceleration of population growth associated with the fall in fertility as a result of industrialization.

A. *Basic Structure*

The basic economic unit is the family. Each individual lives three periods, two of which are periods of economic activity. Generation t within a family consists of n_t siblings, each of whom is born at t-1 as a non-producing, non-consuming infant. At t each sibling works, consumes, and has children. Urban workers sell labor in a competitive labor market, using the excess of wage income over consumption to buy assets; farm laborers work for their parents. At t+1 each rural sibling heads his own family, employing his own children (but not working himself) and consuming the family's entire non-wage surplus. Consumption of urban retirees equals their financial saving plus accumulated interest. For simplicity we number the stages of life for each individual as 0, 1, and 2.

Each individual in stage 1 is endowed with one unit of time. Only part of this unit is supplied to production because bearing and raising children involves a time cost. Call $\theta(n)$ the amount of time consumed when one bears n children, where we assume that all children survive to adulthood. In this section we assume that $\theta(n)$ is a non-decreasing convex function with $\theta(\underline{n}) = 0$ for some small $\underline{n}$, and $\theta(n) = 1$ for some large n.

In the rural sector labor is the only variable factor of production. Total hours supplied by generation t siblings in a family is

$$h_t = n_t\,(1 - \theta\,(n_{t+1})). \tag{4.1}$$

Total output in the family is $F(h_t)$, where F may exhibit either constant or decreasing returns in labor.[4] We further assume that the technology differs across families (perhaps reflecting the quality of land); we index technology by a family-specific rural productivity parameter b.

Output in the urban sector depends on both capital and labor via a constant-returns-to-scale production function that shifts with technical change. Labor supply comes from families that have previously migrated from the rural sector. With perfect labor and asset markets, urban workers need not rely on intrafamily exchange, and will bear only $\underline{n}$ children at a time cost of zero. An urban worker's first-period income is thus the wage rate w. We assume there are no remittances from migrants back to the rural sector.

Utility of an individual is assumed to be a time-separable function of consumption in the first and second periods of life, with a constant discount factor $\beta \leq 1$. In what follows we assume that utility in each period is linear in consumption.

B. *Rural-Sector Decision Problems*

The crucial question for a farm family is how total output of generation t, namely $F(n_t(1 - \theta(n_{t+1})))$, is divided between parents and their n_t children. It makes little sense to impose a competitive solution. We argue instead that the division of rural product between successive generations of any given family is determined through bargaining. We consider the Nash bargaining solution, with the bargaining power of the children as a group depending on their number and on what value they place on the option of working in the urban sector. The timing of bargaining is as follows. Sons (generation t), decide on the number of children n_{t+1} before bargaining over output with fathers (generation t-1), knowing fully how their share of output depends on n_{t+1}.[5] The bargaining process takes as given (n_t, n_{t+1}) and father's first-period income. Let x_t denote the current-period income of a son at time t and y_t the current-period income of his father. These must satisfy

$$y_t + n_t x_t = F(h_t). \tag{4.2}$$

Since no financial assets exist, x and y are also consumption levels. Lifetime utility of an individual born at t-1 who remains on the farm is $u(x_t) + \beta u(y_{t+1})$. Symmetric Nash bargains may be represented as choices of y_t that maximize the product of utility gains over the appropriate threat point, namely,

$$L = u(y_t)\,[u(x_t) + \beta u(y_{t+1}) - v(R_t, w_t)]^{n_t}. \tag{4.3}$$

subject to constraint (4.2).

Here v(R,w) is the indirect utility function of an urban worker, given the interest factor R and the wage rate w. Using (4.2) and rearranging, the bargaining solution satisfies

$$u'(y_t)\,[u(x_t) + \beta u(y_{t+1}) - v(R_t, w_t)] = u(y_t)\,u'(x_t). \tag{4.4}$$

When utility is linear, $v(R,w) = w$. Equation (4.4) then becomes

$$x_t + \beta y_{t+1} = y_t + w. \tag{4.5}$$

Substituting (4.5) into (4.2), the share of the father in the bargain must satisfy the following difference equation

$$(1 + n_t)\,y_t = F(h_t) + n_t(\beta y_{t+1} - w). \tag{4.6}$$

We may now use these relations to find the utility-maximizing level of fertility for generation t, that is, the utility-maximizing choice of n_{t+1}. Lifetime utility may be written

$$V(n_{t+1}) = x_t + \beta y_{t+1}.$$

Using (4.2) to eliminate x_t and then (4.6) to eliminate y_t, we may write

$$\begin{aligned} V\,(n_{n+1}) &= \frac{n_t}{1+n_t}\left[\frac{F(h_t)}{n_t} + \beta y_{t+1}\right] - \frac{w}{1+n_t} \\ &= \frac{n_t}{1+n_t}\left[\frac{F(h_t)}{n_t} + \beta\frac{F(h_{t+1})}{1+n_{t+1}} + \frac{\beta n_{t+1}}{1+n_{t+1}}\,(\beta y_{t+2} - w)\right] - \frac{w}{1+n_t} \end{aligned} \tag{4.7}$$

were

$$y_{t+1} = \frac{n_{t+1}}{1+n_{t+1}}\left[\frac{F(h_{t+1})}{n_{t+1}} + \beta y_{t+2} - w\right] \tag{4.6'}$$

This is maximized over n_{t+1}, taking as given the number of siblings n_t, the generation t+2 variables (n_{t+2} and y_{t+2}), and urban wages w. The first-order condition for fertility is

$$-F'(h_t)\theta'(n_{t+1}) - \beta\frac{F(h_{t+1})}{(1+n_{t+1})^2} + \beta\frac{F'(h_{t+1})}{1+n_{t+1}}\,(1-\theta\,(n_{t+2})\,) + \frac{\beta}{(1+n_{t+1})^2}\,(\beta y_{t+2} - w) = 0$$

After some manipulation, this yields

$$\beta\left[\frac{y_{t+1} - F\,(h_{t+1}) + h_{t+1}\,F'\,(h_{t+1})}{n_{t+1}\,(1+n_{t+1})}\right] - \theta'\,(n_{t+1})\,F'\,(h_t) = 0 \tag{4.8}$$

Equation (4.8) may be interpreted as follows. The objective function V shows that an increase in n_{t+1} will affect utility through a negative effect on current output $F(h_t)$ and a positive effect on future income y_{t+1}. The second term in (4.8) gives the marginal output loss from bearing more children. The first term is β times the increase in y_{t+1}. Equation (4.6)' shows how future income depends on the number of children and via the curvature of $F(h_{t+1})$.

Equations (4.1), (4.6)' and (4.8) form a system of three difference equations in the triple (n_t, y_t, h_t). The dynamical behavior of this system is, not surprisingly, quite difficult to analyze. We will limit ourselves here to steady state analysis.

To analyze steady states, we substitute the stationary versions of (4.1) and (4.6)' into (4.8). The resulting equation may be written

$$\beta w = (1+n-\beta n)\,[\beta\,(1-\theta\,(n)\,) - (1+n)\,\theta'\,(n)]\,F'\,(\bullet) - \beta\,(1-\beta)\,F\,(\bullet) \equiv \varnothing\,(n) \tag{4.9}$$

where $F(\cdot) = F(n(1 - \theta(n)))$. To evaluate this, note first that all families have a minimum of $\underline{n}$ children, given our assumption that $\theta(n)=0$ for $n \leq \underline{n}$. Using this and $\theta(n) = 1$, we note that

$$\begin{aligned} \varnothing(0) &= (\beta - \theta'(0))\, F'(0) \\ \varnothing(n) &= (1+n-\beta n)(1+n)\,\theta'(n)\, F'(0) \leq 0 \end{aligned} \tag{4.10a}$$

The second relation follows from the assumption that θ is an increasing convex function. Since $\varnothing(n)$ is continuous over $(0, n)$ we therefore know there exists at least one stationary state with rural fertility $n > \underline{n}$ if $\varnothing(0)$ exceeds βw (see Figure 2) and $\underline{n}$ is sufficiently close to zero. Hence, a sufficient condition for the existence of an interior steady state is that the marginal cost of the "first" child is low (that is, $\theta'(0)$ small) and that the marginal product of the "first" child is sufficiently high ($F'(0) >> w$). This condition seems intuitive.

To examine uniqueness, we differentiate $\varnothing(n)$ with respect to n to obtain, after some rearrangement,

Since $\theta(n)$ is positive at a steady state, inspection of (4.9) requires $[\beta(1 - \theta(n)) - (1+n)\,\theta'(n)]$ to be positive at a steady state as well. From (4.10b) we

$$\begin{aligned} \frac{\partial \varnothing(n)}{\partial n} = {} & (1+n-\beta n)\,[(1-\theta-n\theta')(\beta(1-\theta)-(1+n)\theta')\,F''(\cdot) \\ & - (2\theta' + (1+n)\theta'')\,F'(\cdot)] \end{aligned} \tag{4.10b}$$

therefore see that a sufficient condition for $\partial\varnothing(n)/\partial n$ to be negative at a steady state is that $(1 - \theta - n\theta')$ be positive at the steady state. This means that the time spent on *non-childbearing* activities must exceed the number of children times the marginal cost of bearing children. We assume this to be the case (which requires that $\theta < 1/2$, since convexity implies $n\theta' > \theta$). On the assumption that $1 - \theta > n\theta'$, $\theta(n)$ must cut w from above at *every* steady state. Continuity then implies the steady state is unique.

Two general questions are of interest: First, which families migrate to the urban sector? Second, how do changes in parameter values affect migration and fertility decisions of rural families? To explore this question we employ the following special form of F,

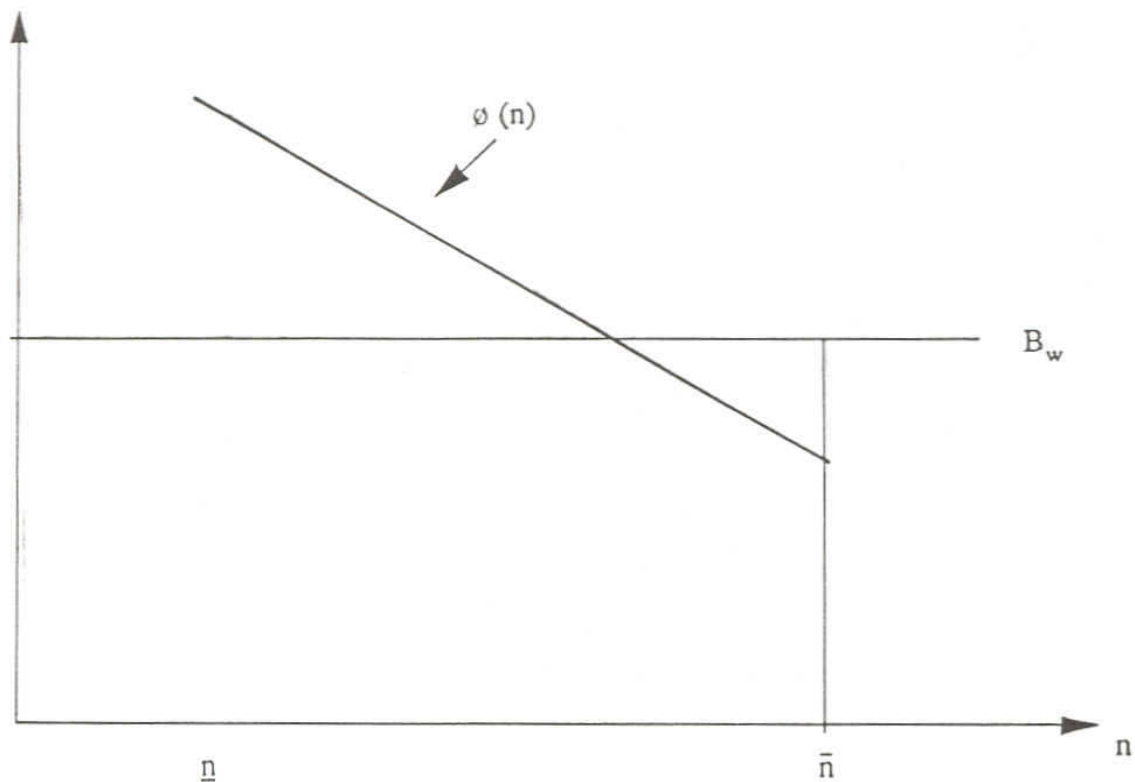
$$F(h;b) = bf(h)$$

where b is a Hicksian rural productivity parameter and f is a standard concave production function.

In the migration decision, the *marginal* farm family is one for which a son is indifferent between remaining on the farm and migrating even under the most favorable bargain he can get from his father. When fertility is at the minimum level $\underline{n}_2$ and the entire farm output is consumed by children, rural and urban utility are equal for the marginal farm family. Using the stationary versions of (4.2) and (4.1), equality of income across sectors for the marginal type b* means

$$b^{*}{}_{f(\underline{n})/\underline{n}} = w, \tag{4.11}$$

FIGURE 2



which defines b^*. (We have used $h(\underline{n}) = \underline{n}(1 - \theta(\underline{n})) = \underline{n}$.) We will demonstrate below that a family of type b^* that sets fertility according to (4.9) chooses $n = \underline{n}$. All families with b greater than or equal to b^* will remain in the rural sector; all those with b less than b^* will migrate.[6]

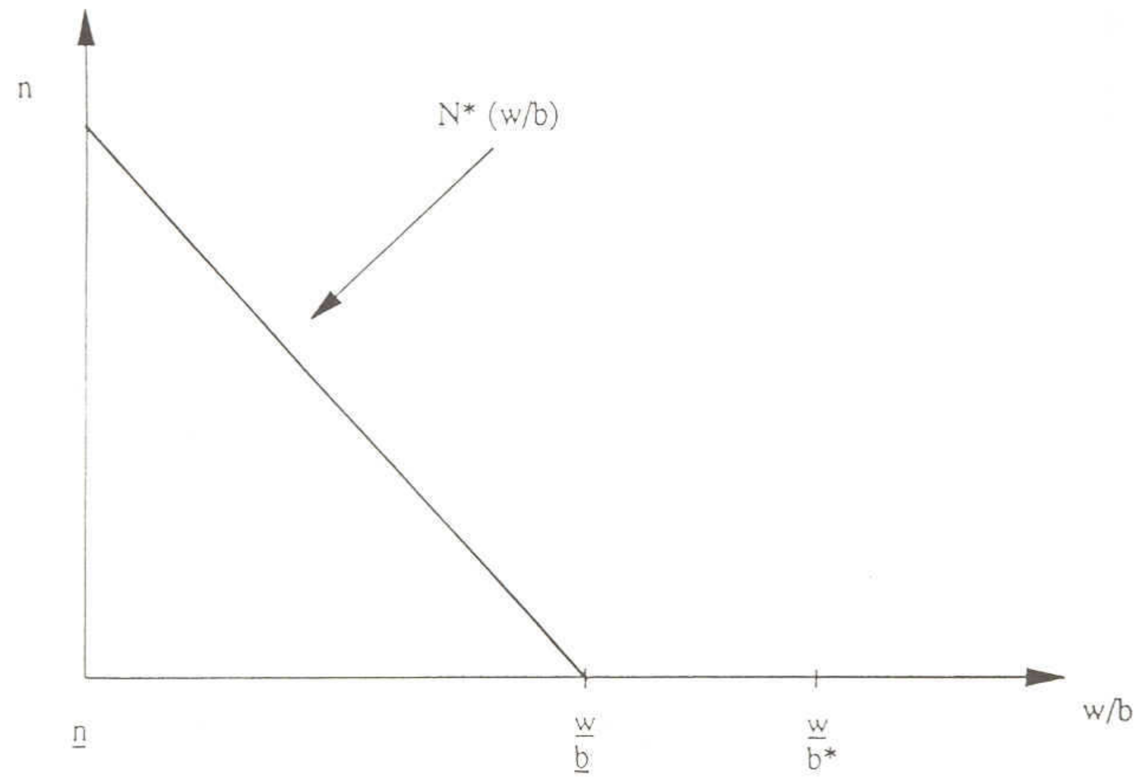
Differentiating with respect to w, we have

$$db^*/dw = \underline{n}/f(\underline{n}) > 0 \tag{4.12}$$

In other words, an increase in the urban wage rate will increase the level of rural productivity necessary to keep people on the farm. Therefore, it will induce migration to the city, a standard result in the development literature. (Since F(h;b) is monotonically increasing in b by definition, both of these results extend to the more general technology).

Optimal fertility for families that remain in the rural sector is given by (4.9). It is immediate from this equation (see also Figure 3) that an increase in the urban wage rate implies a fall in rural fertility. Why should an increase in the return to labor in the city (reflecting technical progress, for example) induce a fall in the incentive to bear children? A higher urban wage rate means that the young have better outside options and more bargaining power; hence the income share of the old is reduced for any given number of offspring. Knowing this functional relation, an individual finds it optimal to bear fewer children if he expects higher urban wages in the future. The depressing effect on rural fertility of technical progress in the urban sector is not a standard result, but it is borne out in the demographic transitions of many countries.

FIGURE 3



To analyze the effect of an increase in rural productivity on fertility, the case where F (h, b) = bf (h) is especially useful. Equation (4.9) becomes

$$\beta w/b = (1+n - \beta n)\ [\beta (1 - \theta (n)) - (1+n)\, \theta' (n)]\ f' (n) - \beta (1 - \beta) f (n) \qquad (4.9')$$

In this case, a rise in rural productivity b is identical to a fall in w which induces an increase in rural fertility. It is the ratio w/b that is important here.

To complete our characterization of rural fertility decisions, we look at families with b close to b^*. Define by $\underline{b}$ the type for whom $\underline{n}$ is just optimal according to (4.9'). That is, let

$$\underline{b} = w/[(1+\underline{n} - \beta n)\ [1 - ((1+\underline{n})/\beta)\, \theta' (\underline{n})]\ f' (\underline{n}) - (1 - \beta) f (\underline{n})] \qquad (4.13)$$

Using the concavity of f(n), we have $(1+ \underline{n} - \beta\underline{n})\, f(\underline{n})/\underline{n} > (1+\underline{n} - \beta\underline{n})\, \underline{n}f' (\underline{n})$ so that

$$f (\underline{n})/\underline{n} > (1+\underline{n} - \beta\underline{n})\, f' (\underline{n}) - (1 - \beta) f (\underline{n})$$

$$> (1+\underline{n} - \beta\underline{n})\, [1- ((1+\underline{n})/\beta)\, \theta' (\underline{n})]\, f' (\underline{n}) - (1 - \beta) f (\underline{n})$$

as long as $\theta' (\underline{n}) \geq 0$. Comparing (4.11) and (4.13), we see that $\underline{b} \geq b^*$ with equality only if $\theta' (\underline{n}) = 0$ and f(h) = h, that is, a linear technology.

We can now fully characterize the rural fertility and migration decisions. Families with rural productivity $b > \underline{b}$ will bear $n > \underline{n}$ children according to (4.9'). Families with $\underline{b} > b \geq b^*$ will remain in the rural sector and bear $\underline{n}$ children. Families with $b < b^*$ will locate in the urban sector (recall that $\underline{n}$ and b^* are increasing functions of w). We summarize the rural fertility decision by the function $n = N^*(w/b)$ drawn in Figure 3. Aggregate population and fertility in both urban and rural sectors is found by summing across types.

C. *Factor Price Determination in the Urban Sector*

To close the model, we must explain how factor prices are set. With a linear utility, the interest factor is determined by the discount rate, that is, $R = 1/\beta$. The wage rate would then be given by the factor-price frontier, which depends on technology. Labor-augmenting technical progress supports secular increase in the urban wage rate.

The interest factor will also determine the capital-labor ratio in the urban sector. Once the urban labor force is determined, saving behavior under linear utility fixes the stock of capital associated with the equilibrium capital-labor ratio. The absolute size of the urban labor force is however not so easy to describe. The wage rate determines which families are located in the urban sector. Once a family has migrated, its population dynamics is simple, since urban families bear the minimum number of children $\underline{n}$. The problem is in the determination of family size *prior* to migration if wages have not been constant historically. Since the size of rural generation t–i of family type b depends on w_{t-i} according to $N^*(w_{t-i}/b)$, the size of the family will depend on the *entire* history of wages. Therefore, though factor prices can be determined simply from current technology, total factor inputs are history-dependent.

In the case of no technical progress, the stationary state in general equilibrium is fully determined by (4.9'), by the steady state versions of (4.1) and (4.6), and by the wage from the factor price frontier (which depends on β and the level of technical progress A). We now consider the effect of technical progress on fertility and migration by considering a one-time upward jump in A (implying a one-time upward jump in w) and compare the two stationary states.

Fertility is lower for every type of family which previously chose $n > \underline{n}$. Average rural fertility in therefore lower, as is the overall rate of population growth. An increase in urban wages also induces migration in the adjustment to the new stationary state. From this two results follow about the urban population. First, there is an increase (relative to what would have been true for lower w) in the *absolute* size of the urban population for all t. This follows from the in-migration into the city combined with there being no effect of the change in w on the size of urban families. Second, there is an increase in the size of the urban sector *relative* to the rural sector. This follows from the previous results, as the urban sector increase in absolute size, while the rural sector contracts.

5. A First Look at the Evidence

The model in the previous section makes a number of predictions about the causes of changes in the rate of growth and sectoral composition in a dual economy. We will not test these predictions here, but, in this section, hope to suggest how these mechanisms are consistent with the data and how they shed light on the demographic transition. Since the theoretical effect of migration from agriculture to manufacturing is well documented, we will concentrate on the determinants of the decline in fertility.

The two main predictions we make about fertility may be summarized as follows:

(i) Industrialization and increased labor market opportunities will directly reduce average fertility in the "traditional" sector, as defined in section 3. More specifically, rural fertility will fall as urban wages rise.

(ii) Fertility in the "traditional" sector will be above that in the "modern" sector. Industrialization will therefore have both a direct and an additional indirect effect on average fertility because it induces migration.

A. *Industrialization and the Decline in Traditional Sector Fertility*

The data suggest that there is a strong connection between the timing of the deceleration in the rate of population growth and the shift in the structure of production in country after country. Though the process of industrialization and the expansion of large-scale markets was often well underway before the demographic transition began in the economies of North America, Europe, and Asia, sharp changes in population growth and fertility occurred first in countries that industrialized relatively early.

The demographic transition began in Britain and the United States before the rest of Europe (with the exception of Holland and France), with sharp increases in population growth rates already in the late 18th century and the levelling off of population growth rates in the mid to late 19th century. The birth rate began a sustained decline in the United States already in 1800, well before most of Western Europe. Western Europe's demographic transition was more a 19th century phenomenon, with birth rates across sectors declining in the late 19th century (Kuznets [1975], Wrigley and Schofield [1981], Coale and Watkins [1986]).

In Southern and Eastern Europe, which developed much later, the demographic transition began only in the late 19th century, with the decline in both rural and urban birth rates and the second demographic transition occurring early in the 20th century (Coale and Watkins [1986]). The developing countries in Latin America and Asia had high fertility rates in the mid-20th century, with birth rates declining only in the 1960's and 1970's (Coale [1983]); the poorest, most backward countries in Africa are still in the first phase of the demographic transition and have not yet experienced declining fertility rates.

A more direct sort of evidence would be in the correlation of market real wage rates with fertility rates. The Malthusian view would suggest a positive correlation between *population* growth rates and real wages in the *first* demographic transition, as higher income would allow for lower mortality and higher net birth rates, while our view suggests a negative correlation in the *second* demographic transition when fertility changes dominate. The former is well illustrated by 19th century England, for example, which exhibits a positive correlation of real wages to population growth (Wrigley and Schofield [1981], Lindert [1986]). In contrast, the increase in fertility in early 19th century Holland after the long period of population stagnation followed a secular decline in real wages (DeVries [1986]). Another piece of evidence may be found in work by Sundstrom and David (1988), in a paper whose arguments are very similar to ours.[7] They consider the relation of rural fertility to measures of labor market opportunities. They begin with a widely used though inexact measure of 19th century rural fertility in the United States, the number of children under 10 divided by the number of women of ages 16-44 in the census year 1840. Taking a cross-section of states, they regress this on a number of variables which may explain fertility, including two which measure outside labor market activities. The first is the ratio between the daily wage rate for nonagricultural labor and the monthly farm labor wage rate, both for 1850; the second is the relative employment share in the nonagricultural sector divided by the agricultural sector's labor force share. They find that both variables have a significant negative coefficient.

B. *Sectoral Differences in Fertility*

Our model further suggests that at each level of development and at given market wage rates, fertility in the "traditional" non-market sectors should be higher than in the market sector. Both Sharlin (1986) (for Europe in the late 19th and early 20th centuries) and Kuznets (1974) for the world as a whole report that rural fertility is uniformly higher than urban fertility. Moreover, after industrialization in Europe, urban areas began their fertility decline prior to rural areas, and urban fertility declined more rapidly in the initial stages of industrialization. However both authors report urban-rural differentials within a country or region are swamped by differences across countries or regions. LDC fertility, for example, is higher in both urban and rural areas than fertility in developed countries. Similar observations characterize Europe.

We interpret these observations to mean that the interesting division is not between rural and urban areas, but between modes of production and economic organizational in general. In developed countries many non-agricultural activities have come to be located in non-urban areas. Conversely, many production activities in urban areas in underdeveloped countries are essentially cottage industries which still give an economic benefit to having a large family. Modes of production are correlated with geographical location, but imperfectly. Both Kuznets [1974] and Lesthaege and Wilson [1986] suggest a strong connection between shifts in occupation and modes of production on the one hand and incentives to bear children on the other.

Footnotes

1 See Deane and Cole (1969), pp. 6 and 8, and *World Development Report* (1987). Many of the data we refer to have been collected by Angelike Kourelis and are analyzed in an independent study project she wrote at Penn.

2 See Coale and Watkins (1986), Lesthaege and Wilson (1986), and Kuznets (1975) for the non-European experience.

3 Kuznets (1974), among others argues that the mode of economic organization in the traditional sector is crucial in understanding the process of development. Drazen and Eckstein (1988) present a simple model stressing the effect of the lack of competitive markets in the rural sector on the process of capital accumulation.

4 This formulation abstracts from the problem of scarcity of land –it is most applicable in a rural sector where land is abundant. In fact, fertility and nuptuality decisions as well as inheritance arrangements in the rural sector in many European countries were very much influenced by the problem of subdividing a limited amount of land among children. See Guinnane (1990).

5 An alternative is that sons can only start their own famililes when parents give them sufficient resources to do so. This view, perhaps more realistic historically, leads to a different sequencing of decisions and is explored in the work of Paul David.

6 Farms of those who have migrated are not economical to operate, given the urban wage relative to their farm productivity b.

7 We became aware of work by Sundstrom and David [1988], which is very close to our model, after completing the work on which this paper is based. They consider a model of the family based on non-altruistic parents, and children who work for them. The young support the old in exchange for receiving their property when they die. The terms of the exchange are the result of bargaining between the two generations, implying, as in our model, that the bargaining power of the young is increased by better outside labor market opportunities.

The models are so similar, they should be consider complementary, though there are some differences. Sundstrom and David use a different solution concept and consider marginal childbearing costs. There are two sorts of differences in the results. First, their model stresses sibling rivalry, with parents "playing off" one child against another. Hence, bearing more children may increase a parent's bargaining power, while in our model it unambiguously lowers it because of the Nash bargaining solution. Second, they report that an increase in the outside earning opportunities of the young induces an unambiguous decline in the demand for children in the special case where parents maximize total wealth. Under more general assumptions about preferences, they find an ambiguous effect on the derived desire for children, in contrast to our model.

References

AZARIADIS, C. and A. DRAZEN (1990), "Threshold Externalities in Economic Development", *Quarterly Journal of Economics* (May).

BECKER, G. and R. BARRO (1989), "Fertility Choice in a Model of Economic Growth", *Econometrica* 57: 481-501.

CIPOLLA, C. (1974), *The Economic History of World Population,* 6th ed., London: PenguinBooks.

COALE, A.J. (1983), "Recent Trends in Fertility in Less Developed Countries", *Science* 221: 828-32.

— (1986), "The Decline of Fertility in Europe since the Eighteenth Century as a Chapter in Human Demographic History", in Coale and Watkins.

— and S. WATKINS, editors (1986), *The Decline of Fertility in Europe,* Princeton University Press.

DEANE, P. and W.A. COLE (1969), *British Economic Growth 1688-1959,* Cambridge: Cambridge University Press (1969).

DE VRIES, J. (1986), "The Population and Economy of the Preindustrial Netherlands", in R. Rothberg and T. Rabb (editors), *Population and Economy,* New York: Cambridge United Press.

DRAZEN, A. and Z. ECKSTEIN (1988), "On the Organization of Rural Markets and the Process of Economic Development", *American Economic Review* 78: 431-43.

GUINNANE, T. (1987), "Intergenerational Bargains, Emigration, and the Rural Irish Household system", mimeo, Princeton Univ.

KUZNETS, S. (1965), *Reflections on Economic Growth.*

— (1974), "Rural-Urban Differences in Fertility: An International Comparison", *Proceedings of the American Philosophical Society,* 118: 1-29.

— (1975), "Population Trends and Modern Economic Growth: Notes toward an Historical Perspective", in United Nations, *The Population Debate: Dimensions and Perspectives,* vol. 1 (New York).

LESTHAEGHE, R. and C. WILSON (1986), "Modes of Production, Secularization, and the Pace of Fertility Decline in Western Europe, 1870-1930", in Coale and Watkins.

LINDERT, P., "English Population, Wages and Prices: 1541-1913", in Rothberg and Rabb, *op. cit.*

LUCAS, R. (1988), "On the Mechanics of Economic Development", *Journal of Monetary Economics* 21: 3-42.

McEVEDY, C. and R. JONES (1978), *Atlas of World Population History,* New York: Penguin Books.

NEHER, P. (1971), "Peasants, Procreation and Pensions", *American Economic Review* 61: 380-9.

ROMER, P. (1986), "Increasing Returns and Long-Run Growth", *Journal of Political Economy* 94: 1002-37.

SHARLIN, A. (1986), "Urban-Rural Differences in Fertility During the Demographic Transition", in Coale and Watkins.

SUNDSTROM and P. DAVID (1988), "Old-Age Security Motives, Labor Markets and Farm Fertility in Antebellum America, *Explorations in Economic History* 25: 164-97.

TAMURA, R. (1988), "Fertility, Human Capital and the 'Wealth of Nations'," mimeo, University of Iowa.

WRIGLEY, E.A., "Urban Growth and Agricultural Change: England and the Continent in the Early Modern Period", in Rothberg and Rabb, *op. cit.*

— and R.S. SCHOFIELD (1981), *The Population History of England, 1541-1871: A Reconstruction,* Cambridge: Harvard University Press.

WORLD BANK (1984 and 1987), *World Development Report,* Washington, D.C.