Liwa Rachel Ngai and Christopher Pissarides

Trends in hours and economic growth

Article (Accepted version) (Refereed)

Original citation:
Ngai, L.Rachel and Pissarides, Christopher (2008) Trends in hours and economic growth. Review of economic dynamics, 11 (2). pp. 239-256.
DOI: 10.1016/j.red.2007.07.002

Trends in Hours and Economic Growth*

L Rachel Ngai
Centre for Economic Performance,
London School of Economics, and CEPR

Christopher A Pissarides
Centre for Economic Performance,
London School of Economics, CEPR and IZA

June 2007 (first draft September 2005)

Abstract

We study substitutions between home and market production over long periods of time. We use the results to get predictions about long-run trends in aggregate market hours of work and about employment shifts across economic sectors, driven by uneven TFP growth in market and home production. The model can rationalize the observed falling or U-shaped pattern for aggregate market hours, the complete marketization of home production in agriculture and manufacturing, and the employment shift from agriculture and manufacturing to services. We find support for the model's predictions in long-run US data.

Keywords: hours of work, labor supply, structural transformation, home production, marketization, balanced growth.

JEL classification: J21, J22, O14, O41

*We have benefited from suggestions and comments from Francesco Caselli, Jeremy Greenwood, Gueorgui Kambourov, James Heckman, Robert Lucas, Torsten Persson, Danny Quah, Valerie Ramey, Richard Rogerson, Randy Wright and Fabrizio Zilibotti. We are especially grateful to Valerie Ramey for making available some of the data reported in Ramey and Francis (2006). An earlier version of this paper was presented as a keynote address at the CEPR/IZA annual labor economics conference at Ammersee in September 2005. We also acknowledge comments from presentations at the NBER meeting at the Cleveland Federal Reserve Bank, the IZA Prize Conference in Berlin, the SED conference in Vancouver, and several universities. This study was financed by the ESRC under award no. RES-000-22-0917 and is part of the CEP's Research Programme in Macroeconomics. The CEP is a designated ESRC Research Centre.

Modern economic growth is usually accompanied by a changing trend in total hours of work. In the United States the trend over the last century is a shallow U-shape, a long decline followed by a small rise. Table 1 shows this decline for some key years. Between the beginning of the century and 1980 weekly per-person hours of work in the population aged 10 and above fell by about six hours. In the two decades that followed hours increased by nearly two hours. The table also shows average weekly hours of work for persons in the employed population. This series falls monotonically, showing that in the last quarter century the rise in hours of work was due to a rise in employment.[1]

The low-frequency trends in hours that one finds in long runs of data are usually neglected by modern growth theory.[2] A seemingly unrelated feature of modern growth is structural transformation: the decline of agriculture and the rise of services, with relatively smaller changes taking place in industrial employment. In this paper we propose a framework for the study of these two phenomena that builds on a common economic cause: the response of hours of work to the uneven distribution of technological change across production sectors located in the market and the home.[3]

In our model production can take place both in the market and the home. The time allocated to market production produces both consumption and capital goods and is a measure of the conventional supply of labor. The time allocated to home production produces consumption goods by using capital goods purchased in the market but it is not part of the conventional definition of labor supply. We show that because of the uneven distribution of technological change the division of total work time between market and home changes during the course of economic development. In our benchmark economy these changes drive the changes in aggregate labor supply. Under plausible conditions the time allocated to market production may increase initially, but as growth progresses it decreases. In later stages of economic growth it increases again. The prediction of a changing trend in the number of market hours is unique to our model: although a variety of mechanisms can yield a fall in market hours during economic growth, such as a rise in the returns to education or a rise in the demand for leisure, to our knowledge no model has been able to explain the turning point in market hours that we get from the substitutions between home and market production.

The intuition behind our results derives from the key assumption that although mar-

[1] Before the twentieth century hours of market work were, at least for a while, on an upward trend, as industrialization changed production from a home economy to a market economy. See for example Voth (1998) for some British evidence and Section 1 for US historical evidence.

[2] A typical statement is the following one, due to Cooley and Prescott (1995, p.16): "In balanced-growth consumption, investment and capital all grow at a constant rate while hours stay constant. This behavior is consistent with the growth observations described earlier [the Kaldor facts]."

[3] Structural transformation has been studied by many authors. See for example Echevarria (1997), Kongsamut, Rebelo and Xie (2001) and Ngai and Pissarides (2007). Home production has been studied extensively in a partial equilibrium context and more recently in the context of equilibrium models (see Gronau 1997 for a survey, and Parente, Rogerson and Wright 2000 and Gollin, Parente and Rogerson 2004 for growth-related work).

Table 1: Weekly hours of work

Year	in population 10+	in employment
1900	25.0	54.0
1909	26.0	52.0
1929	23.7	50.7
1960	19.1	41.7
1980	18.8	38.1
2000	20.5	36.7

The numbers shown are for average weekly hours of market work for persons in each population category heading the column. Sources: Ramey and Francis (2006) for hours and population, and US Historical Statistics and the Bureau of Economic Analysis for employment.

ket activities at the disaggregation level of agriculture, manufacturing and services produce goods that are poor substitutes for each other, home production produces mainly goods that are close substitutes for goods produced in the market. The technological explanation of changes in the allocation of hours of work predicts that when two goods are poor substitutes for each other hours of work move in the direction of the good with the lower TFP growth rate and when they are good substitutes for each other they move in the direction of the good with the higher TFP growth rate. We therefore distinguish two forces that interact to produce changes in hours. A structural transformation force, that moves market hours in the direction of services, the sector with the lowest TFP growth rate; and a marketization force that moves hours from the home to the market, on the plausible assumption that for goods that are close substitutes, TFP growth in the market is superior to that in the home.

Combining the structural transformation and marketization forces we find that the home components of agricultural and manufacturing production, such as the cultivation of one's own food and the making of one's own clothes, lose hours fast over time because both forces work against them. They both have high market TFP growth rates that draw hours from the home to the market and concurrently lose hours from both home and market production to services. In contrast, the home component of services, such as cooking and shopping, gain hours because of the structural transformation in favor of total services, but lose them to market production because of marketization. The tension between these two forces drives the dynamics of overall market hours. It explains why home production of agricultural and manufacturing goods disappears quickly and why the home production of services may rise at first but fall later. Crucially for our purposes, it explains why early on in the industrialization process market hours rise, as the home production of agriculture and manufacturing is marketized; then they fall, as the structural transformation in favor of services moves production to the home; and finally rise again, as the home production of services is marketized.

In our benchmark model we make the conventional assumption that non-work time (i.e., all time other than the hours allocated to market or home production) enters the utility function directly, and our utility function is such that in growth equilibrium non-work time is constant. During periods of transition to an aggregate balanced-growth equilibrium changes in non-work time also contribute to changes in aggregate labor supply, but these periods cannot explain the long swings in labor supply that is the topic of this paper. We report calibrations with the steady state of our model which show that substitutions between market sectors and between the market and the home can explain virtually all of the dynamics of sectoral employment shares and a significant part of the dynamics of market hours. In an extension, however, we show how the model can yield a rising leisure time even when the economy is on a balanced growth path. The reason for pursuing this extension is that the substitutions between market and home do not explain the entire evolution in aggregate market hours, and it is plausible that some part of the big fall in hours of market work that has taken place since the beginning of the 20th century, especially for the employed, was matched by rising leisure.

Ramey and Francis (2006) recently compiled US time series data for hours allocated to market production, home production and education since 1900. Consistent with our model predictions, they find a negative correlation between market hours and home hours.[4] With the help of more recent time use surveys, Freeman and Schettkat (2005) also find negative correlations between market hours and home hours for individuals, whereas Robinson and Godbey (1997) and Aguiar and Hurst (2005) find evidence of rising leisure. Our explanation of the recent rise in labor supply is consistent with this set of findings. It is, however, different from the one put forward by Greenwood, Seshadri and Yorukoglu (2005). Greenwood et al. argue that labor supply increased because of substitutions from labor to capital in the home, following a fall in the price of durable goods. In our model the price of durable goods also falls because of higher TFP growth in manufacturing than in services, but the substitution of capital for labor is not the driving force for the decline in home production time. The driving force is the marketization that takes place because similar goods can be produced more efficiently in the market (see also Rogerson, 2004, for a similar argument). Of course, the two explanations are not mutually exclusive. Freeman and Schettkat (2005) provide cross-country examples that support the marketization hypothesis. They show that in the United States people consume more restaurant food and families with children under three take up more formal daycare than in Europe. In these examples the lower home production time in the US is reflected in higher market work time and is due to the marketization of cooked food and child care.[5]

[4]They also find a negative correlation between market hours and education, given that their sample includes very young workers. We do not attempt to say anything about the rise in education in this paper.

[5]A full test of the merits of each hypothesis is beyond the scope of this paper. Two potential tests are (1) a detailed examination of the relation between the introduction of household appliances and the decline of paid domestic help. Were household appliances "engines of liberation" for the housewife or

Section 1 examines some of the history of home production in the United States and discusses what types of goods are produced at home. Section 2 describes in detail our benchmark model, paying particular attention to the marketization and structural transformation forces that shape the dynamics of hours. Section 3 discusses empirical implications and a numerical calibration based on US data on sectoral employment shares and aggregate market hours. Section 4 discusses an extension with a richer leisure model that gives more general results about the dynamic behavior of aggregate labor supply.

1 What goods are produced at home?

Home production is defined as time spent on the production of goods and services, usually at home but sometimes outside, for one's own use. Two important properties of home production that distinguish it from leisure are (a) the individual derives utility from the output of home production but not from the time that she spends on it, and (b) home production can be "marketized", i.e., someone else can be paid to do it and the individual can still derive the same utility from its output. In contrast, leisure cannot be marketized, the individual has to spend the time herself to enjoy it.

It is important for our modelling that we know the relation between the goods produced at home and the goods produced in the market. The recent literature has focused mainly on aggregate models with one market good and one home-produced good, and argued convincingly that the two aggregates are close substitutes for each other.[6] Here we have three market goods, agricultural goods, manufactures and services. How are home-produced goods related to each one of these? The early literature on home production was concerned with these issues, and a lot of useful information can be obtained from it.[7]

Obvious home production activities are cleaning, cooking and child care. In the early stages of economic development people also grew their own crops, kept small farm animals, made clothes and preserved food (Leeds 1917, Reid 1934). The crops grown at home were close substitutes for the output of the agricultural sector, and the clothes and food preservation were substitutes for manufacturing goods. There is overwhelming evidence, however, that in modern industrial societies virtually all home production produces service goods. These activities include shopping, looking after children and

"engines of job destruction" for low skilled domestic labor? (2) A detailed examination of the behavior of wages. In a decentralized economy our model would predict that women leave home production and join market production because female wages are rising. In the Greenwood et al. explanation the increased efficiency of home production releases time, which is now supplied to the market, so the impact should be from the increased supply of female labor to wages.

[6] The most commonly used substitution elasticities between the two are in the range 1.5-2.3. See Rupert, Rogerson and Wright (1995), McGrattan, Rogerson and Wright (1997), and Chang and Schorfheide (2003).

[7] See among others, Leeds (1917), Reid (1934), Vanek (1973) and Lebergott (1993).

other relatives and administration (keeping bank accounts, dealing with bills, etc.).

Contemporary writers argue convincingly that with urbanization home-grown crops and rearing of small animals for food disappeared as home economic activities, even for those who worked on the farms. Of course, it would be unreasonable to argue that farm owners and farm workers do not consume any of their own products. But these products are grown for the market and are not the output of home production. In the statistics on farm employment the time devoted to growing this component of own food consumption is counted as market work, and the most data-consistent way to interpret the consumption of crops by those employed on the farms is as payment in kind.[8]

The home production of manufacturing goods was also overtaken by modern manufacturing technology early on in the industrialization process. Reid (1934 p.45) made the point forcefully: "After 1800 economic conditions changed rapidly. Roads improved steadily. Trade increased. Modern inventions made the most efficient tools too expensive for small-scale household use. Steam power possible only for centralized industries brought about the withdrawal of much manufacturing from the home." Some home manufacturing activities, however, survived into the twentieth century. Leeds (1917) writes that in his sample of 60 families in Pennsylvania, most families reported 2 to 3 hours a week making clothes for their own use. Although this included the work of paid domestic helpers, this was also an activity undertaken by the housewife.[9] But seventeen years later, Reid (1934, p.47) summarized as follows the then-state of household production: "As time went on, one form of production after another, spinning, weaving, ... and other [manufacturing] tasks have wholly or in part been transferred to commercial production. In addition, child care, education, and the care of the sick are now to a large extent carried on by paid workers." In similar vein, Lebergott (1993, p.60) writes about the advent of "consumerism", by quoting a 1932 paper by Viva Belle Boothe, as arguing that "modern industrial processes have robbed the home of almost every vestige of its former economic function." Lebergott continued by noting that the remaining home work "consists largely of services."[10]

[8] See *Historical Statistics of the United States,* Chapter D on labor: "Employed persons comprise: (a) all those who, during the survey week, worked at all as paid employee, in their own business or profession or on their own farm." Reid (1934, p. 48-51) argues that in the United States growing food specifically for own consumption disappeared as early as the 1920s. In the 1930 census of agriculture, the average proportion of total farm produce used by the operator's family was 13.6%. But this was mainly market-grown food. "Home production farms", which means small holdings that the owners used primarily to grow their own food, amounted to a mere 8% of all farms. Reid calls these "self-sufficing farms" and defines them as farms that the owners consumed over 50% of output. In 1929 the average proportion of own consumption on these farms was 66.1%.

[9] The total weekly hours of work in the household by the "housewife and her assistants, whether hired or members of the family" was 101.75 hours. 5.75 hours were spent on making clothes, and the rest were spent on activities classified as services. See Leeds (1917, p.67).

[10] The number of home production hours that Lebergott reports are out of line with the numbers reported by others, most likely because of differences in the treatment of hours worked by paid domestic

Table 2: Weekly hours of home production, American Time Use Survey

Activity	Hours	Activity	Hours
Housework	4.23	Purchasing goods and Services	5.67
Food preparation and clean up	3.64	Caring for household members	3.83
Garden care	1.36	Caring for non-household members	1.96
Household management	0.95	Total	21.64

The numbers shown are for the average weekly number of hours of home work for the population aged 15 and over for 2003 and 2004. Source: Bureau of Labor Statistics, http://www.bls.gov/tus/, Table 1.

As the home production of agricultural and manufacturing substitutes went into decline, the home production of services increased. Mokyr (2000) writes that at the beginning of the 20th century there was an increased demand for cleaner homes and better-prepared food, which required more home-production time. This is consistent with observations made by Leeds (1917, p. 70), who described approvingly the experience of "a bright young woman" in whose household "The hours given to cleaning are few, because her house has all hard-wood floors covered with rugs; dishes are washed only once daily (immediately after breakfast) and not wiped." Clearly, such standards of cleanliness became unacceptable later in the century. The types of tasks done at home also changed over the century. Vanek (1973, p. 111) finds that "there has been a reallocation of the tasks of household work ... a shift from maintenance and production to managerial and interactional tasks." Shopping is another home production service that became increasingly prominent during the 20th century (Lebergott 1993, Robinson and Godbey 1997).

The principal current home-production activities in the United States are shown in Table 2. As expected, these are all activities whose products are classified as services and which have close substitutes in the market services sector. The biggest item is shopping, followed by caring for other people in and out of the household (presumably children and parents or relations living elsewhere). Moreover, although the time devoted to sub-categories changed over time, the broad categories of activities have not changed significantly since the 1930s.

In view of the historical evidence and evidence from modern time-use surveys, a good

assistants. As Ramey and Francis (2006) note, assistants' hours should be part of market hours, because they are paid for, but Lebergott included them in home production time. There is no disagreement, however, about the type of activities performed at home and reported by Lebergott, which is the evidence that we cite here. In our model hours by paid domestic assistants are market hours.

model of the allocation of time has to explain the reasons that home agricultural and manufacturing production have disappeared in modern industrial societies. It also has to explain why service production at home is surviving in such big numbers. We now describe such a model. As anticipated by the early writers, the driver is technology.

2 A growth model with trends in hours

Although our model can easily be written for any arbitrary number of sectors, we simplify the exposition by focusing explicitly on the three main sectors of the economy, agriculture, manufacturing and services. Agriculture and services produce only consumption goods. Manufacturing produces the economy's capital stock and a consumption good. Home production can also produce three consumption goods with differentiated technologies, each of which is a good substitute for each of the consumption goods produced in the market. Capital goods cannot be produced in the home. Time has three uses - it can be used in market production, in home production or in leisure.[11]

We derive the equilibrium as the solution to a social planning problem that maximizes the utility function of a representative agent. Equilibrium is defined as a set of dynamic paths for the allocation of capital and time to the three market sectors, home production and non-work time (leisure), and the allocation of the output of each sector to consumption and capital. The utility function of the infinitely-lived representative agent is

$$U = \int_0^\infty e^{-\rho t} \left[\ln \phi(.) + v\left(1 - l\right) \right] dt \tag{1}$$

where $l \in (0,1)$ are per capita hours of total work (market and home), $v\,(.)$ is the utility of leisure, with $v' > 0, v'' < 0$, and $v' \to \infty$ as $l \to 1$, and $\phi(.)$ is a CES aggregate over final consumption goods, defined by:

$$\phi\,(.) = \left(\sum_{i=a,m,s} \omega_i c_i^{(\varepsilon-1)/\varepsilon} \right)^{\varepsilon/(\varepsilon-1)}. \tag{2}$$

c_i is the per capita consumption of a composite good, one each for agriculture, manufacturing and services, $\varepsilon > 0$ is the elasticity of substitution between these composites, and $\omega_i > 0$, $\sum \omega_i = 1$. The consumption composites are combinations of the output of the market and home sectors for each good, respectively distinguished by a second subscript, $j = m, h$:

$$c_i = \left[\psi_i c_{im}^{(\sigma_i-1)/\sigma_i} + (1-\psi_i) c_{ih}^{(\sigma_i-1)/\sigma_i} \right]^{\sigma_i/(\sigma_i-1)} \qquad i = a, m, s. \tag{3}$$

[11] Thus we ignore the biggest fraction of the week, which is spent on essential physiological activities, mainly sleep, and which shows remarkable stability over time and across countries (about 70 hours). We also ignore schooling.

Here, $\psi_i \in (0,1), c_{ij} \geq 0 \quad \forall i,j$ and $\sigma_i > 0$. The restrictions on the utility function are a combination of sufficient restrictions consistent with steady-state growth when leisure is endogenous and there are many consumption goods, previously derived by King et al. (1988) and Ngai and Pissarides (2007).

A key assumption is

$$A1 : \sigma_i > 1 > \varepsilon \qquad \forall i. \tag{4}$$

It implies that market and home-produced goods are close substitutes for each other but the agricultural, manufacturing and service goods are not close substitutes for each other. Generally, the three composite goods are distinct goods that households want to consume in near-constant proportions, but within each composite goods are only marginally differentiated and larger substitutions take place. We discuss some more evidence supporting $A1$ in section 3.2.

Our measure of total time is the total time available to the population who can work. We let l_{ij} denote the time allocated to each of the six production activities. Total market employment is $\sum_i l_{im} \equiv q$, which, in the absence of unemployment, is also the conventional definition of aggregate labor supply. Market employment shares are then defined by l_{im}/q, for $i = a, m, s$. Facts about the aggregate labor supply are statements about the evolution of q, whereas structural change refers to changes in the market shares l_{im}/q.

Production functions are identical in all activities except for their TFP parameters A_{ij}, which are Hicks-neutral:

$$F^{ij} = A_{ij} F\left(l_{ij} k_{ij}, l_{ij}\right); \quad \dot{A}_{ij}/A_{ij} = \gamma_{ij} \quad i = a, m, s, \quad j = m, h. \tag{5}$$

The production function F has constant returns to scale, positive and diminishing returns to inputs, and satisfies the Inada conditions; k_{ij} is the capital-labor ratio and A_{ij} is TFP in each sector, with growth rate γ_{ij}.

For convenience we split manufacturing into two sub-sectors, one producing consumption goods and the other producing only capital goods, with the same technology. With some abuse of notation we distinguish by subscripts mm the component used in the production of consumption goods only and by mk the component used in the production of capital goods. Because we are assuming constant-returns technologies and free factor mobility, this is equivalent to assuming one manufacturing sector whose output can be either consumed or invested:

$$\begin{aligned}
c_{im} &= A_{im} l_{im} f(k_{im}) \qquad i = a, m, s, && (6)\\
c_{ih} &= A_{ih} l_{ih} f\left(k_{ih}\right) \qquad i = a, m, s, && (7)\\
\dot{K} &= A_{mm} l_{mk} f\left(k_{mk}\right) - (\delta + \nu) K, && (8)\\
\sum l_{ij} &= l, \quad i = a, m, s, \quad j = m, h, k, && (9)\\
\sum l_{ij} k_{ij} &= lk, \quad i = a, m, s, \quad j = m, h, k; && (10)
\end{aligned}$$

where in general $f(k) \equiv F(k,1)$, δ is the capital depreciation rate, ν is the population growth rate, k is the ratio of the capital stock to hours of "total work" (the sum of market and home hours) and K is the ratio of the aggregate capital stock to the population (so $k = K/l$).

We obtain optimal allocations by maximizing the utility function in (1) subject to (5)-(10). The maximization can be described over three layers. At the highest level, the agent chooses a path for aggregate consumption (essentially for our composite ϕ), hours of total work and the aggregate capital stock. Next, the aggregate capital stock and total work are allocated to the production of the three consumption composites c_i $(i = a, m, s)$ and the capital stock. And finally, the allocation to each c_i is divided between market and home production. The conditions giving the allocations in the last two layers are "static". We start with the lowest level, the division of the allocation to each c_i between home and market, and move to the highest.

2.1 Optimal allocations between market and home: marketization

Suppose that the agent has allocated labor l_i and capital per hour k_i to the production of consumption composite c_i. What is the optimal allocation of these between home and market production? To find the answer we maximize (3) separately for each i subject to the production functions in (6) and (7) and:

$$
\begin{aligned}
l_i &\geq l_{ih} + l_{im}, &(11)\\
l_i k_i &\geq l_{ih}k_{ih} + l_{im}k_{im}. &(12)
\end{aligned}
$$

Optimal allocations satisfy the first-order conditions

$$
\begin{aligned}
\frac{\psi_i}{1-\psi_i}\left(\frac{c_{im}}{c_{ih}}\right)^{-1/\sigma_i} &= \frac{A_{ih}}{A_{im}}, &(13)\\
k_{im} &= k_{ih}. &(14)
\end{aligned}
$$

Free capital and labor mobility imply that production efficiency is achieved at all times with equal capital-labor ratios in the home and the market. We can therefore drop the second subscript and write k_i for the common capital-labor ratio in sector i (in manufacturing it will also be optimal to have the same capital-labor ratio in the production of capital goods, as we show below). Making use of the production functions and (13)-(14) we obtain:

$$
\frac{l_{ih}}{l_{im}} = \left(\frac{1-\psi_i}{\psi_i}\right)^{\sigma_i}\left(\frac{A_{im}}{A_{ih}}\right)^{1-\sigma_i}. \qquad (15)
$$

Equation (15) contains the important "marketization" result of this paper: Because the relative TFP levels are changing over time, the employment shares in market and home production are also changing. By differentiation with respect to time we obtain:

$$\frac{\dot{l}_{im}}{l_{im}} - \frac{\dot{l}_{ih}}{l_{ih}} = (\sigma_i - 1)(\gamma_{im} - \gamma_{ih}). \tag{16}$$

With $\sigma_i > 1$, and if TFP in the market sector is rising faster than in the home sector, the home sector is losing labor to the market sector. It implies that if the TFP growth rate of the market sector remains above the TFP growth rate of the home sector for a sufficiently long time, eventually the home sector will vanish and all consumption goods will be produced in the market.

From (15) we obtain the share of home production in the production of composite good i :

$$\frac{l_{ih}}{l_i} = \frac{\left(\frac{1-\psi_i}{\psi_i}\right)^{\sigma_i} \left(\frac{A_{ih}}{A_{im}}\right)^{\sigma_i - 1}}{1 + \left(\frac{1-\psi_i}{\psi_i}\right)^{\sigma_i} \left(\frac{A_{ih}}{A_{im}}\right)^{\sigma_i - 1}}. \tag{17}$$

We give it here for future reference.

2.2 Optimal sectoral allocations: structural transformation

We now consider optimal allocations at the level of the composite sector. The analysis of the preceding section enables us to implement a convenient aggregation. Making use of (13) and (3), we derive the optimal relation between the consumption composite c_i and the part of it produced in the market:

$$c_i = z_i^{\sigma_i} c_{im} \tag{18}$$

$$z_i \equiv \psi_i^{1/(\sigma_i - 1)} \left[1 + \left(\frac{1-\psi_i}{\psi_i}\right)^{\sigma_i} \left(\frac{A_{ih}}{A_{im}}\right)^{\sigma_i - 1} \right]^{1/(\sigma_i - 1)}. \tag{19}$$

We note that z_i depends only on parameters and it is a function of time because of its dependence on the ratio of home to market TFP. Similarly, from (15) we can write the aggregate l_i allocated to sector i in terms of the market allocation:

$$l_i = l_{im} + l_{ih} = \psi_i^{-1} z_i^{\sigma_i - 1} l_{im}. \tag{20}$$

Therefore, we can aggregate the production functions in (6) and (7) into one for the composite c_i :

$$c_i = \psi_i z_i A_{im} l_i f(k_i) \qquad i = a, m, s. \tag{21}$$

Maximization at the level of the sector takes place by maximizing $\phi(.)$ in (2) for given l and k, with controls c_i, l_i, k_i, l_{mk} and k_{mk}. The constraints are (21) and as before, (8)-(10), noting that $l_{im} + l_{ih} = l_i$ and $k_{im} = k_{ih}$.

Maximization with respect to the factor inputs yields

$$k_{mk} = k_i = k \qquad i = a, m, s, \tag{22}$$

so capital-labor ratios are common in all production activities. Maximization over the consumption allocations yields,

$$\frac{\phi_i}{\phi_j} = \frac{\psi_j z_j A_{jm}}{\psi_i z_i A_{im}} \quad i, j = a, s, m, \tag{23}$$

where the notation is in general $\phi_i \equiv \partial\phi/\partial c_i$. Given the definition of ϕ in (2), we can write (23) as

$$\frac{c_i}{c_j} = \left(\frac{\omega_i \psi_i z_i A_{im}}{\omega_j \psi_j z_j A_{jm}}\right)^{\varepsilon}, \tag{24}$$

and from this equation and (21) we get:

$$\frac{l_i}{l_j} = \left(\frac{\omega_i}{\omega_j}\right)^{\varepsilon} \left(\frac{\psi_j z_j A_{jm}}{\psi_i z_i A_{im}}\right)^{1-\varepsilon}. \tag{25}$$

This equation is the basis of the structural transformation force in our model. Traditionally, structural transformation is discussed in the context of market hours of work only. For market hours the equation is derived from (25) by making use of (17):

$$\frac{l_{im}}{l_{jm}} = \left(\frac{\omega_i \psi_i}{\omega_j \psi_j}\right)^{\varepsilon} \frac{z_j^{\sigma_j - \varepsilon}}{z_i^{\sigma_i - \varepsilon}} \left(\frac{A_{jm}}{A_{im}}\right)^{1-\varepsilon}. \tag{26}$$

We note that if there is no home production of goods i and j, i.e., if $\psi_i = \psi_j = 1$, then $z_i = z_j = 1$, equations (25) and (26) become identical and structural transformation yields:

$$\frac{\dot{l}_i}{l_i} - \frac{\dot{l}_j}{l_j} = (1-\varepsilon)(\gamma_{jm} - \gamma_{im}). \tag{27}$$

For $\varepsilon < 1$, sectors with fast TFP growth are losing labor to sectors with low TFP growth.

When there is home production the dynamics of z_i also matter in sectoral allocations. By differentiation of the expression for z_i in (19) we obtain:

$$\frac{\dot{z}_i}{z_i} = (\gamma_{ih} - \gamma_{im}) \frac{\left(\frac{1-\psi_i}{\psi_i}\right)^{\sigma_i} \left(\frac{A_{ih}}{A_{im}}\right)^{\sigma_i - 1}}{1 + \left(\frac{1-\psi_i}{\psi_i}\right)^{\sigma_i} \left(\frac{A_{ih}}{A_{im}}\right)^{\sigma_i - 1}} \tag{28}$$

$$= (\gamma_{ih} - \gamma_{im}) \frac{l_{ih}}{l_i}, \tag{29}$$

where use has been made of (17). Bringing now results together, by differentiating (25) with respect to time and making use of (29), we obtain:

$$\frac{\dot{l}_i}{l_i} - \frac{\dot{l}_j}{l_j} = (1-\varepsilon)\left(\gamma_j - \gamma_i\right) \qquad i,j = a,m,s. \tag{30}$$

$$\gamma_j \equiv \left(1 - \frac{l_{jh}}{l_j}\right)\gamma_{jm} + \frac{l_{jh}}{l_j}\gamma_{jh}. \tag{31}$$

A comparison with (27) shows that when there is a home sector the TFP growth rates of the market sectors are replaced by the weighted average of the TFP growth rates of the market and home sectors. It is clear from the definition of γ_j that we need some quantitative restrictions on TFP growth rates to sign the direction of labor movement. We return to this question in section 3.

We now solve for the sectoral distribution of employment and capital for given aggregate l and k. From (22), capital is distributed such that capital-labor ratios are equal in all sectors. But given $k_{mk} = k$, employment in the capital-producing sector is immediately obtained by inverting the production function, since the output of the sector is given by the assumption, made so far, that the path of the aggregate capital stock is given. Therefore, the distribution of employment in the consumption-producing sectors satisfies equations (25) for a given total allocation of time $l - l_{mk}$. The solution for each sector's employment follows immediately:

$$\frac{l_i}{l - l_{mk}} = \frac{\omega_i^{\varepsilon}\left(\psi_i z_i A_{im}\right)^{-1+\varepsilon}}{\sum_j \omega_j^{\varepsilon}\left(\psi_j z_j A_{jm}\right)^{-1+\varepsilon}} \tag{32}$$

With knowledge of l_i the hours of work in market and home production are obtained from (20), completing the description of equilibrium at this level.

2.3 Aggregate growth

Aggregate equilibrium is obtained by defining per capita aggregate consumption of all goods in terms of the manufacturing market price. The objective is to aggregate up from the composite goods such that the utility function (1) and dynamic constraint (8) become functions of aggregate consumption, the aggregate capital stock and non-work time.

We first obtain the aggregate utility function. Because of the competitive allocations that we have assumed, the price of consumption composite i in terms of the manufacturing market price is equal to the marginal rate of substitution ϕ_i/ϕ_{mm}. We define aggregate per capita consumption as follows:

$$c \equiv \sum_{i=a,m,s}\left(\frac{\phi_i}{\phi_m}\right)\left(\frac{\phi_m}{\phi_{mm}}\right)c_i. \tag{33}$$

The first marginal rate of substitution is obtained from (23) and the second by differentiation of (2) and (3) and use of (18). The relative price of composite i to the manufacturing market price that we obtain is $A_{mm}/(\psi_i z_i A_{im})$. From (21) we then derive:

$$c = A_{mm} f(k)(l - l_{mk}). \tag{34}$$

From (21) again and (32) we obtain

$$\frac{c_i}{c} = \frac{(\omega_i \psi_i z_i A_{im})^{\varepsilon}}{A_{mm} \sum_{\forall j} \omega_j^{\varepsilon} \left(\psi_j z_j A_{jm}\right)^{\varepsilon - 1}}. \tag{35}$$

We use (35) to substitute all c_i out of ϕ. Because ϕ is homogeneous of degree 1 we can write $\phi = c\tilde{\phi}(.)$, where $\tilde{\phi}(.)$ is a function of parameters (albeit changing over time).

The aggregate constraints are (34), the definition $k = K/l$, and (8). We substitute (34) into (8) to obtain the single constraint that describes the evolution of the aggregate state variable:

$$\dot{K} = A_{mm} l f\left(K/l\right) - c - (\delta + \nu) K. \tag{36}$$

We also define the new maximand, derived from (1) and $\phi(.) = c\tilde{\phi}(.)$,

$$\tilde{U} = \int_0^{\infty} e^{-\rho t} \left[\ln c + v\left(1 - l\right)\right] dt. \tag{37}$$

Aggregate equilibrium is defined as the paths of c, l and K that maximize (37) subject to (36).

Inspection of the maximization problem shows that it has the structure of the maximization problem of the one-sector Ramsey economy, except for one difference: technological growth in the Ramsey economy needs to be labor-augmenting but here it is Hicks-neutral. We therefore assume that the production function is Cobb-Douglas, which make the two equivalent: $f(k) = k^{\alpha}$. Under this assumption there are unique convergent paths for c, l and K and a balanced-growth equilibrium with l constant and c and K growing at the rate of labor-augmenting productivity growth in manufacturing, $\gamma_{mm}/(1 - \alpha)$. Once the equilibrium paths for the aggregates are known, the rest of the model is solved by working backwards through our derivations: the evolution of the consumption composites is given by (35) and their breakdown between home and market consumption by (18). The capital-labor ratio in all production activities is given by $k = K/l$ and the evolution of hours of work used in the production of capital goods by (8). With knowledge of l and l_{mk}, (32) gives employment in the production of each composite good i and (17) gives its breakdown between home and market, completing the description of equilibrium.

3 Empirical implications and other properties

3.1 Qualitative properties and aggregate facts

It is straightforward to show with standard techniques that the stationary equilibrium of the aggregate maximization problem is saddlepath-stable. In a diagram with hours of work on the vertical axis and capital per efficiency unit on the horizontal axis the saddlepath is downward-sloping, which implies that starting with low capital, in the adjustment to equilibrium hours of work are falling. But given our interest in long-run trends, we focus at the properties of steady-state equilibrium. The model satisfies:

Property 1 (steady state). *On the steady state the following aggregates are constant: the capital-output ratio, the consumption-output ratio, total hours of work and hours of work in the capital-producing sector. The following can change, depending on parameter values: total hours of market work, total hours of home work, the employment and output shares of each consumption-producing sector, and relative prices.*

That the total hours of market and home work can change follows immediately from the fact that each consumption sector's hours share can change, because total market hours are $q \equiv \sum_i l_{im} + l_{mk}$ and total home hours $\sum_i l_{ih} = l - q$. Each sector's hours share can change by (17) and (32), which are consistent with the Cobb-Douglas restrictions imposed on production functions to derive the steady state. Relative prices change because they are inversely proportional to relative TFP levels.

When deriving the steady state we showed that total hours of work, l, and the capital-labor ratio in all sectors, k, are constant. In order to show that the "Kaldor facts" of constant capital-output ratio and consumption-output ratio also hold, we define aggregate per capita output, y, analogously to aggregate per capita consumption, in terms of the manufacturing market price:

$$y = c + A_{mm} l_{mk} k^{\alpha} = A_{mm} l k^{\alpha}. \tag{38}$$

Since in this expression $A_{mm}k^{\alpha-1}$ is constant in the steady state, l_{mk} must also be constant and y, c and k must grow at the same rate, as claimed in Property 1.

If we restrict attention to the market sector, we find that the capital-output ratio is also constant and output per hour is growing at constant rate. The aggregate capital stock in the market sector is given by

$$K_{market} = \textstyle\sum_i (l_{im} + l_{mk}) k = qk, \tag{39}$$

and so the market capital-labor ratio, K_{market}/q, is simply k. Market output is

$$y_{market} = \textstyle\sum_i \left(\dfrac{\phi_{im}}{\phi_{mm}} \right) A_{im} k^{\alpha} l_{im} + A_{mm} k^{\alpha} l_{mk} = q A_{mm} k^{\alpha} \tag{40}$$

and so market output per hour, y_{market}/q is growing at the same constant rate as the other aggregates. The capital-output ratio in the market economy is constant. This confirms our claim that our economy satisfies Kaldor's stylized facts of aggregate balanced growth, despite the changes in hours of work.

We now derive some important qualitative properties of the allocation of total hours of work by making the following assumptions on productivity growth rates:

$$\begin{aligned} A2m &: \gamma_{am} \geq \gamma_{mm} > \gamma_{sm} \\ A2h &: \gamma_{im} \geq \gamma_{ih} \qquad \forall i. \end{aligned}$$

$A2m$ is consistent with the observed fact that the price of services is rising faster, and the price of agricultural goods is rising less fast, than the price of manufacturing goods. It is also consistent with the direct estimates of Jorgensen and Gallop (1992) for the period 1947-85 and Jorgensen and Stiroh (2000) for 1959-1995. $A2h$ is more difficult to justify with hard empirical evidence, but it can be justified on the grounds that the market can replicate a home technology but not vice versa. Anecdotal evidence in its favor abounds, as for example the statements by Reid (1934) and others cited in section 1 for manufacturing.

Property 2 (sector share dynamics). *Under $A1$ and $A2h$, home production is marketized monotonically in all sectors. If, in addition, $A2m$ holds, the market hours share of services is rising monotonically over time and the home production hours of agriculture is falling monotonically over time. All other sector shares should eventually decline except for market services, so as $t \to \infty$ the market production of services is the only consumption sector that survives.*

That assumptions $A1$ and $A2h$ have the marketization implication follows immediately from (16). Equation (16) also shows that the marketization force is stronger the closer substitutes home-produced goods are to market-produced goods, and the bigger the difference between their TFP growth rates. Assumption $A2m$ implies that the agricultural composite good is always losing hours and the services composite always gaining hours, which, when combined with the marketization forces gives the other results summarized in Property 2. For market hours in agriculture and manufacturing, however, the marketization and structural transformation forces work in opposite directions. Whether the net impact on each sector is positive or negative depends largely on the size of the sectors with higher TFP growth and their own size. So early on, when agriculture is large, all sectors that receive labor from agriculture are likely to grow, implying a hump shape employment share for manufacturing (see Ngai and Pissarides, 2007, for more on this point)

Property 3 (market hours of work). *During economic growth total market hours may rise or fall but eventually they rise. Under assumptions $A1$ and $A2$ they initially rise when the share of the home economy is large enough, they subsequently fall when the share of agricultural employment is large enough, and eventually rise when the share of services becomes large enough.*

Total market hours in the steady state of our model fall when production is transferred to the home and rise when home production is marketized. In the very early stages of industrialization production is transferred from a home economy to the market, implying a large marketization force in favor of both industry and agriculture. The evidence that we examined in section 1 indicated that the home production of agricultural goods virtually disappeared by 1930. Similarly, the evidence on the home production of manufactured goods is that by 1930 it was overtaken by market production because of technological improvements in the market. But time use surveys show substantial home production of services. Why did agricultural and manufacturing home production vanish so fast and yet service home production is surviving in such big numbers?

The reason is found in the way that the marketization and structural transformation forces combine to cause sector employment dynamics. Looking at agriculture, we argued that it has the highest TFP growth rate, so the sector overall is losing hours at fast rate. Moreover, the output of home production and market production are very close substitutes, and TFP in the market, because of economies of scale in land use, is likely to be growing much faster than the TFP of food production at home. So in agriculture both the marketization and the structural transformation forces are strong and both work against home production, which as a result disappears fast.

Similarly in manufacturing, the output of the home sector is a close substitute to the output of home production (e.g., home-made versus ready-made clothes), and technology in the market has risen much faster than in the home after the industrial revolution. For both these reasons, the marketization force in manufacturing is strong. But manufacturing as a whole gains labor from agriculture, so at least when there is a substantial agricultural sector, the structural transformation force is not strongly against manufacturing home production. In the early stages of industrialization there is a tension between the two forces in the home production of manufacturing goods, the transformation out of agriculture pushing for a rise in both market and home hours and technological improvements in the market pushing for a rise in market hours and a fall in home hours. Eventually, however, as the share of agricultural employment shrinks, manufacturing as a whole loses labor to services. So although we may not see the home production of manufacturing goods fall rapidly at first, it should be marketized fast during the industrialization process.

In contrast to agriculture and manufacturing, market-produced services are not as close a substitute for home-produced services. Whereas the outputs of agriculture and manufacturing are "standardized," service output is more diverse. For example, child care, looking after needy relatives and shopping for one's own clothes are not standardized activities that have very close substitutes provided by the market. Equally importantly, because TFP growth in the production of market services is low, the marketization force for home services is weak. Opposing this weak force against home hours, there is a strong structural transformation force increasing hours of total work spent on services. The net effect on home-produced services is ambiguous, but if it is positive, it is so when agriculture or manufacturing are shedding a lot of labor, which makes the structural transformation force stronger. Eventually, when the structural transformation force weakens through the diminishing importance of agriculture and manufacturing, the marketization force takes over, leading to a shrinkage in the home sector. So in contrast to home-produced food and manufacturing goods, we should observe a non-monotonic, hump-shaped path for hours of work spent on home-produced services. Moreover, the marketization of home services is weak, and so the fall in home hours in the later stages of economic growth is slow, because of both a small substitution elasticity and small productivity-growth differentials between market and home. Sub-sectors within services that have either no close substitutes in the market or have practically zero TFP growth in both the market and the home, such as aspects of child care, may never marketize completely.

Figure 1 shows the trends in market hours of work and in the market employment shares of the three industrial sectors.[12] Our model's predictions are consistent with the broad trends that we see in the figure. The evolution of the sectoral shares is consistent with the assumptions of low substitutability between their final products and the ranking of their TFP growth rates. Manufacturing employment does not fall as rapidly as agricultural employment because it produces capital goods that are needed by the expanding (market and home) service sector. More interestingly, our model's predictions are consistent with what we see in total market hours. According to our model, in the early part of the twentieth century the home production of agriculture and manufacturing should be losing hours fast but the home production of services should be gaining them. The net impact on overall market hours is small and ambiguous. In the middle years, which cover the middle two quarters of the century, the home production of agricultural and manufacturing had practically disappeared, but the structural transformation force out of agriculture was still strong because of the relative size of this sector. The prediction of our model is that the structural transformation force should dominate the marketization of services, and so the hours allocated to the home production of services should be rising and total hours of work falling. This is consistent with that historical evidence of Mokyr (2000) and others, and with the trends in the figure. But eventually the structural transformation force weakens because of the shrinkage of agricultural employment, and the marketization of services takes over. The impact on overall market work should be a rise in hours, especially by women, who performed the home tasks before marketization.

[12]The series shown for total hours are due to Ramey and Francis (2006) and include unpaid family workers, the self-employed, government employment and commuting time (which is a constant 10 percent of the sum of the previous three). We are grateful to Valerie Ramey for sending us these data. We divided the total hours of market work by the population over age 10, because in the early years many children aged 10 and above worked in the market. However, our results are not affected by the choice of denominator.

3.2 Quantitative implications

Having established that under restrictions $R1$, $R2m$ and $R2h$ the broad trends in the data are qualitatively consistent with the model's predictions, we investigate here more closely its quantitative implications. We compare our model's predictions with the US time series under the assumption that the economy is on the steady state that solves the maximization of (37) subject to (36). This restriction implies that we focus here on substitutions between market and home production for trends in overall market hours and on substitutions between all three goods for the sectoral allocations. How much of the evolutions in the data can these substitutions explain?

In order to answer this question the model requires, (1) an initial allocation of hours to the six production technologies; (2) four elasticities of substitution, ε and σ_i for $i = a, m, s$; (3) five TFP growth differences, $\gamma_{am} - \gamma_{mm}$, $\gamma_{mm} - \gamma_{sm}$ and $\gamma_{im} - \gamma_{ih}$ for $i = a, m, s$; and (4) the steady-state investment rate, η, which gives the employment share of capital production. As we explain below, there are only some recent estimates of the elasticity of substitution between all home goods and all market goods and price data for services (from which we get a time series of TFP growth rates) are available only since 1929. Given the early marketization of manufacturing and agricultural home production, we therefore do not have estimates of the elasticity of substitution between home and market goods for agriculture and manufacturing goods, and we also do not have TFP estimates for services before 1929. However, we argued that historical evidence shows that the home production of agricultural and manufacturing goods virtually disappeared by the late 1920s. In view of this fact and the data limitations we start our calibration in 1930 and assume that all home production is of service goods.

Initial allocations. The annual series for market shares and total market hours that we use to extract initial distributions are shown in figure 1. We obtained the initial allocation to home production from the data provided by Ramey and Francis (2006).[13]

Elasticities of substitution. Estimates in the literature are for the elasticity of substitution between all market goods and home production and are in the range 1.5 to 2.3 (see Rupert, Rogerson and Wright 1995, McGrattan, Rogerson and Wright 1997 and Chang and Schorfheide 2003). In our model σ_s is the elasticity of substitution between home goods and a smaller set of goods than estimated, so our σ_s should be at least as large as the existing estimates. We choose the biggest of these estimates, $\sigma_s = 2.3$.

For the elasticity of substitution ε we do not have direct estimates. It is clear from (24) that in a model without home production, and because relative prices are inversely related to relative TFP levels, the own price elasticity of the three goods is $-\varepsilon$. It is also clear from (25) that in this case the slope of the regression line between changes in relative employment levels and changes in relative prices should be $1 - \varepsilon$. But with home

[13] Because home hours in the early period may not be accurately measured, we also experimented with initial values that are ± 20 per cent of the Ramey-Francis data, with virtually no impact on our predictions (the impact was too small to show on the graph below).

production, and because at least some market-produced services have good substitutes in home-produced services, the estimated price elasticity should be higher than $-\varepsilon$ in absolute value. Falvey and Gemmell (1996) estimate the price elasticity of the entire service sector and they find it to be -0.3. They compare their estimate to one by Summers (1985), which is -0.06 and not significantly different from zero. Blundell, Pashardes and Weber (1993) report a "services" price elasticity for Britain of -0.7. However, they do not give a list of what services are included and since the budget share of their services is only 0.12, it must be a very small list. Their estimate is comparable to the estimates obtained by Falvey and Gemmell (1996) for each of their seven sub-sectors, whose budget shares are on average of the same order of magnitude as the Blundell et al. (1993) sector. In a model with home production, the estimate $\varepsilon = 0.3$ seems to be an upper bound for the elasticity of substitution, with 0 as lower bound.

With regard to the relation between employment and price changes, we regressed relative employment changes and relative price changes for thirteen 2-digit consumption-goods sectors drawn from the OECD STAN database and input-output tables for 1977-2001, and obtained an average estimate $1 - \varepsilon = 0.7$.[14] Given the broader aggregation in this paper, the estimate $\varepsilon = 0.3$ again emerges as an upper bound for the elasticity. Following these findings, we selected $\varepsilon = 0.1$ as a good guess for the benchmark elasticity of substitution between our three sectors.

TFP growth rates. We use the link between relative prices and TFP levels to derive the differences in TFP growth rates. They are set to match the changes in the prices of agriculture and service goods relative to manufacturing goods. We first compute annual growth rates for each year, then take the average for the entire period. This average is 0.93 per cent for the price ratio of services to manufacturing and -1.2 for the price ratio of agriculture to manufacturing.[15]

We cannot adopt the same methodology to calibrate $\gamma_{sm} - \gamma_{sh}$, as there are no estimates on the implicit price of home goods. We set as benchmark zero growth rates in home TFP, although negative TFP growth in the home sector is consistent with our model and with rising labor productivity, because the accumulation of consumer durables could offset it.[16] We reason as follows to get the TFP growth differentials.

[14] These results are available in the longer version of Ngai-Pissarides (2004) that circulated as CEPR discussion paper no. 4763 and on our personal web sites.

[15] Source for 1929-1970: *Historical Statistics of the United States: Colonial Times to 1970, Parts 1 and 2.* The implicit price deflator for services is in series E17, and the wholesale price index for industrial commodities and farm products are in series E24-25. For 1970-2000, see *Economic Report of the President*, Tables B-62 and B-67. The measurement of both prices and TFP, especially in the earlier period, is fraught with difficulties, so we use the same TFP differences for the whole period, rather than looking at different sub-periods, even though our balanced growth path allows γ_{sm} and γ_{am} to change over time.

[16] The capital-labor ratio in home production is k, the same as in the market, and so it grows at positive rate $\gamma_{mm}/(1-\alpha)$. "Real" labor productivity in home production is $A_{sh}k^{\alpha}$, which grows at rate $\alpha\gamma_{mm}/(1-\alpha) + \gamma_{sh}$, so a negative γ_{sh} is consistent with positive rate of growth of real labor

Table 3: Baseline Parameters, United States, 1930-2004

η	σ_s	ε	$\gamma_{mm}-\gamma_{ma}$	$\gamma_{mm}-\gamma_{sm}$	$\gamma_{sm}-\gamma_{sh}$
0.104	2.3	0.1	-0.012	0.0093	0.004

Given the observed rate of growth of aggregate labor productivity of 2 per cent and a capital share of 1/3, a plausible estimate of manufacturing TFP growth is $\gamma_{mm} = 1.33$ per cent. If we subtract from γ_{mm} our computed difference between manufacturing and services, 0.0093, we find $\gamma_{sm} = 0.004$. Thus, $\gamma_{sm}-\gamma_{sh} = 0.004$ is the maximum difference consistent with non-negative TFP growth rates for home production. These numbers are consistent with the direct estimates of Jorgenson and Gallop (1992), who calculate an average TFP growth rate for the period 1947-85 of 2.06 per cent for agriculture and 0.82 per cent for the private non-farm sector.[17] Within their non-farm sectors, TFP growth rates vary but the TFP growth rates for industrial sectors are in general higher than the ones for service sectors.

Investment rate. Finally, the steady-state investment rate is $\eta = \eta_m/\left(1 + l_{sh}/q\right)$, where η_m is the investment (or saving) as a fraction of market production, which we get from Maddison (1992), and l_{sh} is the total number of hours in home production for this period. To minimize the impact of the Great Depression on our estimate of the average savings rate, we use the average of 1925-30 as an estimate for 1930, so $\eta_{m0} = 0.189$. To compute η we also need the initial home-to-market hour (l_{sh0}/q_0). We obtain this ratio from the home and market hours data of Ramey and Francis (2006). To be consistent, we also use the average of 1925-30 as an estimate for 1930, to obtain $l_{sh0}/q_0 = 0.812$. Therefore, $\eta = 0.104$. The calibrated benchmark values are shown in Table 3.

Results. The results are shown in figure 2. The model tracks the dynamics of employment shares remarkably well, given the parsimonious nature of the model. Each dynamic path is essentially driven by the product of two parameters, the elasticity of substitution and the sector's TFP growth differential. The model picks up the fast rise of service employment and the fall in agricultural employment, with smaller changes in manufacturing. In 2000, the employment shares for agriculture, manufacturing and services were $0.02, 0.25$ and 0.73 respectively. The model predicts $0.06, 0.29$ and 0.65: given the initial distribution of $0.21, 0.36$ and 0.43, there is a lot of predictive power in

productivity. Of course, as in the other sectors, the value of average product in the home sector (with manufacturing as numeraire) grows at rate γ_{mm} and the implicit price of home-produced goods rises at rate $\gamma_{mm} - \gamma_{sh}$.

[17] The numbers are obtained from adding the productivity growth rates due to input quality adjustment from their Table 4 to the TFP growth rates in their Table 1, 1.58 for agriculture and 0.44 for the non-farm sector.

the model.

With respect to total market hours, the combination of the structural transformation and marketization forces generates a shallow U-shape path. Not surprisingly, the model does not track the changes in hours in the Great Depression and the war, but as in the data it predicts a downward trend up to the mid 1970s and a rise in the last quarter century. As we pointed out, predicting a turning point as part of the same dynamic process that predicts the structural transformation is unique to our model. Moreover, the matching of the turning point to the data is remarkably good, considering the small number of parameters that drive the aggregate dynamics and the fact that we matched only the initial distribution of market and home hours. It is clear from the figure, however, that a full explanation for the deep fall in hours after the war requires additional explanations. We explore one explanation in the next section.

Raising σ_s in these computations increases marketization, so it reduces the fall in market hours and increases the subsequent rise. More interestingly, given the uncertainty attached to the TFP calculations, we calculated results also for a higher manufacturing TFP growth rate. We chose manufacturing because market prices for manufactures may not reflect accurately the improvement in quality. This change implies a faster decline in the share of manufacturing and a faster rise in the share of services, moving the model sectorial predictions closer to the data. The impact on the dynamics of overall hours is small, although the prediction moves it in the direction of the data, implying a slightly bigger fall in hours after the war for reasonable parameters.

4 More on the economics of leisure

We have treated non-work time so far as in conventional growth and real business cycle models, as leisure time that yields utility directly, without the help of any goods. But a large amount of leisure in time use surveys is enjoyed with the use of some capital or intermediate goods, such as watching TV, surfing the net or talking on the telephone. We generalize our benchmark model by introducing a leisure good c_l that is produced mostly at home using time and capital goods.[18] One important outcome of this extension is that now changes in leisure time can also cause changes in labor supply, even if the economy is on a balanced growth path.

[18]In time use surveys by far the dominant good of the kind that we have in mind is watching TV. See below in this section for some data. Greenwood and Vandenbroucke (2005) also put forward the idea that the dynamics of leisure time are influenced by the complementarities between durables and time. Their approach, however, is different from ours. They claim that leisure has increased because the quality and variety of durables which are complementary to leisure time, has gone up. Our claim runs along the lines of our previous discussion, people consume more time watching TV and doing other similar things because technological progress elsewhere has increased their consumption of other goods and other goods are poor substitutes for TV watching time.

We assume that leisure is of two types, one as in the benchmark model and one that is the output of a "production" process that uses capital and labor through a production function that is identical to the one for other goods. We use subscript l for leisure-goods production and let A_l denote its TFP level. We assume that the leisure good (say TV viewing services) is a better substitute for service goods than it is for agricultural and manufacturing goods. But it is not as good a substitute for market services as home production is. This is the main feature that differentiates home production from leisure production. Home production such as cooked food has market-produced close substitutes but leisure production such as TV viewing does not have close substitutes in the market; if an individual hires somebody to do her TV viewing for her the end product will not be a close substitute to watching the TV herself. Yet both cooked food and TV viewing are produced at home with some durable good purchased from the manufacturing sector.

Formally, we assume that the services aggregate now consists of three goods, market services and home production as before, combined into c_s as in the benchmark model, and leisure goods, which are combined with c_s into a grand service good, c_S. We want the elasticity of substitution between c_s and c_l to be bigger than the one between service goods and manufacturing goods (our ε) but smaller than the elasticity of substitution between market and home produced services (our σ_s). We choose it to be 1, which gives a particularly simple and appealing result on the dynamics of leisure time. But the model also has a solution if the elasticity is bigger or smaller than one.

The utility of goods now is,

$$\phi(.) = \left(\sum \omega_j c_j^{(\varepsilon-1)/\varepsilon}\right)^{\varepsilon/(\varepsilon-1)} \quad j = a, m, S; \quad c_S = c_s^{1-\xi} c_l^{\xi}, \tag{41}$$

with c_s defined as before, as a CES between c_{sm} and c_{sh} with elasticity σ_s. This specification reduces to the benchmark model when $\xi \to 0$. The marketization conditions (15) still hold between the market and home production of service goods. By direct extension a similar condition holds between the service composite c_s and leisure production c_l :

$$\frac{l_l}{l_s} = \frac{\xi}{1-\xi}. \tag{42}$$

This is an important result that is due to our unit elasticity assumption for c_s and c_l : the ratio of leisure-production time to service-production time is a constant. The size of the constant depends on the parameter ξ. It should be obvious and it is straightforward to show that all the other results of the benchmark model still hold, with the composite c_S replacing c_s. The composite c_S now has two "marketization" forces beneath it, the one between market production and home production which holds as before, and the one between leisure and the other two service sectors, given by (42). The aggregates (consumption, income and capital stock) are still defined as before and a balanced growth path with constant capital-output ratio exists. The new element is that on this steady state total leisure is now defined as $(1 - l) + l_l$, and it is not constant because of the dynamics of l_l.

As in the benchmark model and for as long as TFP growth in agriculture and manufacturing exceed TFP growth in the service sectors, service employment is monotonically increasing over time. With l_s increasing over time, we get from (42) that l_l is also monotonically increasing over time. Thus, total leisure time, $1 - l + l_l$, is increasing over time, with l constant on the balanced growth path and l_l rising. We address two questions about this dynamic. First, how big is the share of leisure in time use surveys now and how big is it in the asymptotic state? This will give an idea of the dynamics involved. Second, what happens to overall labor supply when there is leisure production?

The answer to the first question depends mainly on the preference parameter ξ. This is because both the current and asymptotic l_l are a constant fraction $\xi/(1 - \xi)$ of service employment. In the American Time Use Surveys (ATUS) of 2003 and 2004 there is a fairly detailed breakdown of the activities in which people engage in their leisure time. We include under our leisure production TV watching, sports participation and telephone, mail and email and we find that individuals over the age of 15 spend about 21 hours a week in these activities. Total leisure time is about 39 hours and total work time (market and home) 50 hours.[19] Making use of the data on home and market production from the same surveys we get an approximate value of $\xi = 1/3$. In the asymptotic steady state our model prediction (on the assumption that the time devoted to the other activities mentioned in the preceding footnote remains the same) is that total work converges to 44 hours and total leisure time to 45 hours. So the prediction is that once the structural transformation and marketization forces run their course, there will be a net shift of 6 hours a week from work to leisure activities. It is also predicted that the shift will take a very long time to complete because of the small differentials in the TFP growth rates.

Labor supply with leisure production is $q = l - l_h - l_l$. Since home production converges to zero and leisure converges to a constant, labor supply must also converge to a constant. Leisure is rising throughout the adjustment to the asymptotic steady state, whereas we have argued that the structural transformation and marketization forces that drive labor supply in the benchmark first lower labor supply and then increase it. So with leisure production the predicted initial fall in labor supply is faster and due to both the rise in leisure and the rise in home production, whereas in the second phase, when labor supply increases, the rise is mitigated. Two forces are acting against each other in the second phase, the marketization of home production pushes for a rise in labor supply and the rise in leisure for a fall. With the parameter values used in our benchmark calibrations and ξ set equal to 1/3, the marketization force dominates and labor supply is on a very slowly increasing trend.

[19] The remainder is spent on essential activities like sleep, 74 hours, education, 3.5 hours and unclassified items, 1.5 hours.

5 Conclusions

We have shown that a unified framework can simultaneously account for structural change between agriculture, industry and services and a changing trend in aggregate hours of work without violating balanced aggregate growth. Our prediction of the coexistence of a changing trend in hours on the one hand and balanced aggregate growth on the other is new to a model of economic growth. On the aggregate economy's balanced growth path the dynamics of aggregate market hours are driven by the dynamics of home production, but off the steady state there are transitional dynamics with leisure time rising and the supply of labor falling. We have also shown that an extension which refines the use of leisure time and pays attention to the fact that most leisure time is spent with some capital good, such as a TV set, has the implication that leisure time is also rising over time on the balanced growth path.

The qualitative predictions of our model are consistent with the dynamics of hours of work in the United States. Quantitative analysis shows that the model matches well the dynamics of employment shares since 1930 and reasonably well the aggregate dynamics. The recent rise of female employment is consistent with the marketization of home production emphasized in this paper. However, as our model predicts only a fraction of the fall and subsequent rise in hours, other factors must have contributed to the explanation of the dynamics of market hours of work.

We abstracted from international trade and all distortions to competitive market allocations. Distortions can influence the allocation of time between market and home and trade affects manufacturing and services differently, so it is likely to influence structural change. European data show the same general patterns for market hours of work as in the United States, but there are substantial cross-country differences on both sector shares and overall market hours of work. In order to explain such differences, future work needs to enrich the technological explanation of trends that we have emphasized in this paper with the introduction of taxes, regulation and international trade (see Freeman and Schettkat, 2005, Prescott, 2004, Rogerson, 2004, and Messina, 2006, for related work).

References

[1] Aguiar, M. and E. Hurst (2005). "Measuring Leisure: Evidence from Five Decades of Time Use Surveys", forthcoming *Quarterly Journal of Economics*.

[2] Blundell, R., P. Pashardes and G. Weber (1993). "What Do We Learn About Consumer Demand Patterns from Micro Data?", *American Economic Review* 83: 570-597.

[3] Cooley, T. F., ed. (1995). *Frontiers of Business Cycle Research.* Princeton, NJ, Princeton University Press.

[4] Chang, Y. and F. Schorfheide (2003). "Labor-supply shifts and economic fluctuations", *Journal of Monetary Economics* 50: 1751-1768.

[5] Echevarria, C. (1997). "Changes in Sectoral Composition Associated with Economic Growth." *International Economic Review* 38: 431-452.

[6] Falvey, R. E. and N. Gemmell (1996). "Are Services Income Elastic? Some New Evidence." *Review of Income and Wealth* 42: 257-269.

[7] Freeman, R. and R. Schettkat (2005), "Marketization of Household Production and the EU-US Gap in Work', *Economic Policy*, January, 5-50.

[8] Gollin, D., S. Parente, and R. Rogerson, (2004). "Farm Work, Home Work, and International Productivity Differences." *Review of Economic Dynamics*, 7: 827-850.

[9] Greenwood, J. and G. Vandenbroucke, (2005). "Hours Worked: Long-Run Trends." Research Report No. 10, Economie d'avant garde, University of Rochester.

[10] Greenwood, J., A. Seshadri and M. Yorukoglu (2005). "Engines of Liberation." *Review of Economic Studies* 72: 109-133.

[11] Gronau, R. (1977). "Leisure, Home Production, and Work – the Theory of the Allocation of Time Revisited." *Journal of Political Economy* 85: 1099-1123.

[12] Gronau, R. (1997). "The Theory of Home Production: The Past Ten Years." *Journal of Labor Economics*, 15: 197-205.

[13] Jorgenson, D. and F. Gallop (1992). "Productivity Growth in U.S. Agriculture: A Postwar Perspective." *American Journal of Agricultural Economics* 74*:* 745-750.

[14] Jorgenson, D. and K. Stiroh (2000). "U.S. Economic Growth at the Industry Level." *American Economic Review* 90: 161-167.

[15] King, R., C. Plosser and S. Rebelo (1988). "Production, Growth and Business Cycles I. The Basic Neoclassical Model." *Journal of Monetary Economics* 211: 195-232.

[16] Kongsamut, P., S. Rebelo and D. Xie (2001). "Beyond Balanced Growth," *Review of Economic Studies* 68: 869-882.

[17] Lebergott, S. (1993). *Pursuing Happiness.* Princeton University Press. Princeton, New Jersey.

[18] Leeds, J. (1917). *The Household Budget: With A Special Inquiry into the Amount and Value of Household Work*. Columbia University, Ph.D. dissertation.

[19] Maddison, A., (1992). "A long-run perspective on saving," *Scandinavian Journal of Economics*, 84: 181-196.

[20] McGrattan, E., Rogerson, R. and R. Wright (1997) "An Equilibrium Model of the Business Cycle with Household Production and Fiscal Policy." *International Economic Review*, 38: 267-90.

[21] Messina, J. (2006). "The Role of Product Market Regulations in the Process of Structural Change" *European Economic Review*, 50: 1863-1890.

[22] Mokyr, J. (2000). "Why "More Work for Mother?" Knowledge and the Household Behavior, 1870-1945." *Journal of Economic History*, 60: 1-40.

[23] Ngai, L. R. and C. Pissarides (2007). "Structural Change in a Multi-Sector Model of Growth." The *American Economic Review*, 97: 429-443.

[24] Parente, S., Rogerson, R., Wright, R., (2000). "Homework In Development Economics: Household Production and the Wealth of Nations". *Journal of Political Economy* 108: 680-688.

[25] Prescott, E., (2004). "Why Do Americans Work So Much More than Europeans?" *Quarterly Review of the Federal Reserve Bank of Minneapolis*, July, 2-13.

[26] Ramey, V. and N. Francis. (2006). "A Century of Work and Leisure." NBER Working Paper 12264, May.

[27] Reid, M. (1934). *Economics of Household Production*. New York: John Wiley & Sons.

[28] Robinson, J. P. and G. Godbey (1997). *Time for Life: The Surprising Ways Americans Use Their Time*. University Park, PA, Pennsylvania State University Press.

[29] Rogerson, R. (2004). "Structural Transformation and the Deterioration of European Labor Market Outcomes." Working Paper.

[30] Rupert, P., R. Rogerson and R. Wright. (1995)."Estimating Substitution Elasticities in Household Production Models." *Economic Theory,* 6: 179-193.

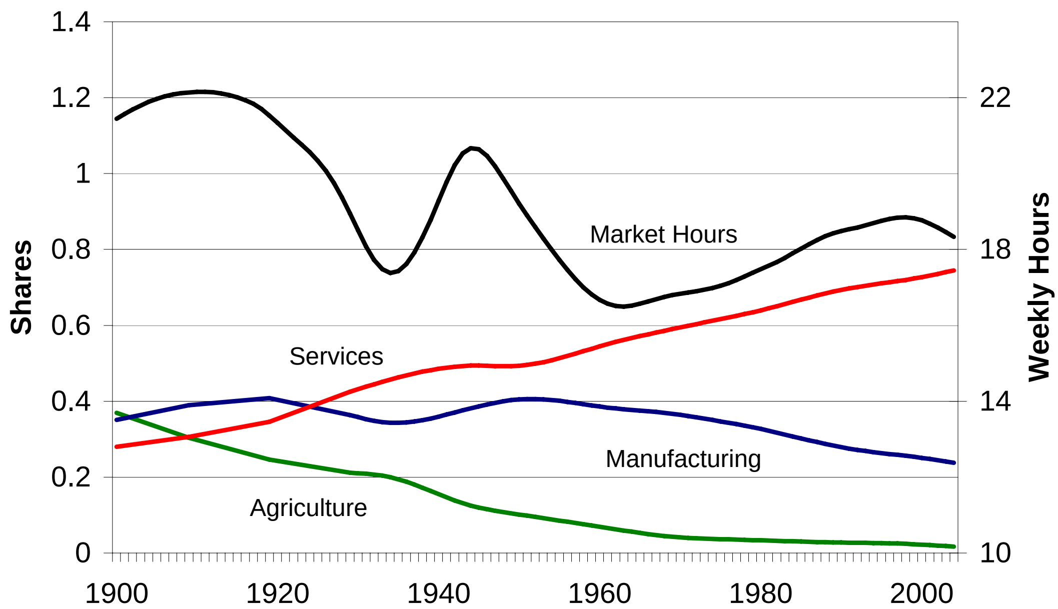
[31] Summers, R.(1985), "Services in the International Economy", in R. P. Inman (ed.), *Managing the Service Economy. Problems and Prospects*, Cambridge University Press, Cambridge.

[32] US Bureau of the Census (1975). *Historical Statistics of the United States, Colonial Times to 1970.* Bicentennial Edition, Part 1 and Part 2. US Government Printing Office, Washington, DC.

[33] Vanek, J. (1973). *Keeping Busy: Time Spent in Housework, United States, 1920-1970.* The University of Michigan Ph.D. Dissertation.

[34] Voth, H-J. (1998). "Time and Work in Eighteenth-Century London", *Journal of Economic History*, 58: 29-58.

Figure 1
Trends in weekly hours of work and employment shares, United States 1900-2004



Definitions: Agriculture includes agriculture, forestry and fisheries, industry includes mining, manufacturing, construction, utilities, transportation and communication and services all others (left scale)

Market Hours is total market hours divided by the population aged 10+ (right scale)

Source: Employment shares, US Historical Statistics and BEA, HP filtered

Market Hours, Ramey and Francis (2006), HP filtered

Figure 2
Model predictions, 1930-2004