The Rise of the Service Economy*

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Abstract

We present four facts and a model explaining the rise of the service economy. First, the rising share of services in output is a recent phenomenon, starting around the mid-20th century. Second, it reflects increases in both the relative price *and* relative quantity of services to commodities. Third, this rising share is entirely explained by the surge of skill-intensive services, and is contemporaneous with the increases in the relative quantity of skilled labor and the skill premium. Finally, individual services follow a distinct product cycle as an economy grows. They start being provided as market services, but are later produced at home with the purchase of manufactured intermediate inputs and durable goods. In our model, agents make decisions between the market and home provision over a continuum of wants that are satiated sequentially. The disutility of public consumption and economies of scale (in the use of specialized capital and skills) are the key elements explaining the rich dynamics of the service economy. If skilled labor has a comparative advantage in the production of newer services, the theory explains the late rise in the service economy characterized by rising relative prices and quantities of services, and growth in the relative quantity of skilled labor and the skill premium.

1 Introduction

Four important facts characterize the rise of the service economy. First, the growing nominal share of the service sector is driven by increases in both the price and quantity of services relative to commodities. Second, this rising share is a recent phenomenon, starting only around 1950. Third, this increase in the share of services is entirely explained by the growth of skill-intensive services, and is contemporaneous with an increasing relative quantity of skilled labor and a rising skill premium. The fourth relevant fact, which we establish, is that many of the declining individual services have actually transitioned from being market-purchased to home-produced, through household purchases of specialized intermediate inputs or durables into home production. Examples of this product cycle include: laundry; dairy, ice and other refrigeration services; street cars and buses; taxis; and motion pictures.[1]

Together, these interrelated facts describe the greatest transformation of the structure of production since the Industrial Revolution. However, standard theories either miss these facts, or are mere reduced form models that cannot be used to think about the policy implications of this transformation. In particular, facts 3 and 4 highlight the heterogeneity of services, and importance of the household decisions to market-purchase or home-produce individual services. These decisions affect not only the market for services, but also the goods markets, and provide insight into the microforces behind all four facts. Analyzing these decisions – that is, developing a theory of services – is critical in understanding the service economy.

The theory we develop, therefore, endogenizes the margin of market to home production of individual services, and is consistent with the relevant facts. We develop a model of the home vs. market decision for a particular want as depending on several factors that capture the heterogeneity of individual wants and services. In explaining the secular time trends, we focus on the important role of three of these factors: the disutility of public consumption, economies of scale, and the comparative advantage of skilled labor in production.

Beyond this theory of services, the growth model includes two ingredients that are essential to reproduce the stylized facts. First, agents order their wants, and then satiate these desires sequentially. As labor productivity grows at an exogenous constant rate and income rises, the consumption set expands to ever more luxury services. Wants are

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[1] Of these facts, only the first two were recognized by a subset of the literature. Lee and Wolpin (2006) make passing mention of the fact that the relative price and relative quantity of services has grown. Kuznets (1957) discussed the lack of a clear relationship between development and the share of service in output before the 1950's, while he, as well as Stigler (1956), documented the secular rise in the share of services in employment. With a few exceptions (e.g., Kuznets (1973)) most of the literature overlooked the late nature of the rise in the service economy (e.g., Maddison (1987)).

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initially satisfied through market services because market production has the advantage of economies of scale in the utilization of intermediate goods, and the cost of these goods are relatively more important at lower incomes. Given a constant disutility of public consumption, as income rises service production moves into the home. The simple model yields (temporarily) balanced growth in which the service sector produces a constant share of output and services follow the market-to-home product cycle.

Second, we assume that agents have skill-biased income expansion paths. That is, luxury services are ever more complex services in which specialized skilled workers hold a comparative advantage. Since the acquisition of any particular skill entails paying a fixed cost, agents choose to attain specialized skills in the production of at most one service. They work as highly productive skilled workers on the market, which increases utilization of the skill, but are less skilled in the broad range of services potentially produced at home.[2] Hence, skill-intensive services have a bias toward market provision, and consequently have slower product cycles. As incomes rise, the service sector expands, the demand for specialized skill increases, investment and returns to skill increase, and the composition of the service sector shifts toward skill-intensive services. Since the service sector is more skill-intensive, the rising returns to skill cause the relative price of services to rise over time. The takeoff of this rising service economy occurs, when incomes are high enough for agents to demand services in which skilled workers have this comparative advantage in production.[3]

Though policy evaluation is not the focus of this paper, we conjecture that the model would have different implications than existing theories in several areas, including the elasticity of labor supply, trade, and productivity growth. The home-market decision makes labor supply more elastic than otherwise, but this elasticity may fall as market production becomes more skill-intensive. This would have implications for the welfare costs of distortions to labor supply or the service sector (relative to Rogerson, 2005). Similarly, trade policies could change relative prices and have similar impacts. Distortions or changes in the relative price of market goods (i.e., tradables) affect not only the production of goods, but also services, through the effect of the prices of goods on the home production decision. Finally, the model illustrates that service sector growth does not rely on slower productivity growth in the service sector. Hence, the theory has no "Baumol's disease" implications of slower long run growth prospects (Baumol, 1967).

Our paper is related to a vast existing literature on structural change, for which we provide a (very) incomplete summary. Earlier discussions of the facts and explanations for the changes in the structure of production include Clark (1941), Stigler (1956), Kuznets

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[2]More formally, if specialized, they will only be producing a measure zero set of home services with a skilled technology.

[3]We view college education as producing specialized skills, whereas elementary and high school education produce general skills. We do not explicitly model the investment in general skills.

(1957), Baumol (1967), Chenery and Syrquin (1975), Fuchs (1980), Kravis et. al. (1984), and Maddison (1987). They posited that a combination of Engel's law and biased productivity rates were important in explaining labor shifts across sectors. Recent important contributions focusing on these labor market shifts include Rogerson (2005) and Lee and Wolpin (2006). Another recent literature that attempts to explain long run structural change within models that are consistent with Kaldor facts includes: Kongsamut, Rebelo and Xie (2001), Acemoglu and Guerrieri (2005), Foellmi and Zweimuller (2005), and Ngai and Pissarides (forthcoming).

The paper is also related to a number of other papers that are not directly concerned with structural change in production. In linking structural change to the rising demand for schooling, our model is related to Kaboski (2006), who focuses on the growth effects of schooling within a model of skill-biased technical change and structural transformation. Our model posits a potential explanation for the important relationship between the relative price of manufactured goods (capital, tradables) and income which has been observed and studied both over time and in the cross-section (e.g., Greenwood, Hercowitz, and Krusell, 1997, Hsieh and Klenow, 2005, Alessandria and Kaboski, 2006). Finally, our modeling of home production draws mainly from the early analysis by Becker (1965), while our non-homothetic preferences follow Matsuyama (2000, 2002). Hall and Jones (forthcoming) provide an important contribution in explaining the underlying non-homotheticity for one important area of consumption: healthcare.[4] We instead take the non-homothetic preferences as given, focusing on their implications rather than their origins.

The paper is organized as follows. Section 2 motivates the need for a theory of services, and presents the evidence for product cycles. We develop a model of the home production vs. market production margin in Section 3, and highlight some of the driving forces at work. Section 4 embeds a simplified version of this model into a growth economy. In Section 5, we characterize this model for the balanced growth case in which skilled labor holds an absolute advantage in all services, and show the driving forces behind the product cycle. The assumption of comparative advantage in Section 6 yields the rise of the service economy and the observed trend in relative prices. Section 7 provides a few interesting extensions, and Section 8 concludes.

2 Empirical Evidence

This section explores the facts associated with the rise of the service economy, showing how standard explanations for the service-related structural change observed in modern

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[4]For other important growing service industries (finance and education), demand could plausibly be increasing in life expectancy.
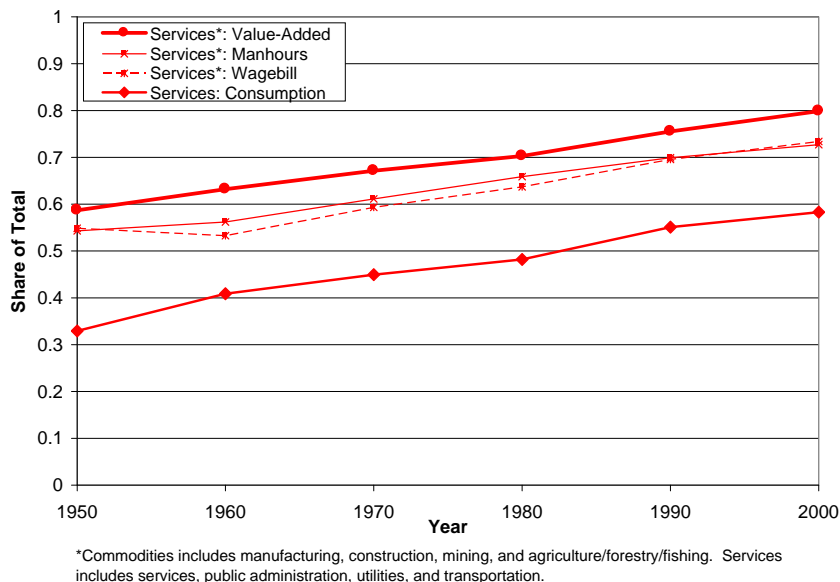
Figure 1: Post-1950 Rise in Services Relative to Commodities

economies fail to account for these observed facts, and emphasizing the need for a theory of the home production vs. market services margin.

Figure 1 shows what we refer to as the rise of the service economy in the United States. In 1950, the value-added of the service sector is comparable to the commodity (i.e., non-service) sector, but by 2000 the service sector is about four times as large.This post-1950 transformation occurs whether measured as fractions of output, consumption, labor employed, or total labor payments in the economy.[5] We have used a broad measure of services (including those provided by government, public utilities and transportation), but the same substantial trend exists in more narrow concept of services as well, and the decline in commodities exists for each of the commodity sectors (agriculture, manufacturing, mining, and construction).

While the focus of the paper is to explain the rise in services, economists and policy-

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[5]We argue that output is the most meaningful of these metrics. Our model is about the consumption of services, which Figure 1 shows is driving force behind the growth in service output. Still, consumption of services excludes many services that have had a transition into the home (e.g., retail services for commodities). Output and labor income share numbers are available at a more detailed level. Labor income share is used as a proxy for output at very detailed industry levels. Raw workers are of less interest because the skill level of workers differ substantially across industries, especially in the earlier period.
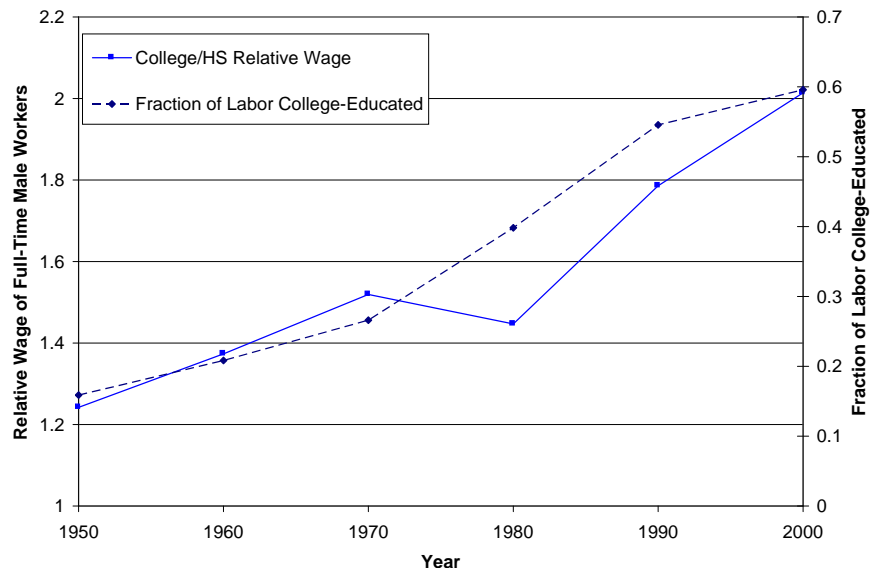
Figure 2: Rise in Relative Wage and Supply of College-Educated Labor

makers often draw a link between the rise in the service economy, and the growing disparity between high and low-skilled workers over the same period. Figure 2 shows an example of this disparity using high school- and college-educated workers as measures of low- and high-skill, respectively. The wage of college-educated workers rose from 125 percent of the high school-educated wage in 1950 to over 200 percent by 2000. At the same time, the ratio of college- to high school-educated labor in the workforce rose from about fifteen percent to sixty percent. Existing theories do not establish a link between the trends in Figure 1 and Figure 2.

2.1   New Set of Facts

While the rising importance of the service economy and the trends in returns to skill are well-known, several other facts are less well-known. The first stylized fact is that the rise in services reflects increases in both the relative price *and* relative quantity of services. These trends are illustrated in Figure 3, which plots the growth in the *nominal* output (i.e., value-added) of services relative to commodities, and decomposes it into the growth in the measured relative price of services, and the growth in the relative *real* quantity of
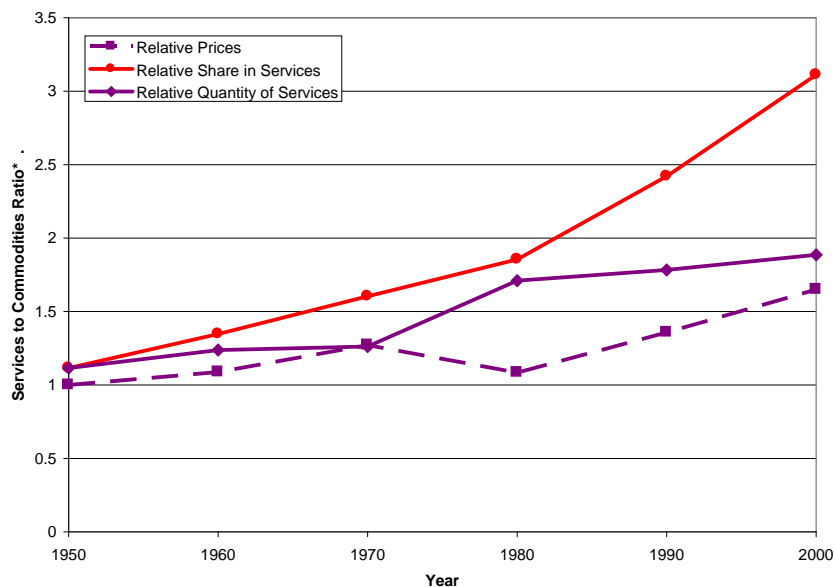
Figure 3: Increase in Relative Price and Quantity of Services to Commodities

services (after deflating).[6] All three trends show substantial growth.

The first fact is important because a substition story alone cannot simultaneously account for the increase in the relative quantity and price of services.[7] The common story of relatively slow productivity growth in the service sector and a low elasticity of substitution across sectors (e.g. Baumol, 1967, Ngai and Pissarides, forthcoming, Acemoglu and Guerreri, 2005) is consistent with the rising relative price and rising nominal output share of services, but not the increase in real relative quantities.[8] A movement of relative quantities and relative prices in the same direction requires an income effect coming from non-homothetic preferences.

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[6]The price data used to construct the relative price and quantity series fluctuates considerably at high frequency. We have smoothed using an eleven-year moving average to show the long run trends of interest.

[7]Clark (1944) proposed the earliest hypothesis of structural transformation caused by slower productivity growth in the service sector. Since the output share of services had not yet risen, he was interested in only explaining the rise in the service sector's share of the workforce. Biased productivity growth models can potentially explain an ever rising fraction of the workforce in services, but not the growth in relative real quantities observed after 1950.

[8]Acemoglu and Guerrieri (2005) features neutral technological progress, but capital accumulation and differences in capital shares across sectors imply a rise in the relative price of services.
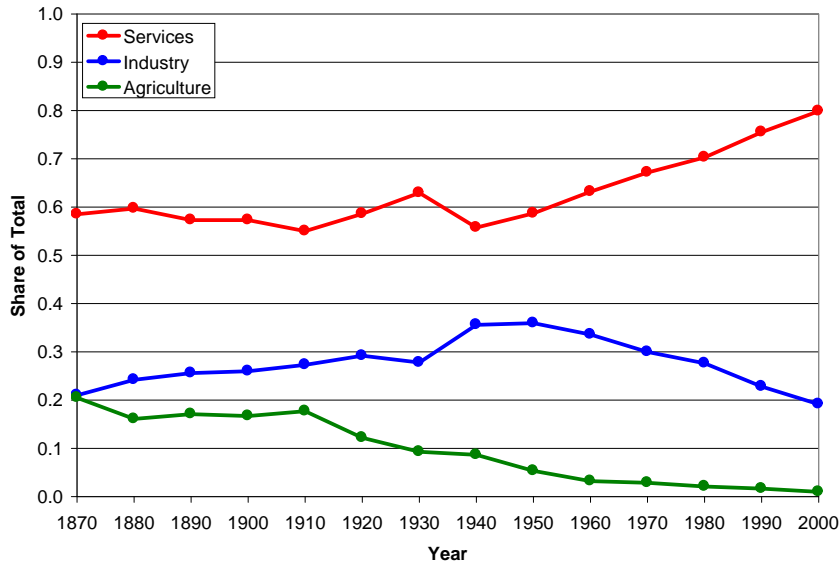
Figure 4: Late Rise of the Service Economy

In considering non-homothetic preferences, for which services are luxury goods, our second fact is important: the rise of the service economy is only a recent phenomena. Figure 4 illustrates 130 years of the structural transformation of the US economy between the standard sectors of agriculture, industry, and services.While the decline in agriculture is present even at the beginning of this period, the share of output in services is nearly constant between 1870 and 1950, and rises only during the last fifty years.[9] The lack of growth in the service sector before 1950 is robust to the exclusion of government and/or utilities from services.[10]

The late rise of services is particularly damaging for existing explanations involving non-homothetic preferences over aggregate commodities and services. In particular, unlike the early decline in agriculture, the late rise in services cannot be driven by Stone-Geary type preferences. Initial endowments of household services, as in Kongsamut, Rebelo, and

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[9]Similarly, the evidence suggests that, if anything, the skill premium fell over the first half of the twentieth century. For a review of the evidence and for the most comprehensive time series see Goldin and Katz (1999a).

[10]The raw labor numbers differ substantially from output numbers, with agriculture showing a much steeper decline and services showing a much more gradual increase in labor. See Kuznets (1957) for an earlier discussion of these distinct trends.

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Xie (2000), are most important at lower levels of income, and lead to an early rise.[11] Alternative stories of pure non-homotheticities would also face the problem of reconciling the cross-sectional relationship between service consumption share and income with the time series data. For example, in 1935-36, before the rise of services in the aggregate economy, the consumption share of services increased strongly with individual income, with average shares ranging between 29.1 for families with incomes below $1000 to 43.9 percent for families above $5000, but does not show a sharp acceleration at high incomes. (See National Resources Planning Board, 1941, Table 101, p. 34). Finally, such a theory on aggregate services would miss important heterogeneity within the service sector.

One aspect of this heterogeneity is captured by Fact 3, the shift in the composition of the service sector toward skill-intensive industries. Figure 5 separates the growth in services in Figure 1 into the contributions of high- and low-skill industries. We rank industries according to their skilled intensity as measured by the fraction of workers college-educated in 1940. We place the top most skilled intensive industries that account for half of the aggregate wagebill in the high-skill group[12] Clearly, the rise of the service economy has been completely driven by high-skill industries, while the importance of low-skill service industries in the overall economy has actually declined. Demand growth does not appear to be common to services in the aggregate, but differs across skill-intensity.

Figure 6 provides even more detail on the growth vs. skill intensity relationship by plotting the absolute change in the labor income share of different service industries between 1950 and 2000 against the skill-intensity of the industry (measured as the fraction of workers with college-education in 1940).[13] The absolute importance of each industry to the total growth in services is its vertical distance from the zero growth line.

2.2   Product Cycles and the Need for a Theory of Services

The fourth stylized fact involves the particular industries which have tended to grow and contract. The growth in services involves a variety of quantiatively important industries, but all have specialized skill-labor as a common factor. These services include education (especially higher education), legal services, banking, real estate and accounting, broadcasting and television, air transportation, and health care. Although health and hospitals

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[11] An initial endowment of services could lead to a late rise in services if the endowment were so large that no market services were purchased, but services in 1870 were already a substantial fraction of output and consumption, and not zero as the theory would require.

[12] Because this classification relies on classifying broader, more aggregate industries than those in Figure 6, the sum of the vertical distances is not exactly equal to the difference presented in 5.

[13] The detailed industry data comes from IPUMS census. Therefore, output shares are not available at this detailed level. Using manhours instead of labor income yields a very similar picture.

* We rank industries according to their skilled intensity as measured by the fraction of workers college-educated in 1940. We place
the top most skilled intensive industries that account for half of the aggregate service wagebill in the high-skill group.
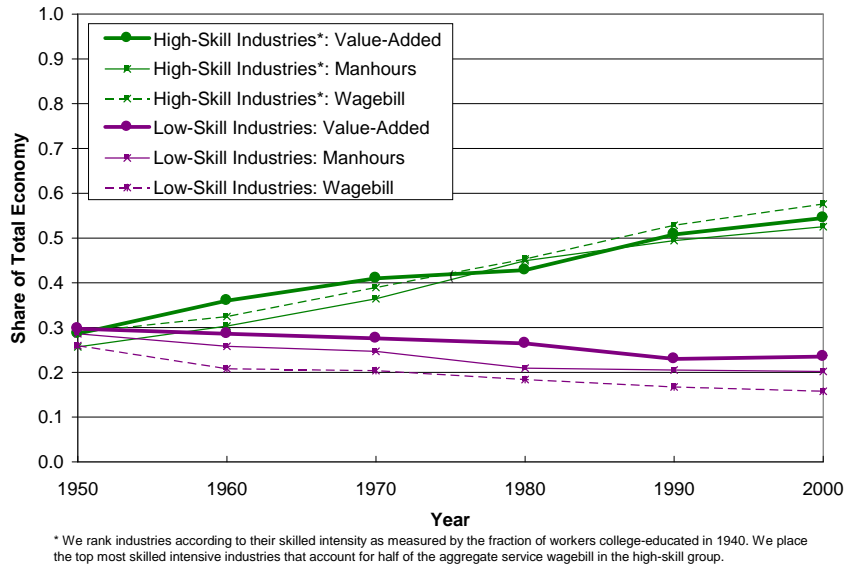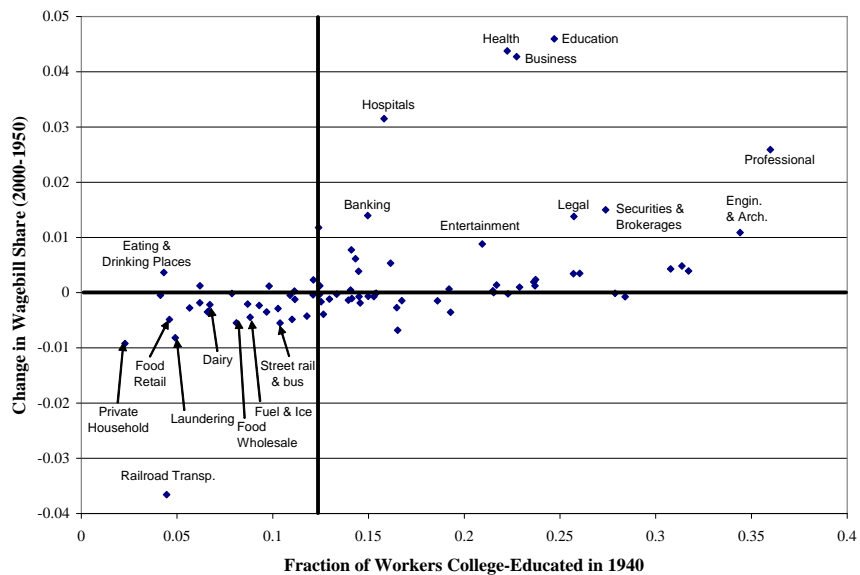
Figure 5: Growth of Low- and High-Skill Services

Figure 6: Growth vs. Skill Intensity of Individual Service Industries

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together account for an almost 8 percentage point increase, or nearly 40 percent of the overall increase in services (in Figure 3), they constitute less than one-quarter of the total rise in high-skill services. The rise in the service industry is not simply a story of increasing demand for health care. Indeed, even within the category of health care, there has been a rise in the service economy. Health care is provided as both services (medical services, hospitals) and commodities (medical equipment, pharmaceuticals), but the share of services in health care consumption rose from 77 percent in 1950 to 84 percent in 2000.

In contrast to the growing skill-intensive services, the declining service industries involve less-skilled industries with home production substitutes, such as railroads, private household workers, laundering, railways and bus lines, food stores, dairy retailing, fuel and ice retailing, auto repair, postal service, taxicab service, and theaters and motion pictures. Together, these industries constitute nearly three-quarters of the total decline in all low-skill industries (See Appendix A).[14] Moreover, their decline is contemporaneous with the spread of durable goods that are used as inputs in the home production of these services.

The services vs. commodities distinction is less a question of what needs are being met or what is ultimately consumed, than how this consumption is delivered. Home production requires the market purchase of goods instead of services. This is true even for high skill services. The recent growth of home dialysis, which involves the purchase of home dialysis equipment, is an example of a health care service requiring an important decision between home production or market provision.[15] As Rogerson (2005) points out, this margin between home and market is crucial for understanding the service sector, if only because home production of services is not measured in standard income accounts.

The argument that the rise in the service sector is driven by the marketization of previously home produced services is not supported, however, by the detailed industry-level evidence in Figure 6. There are of course examples of such marketization, but the opposite product cycle in which wants are initially satisfied through market services and later transition to home production is the quantitatively important cycle, at least in recent times. Again, such industries account for three-quarters of the total decline of low skill industries. This product cycle is Fact 4. Important examples of this cycle in the data are illustrated in Figure 7, which shows the rise and fall of market services over time and the corresponding diffusion of the relevant commodities.[16]

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[14]We have omitted postal service (56 percent college graduates) and theaters and motion pictures (51 percent college graduates) from this number, since these are technically high skilled in 2000 according to our fifty-percent definition.

[15]See Blagg (1997, 2006) for an overview of the history and recent trends of home dialysis for end-stage renal disease.

[16]The model we present gives complicated dynamics for the value of output because of price effects, so instead we count real services and establishments. Related, in the graphs the commodities that diffuse are

The top panel graphs the growth and decline of important transportation services (i.e., railways, trolleys, and buses) on the left axis, and the spread of the stock of registered automobiles on the right axis. Because the three services are substitutes for one another, the dynamics of individual service industries are complicated, but clearly the spread of the automobile has played an important role in the decline of all three.

The middle panel displays the related dynamics of market services for "domestic work" (i.e., laundering and dry cleaning, domestic servants) together with the diffusion of vacuums, washing machines, dryers, and dishwashers. Laundering and dry cleaning services show a rise and then fall that corresponds to the spread of the washer and dryer. Domestic servants shows a continuous decline, but seems to also be related to the spread of these household items. Indeed Greenwood et. al. (2005), from whom we take the data on household items, also draw a link between these trends.

Finally, the third panel plots the rise and fall of retail food, drinking, ice and fuel service establishments, and the corresponding expansion of important household amenities: private refrigerators, freezers, and central heating. We argue that the expansion of refrigerators and freezers has moved these services from market production to home production, eliminating the need for frequent shopping, neighborhood grocery stores, and milk, ice and fuel delivery services.

These product cycles underscore the need for a theory of services. For further motivation, Figure 8 provides a list of wants that can be met either through market services, or through home production and the purchase of an important manufactured good. The first item, casual attire is never provided as a market service, but the second item, formal attire, is often provided as a market service. A major difference is the lower utilization of formal attire. Item 3, laundry, is associated with a declining service industry, while item 4, air transportation is a growing industry. The relative cost of the necessary goods purchase for home production is an important reason that air transportation is almost exclusively a market service, while laundry has become increasingly home produced. Item 5, oil changes are purchased on the market by relatively high income people but at home by low income people. Here, the driving factor is not the goods cost, but instead the opportunity cost of time. Finally, item 6, and more extremely item 7, are generally purchased on the market, and the reason is the importance of specialized skills in their production.

There are many important questions requiring a theory of services. Why are some services done on the market, while others are done at home, and what determines the size of the service sector? Why do we see many of the above low-skill services transitioning from market production to home production? How do these transitions affect the market for manufactured goods? How is the service sector related to the demand for and relative price

durables, so we choose measures related to the stocks of these items instead of the flows.
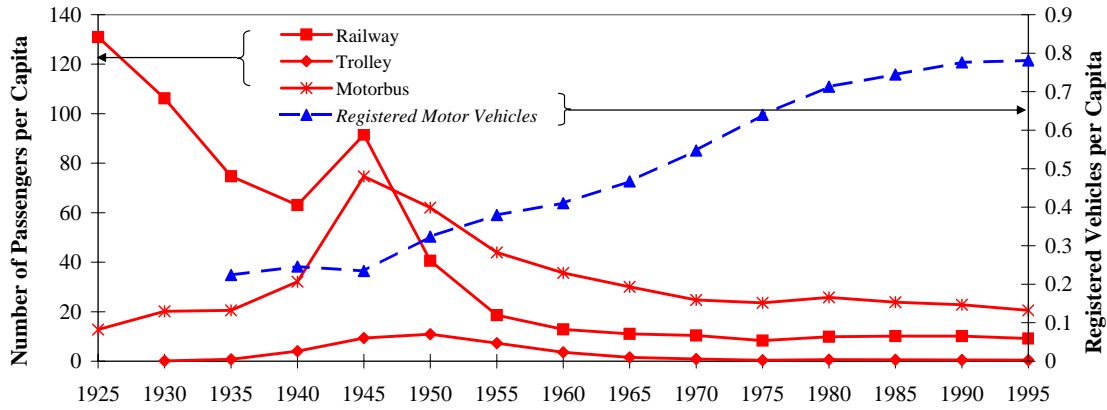
Domestic Services Product Cycles and the Spread of Household Appliances
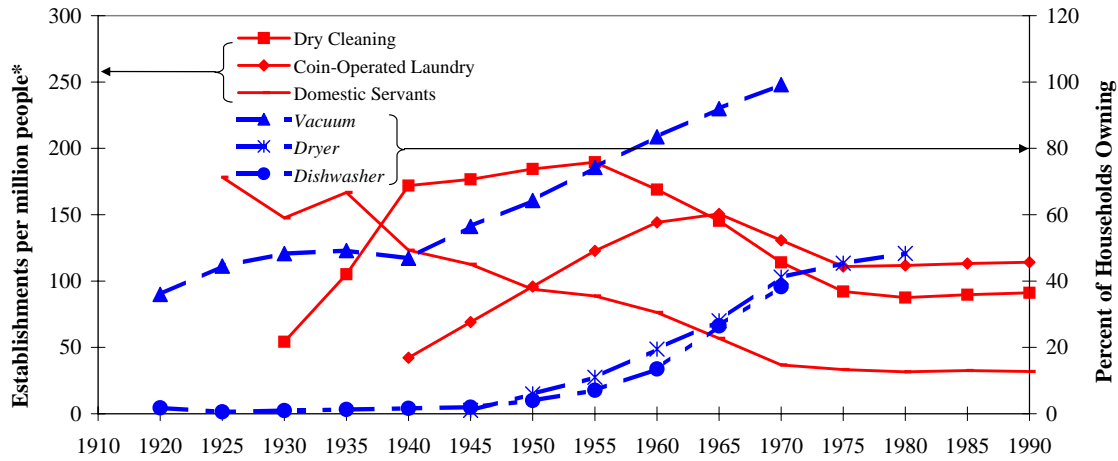
*Domestic servants establishments are arbitrarily normalized to ten workers to fit the scale.

Retail Service Product Cycles and the Spread of Household Amenities
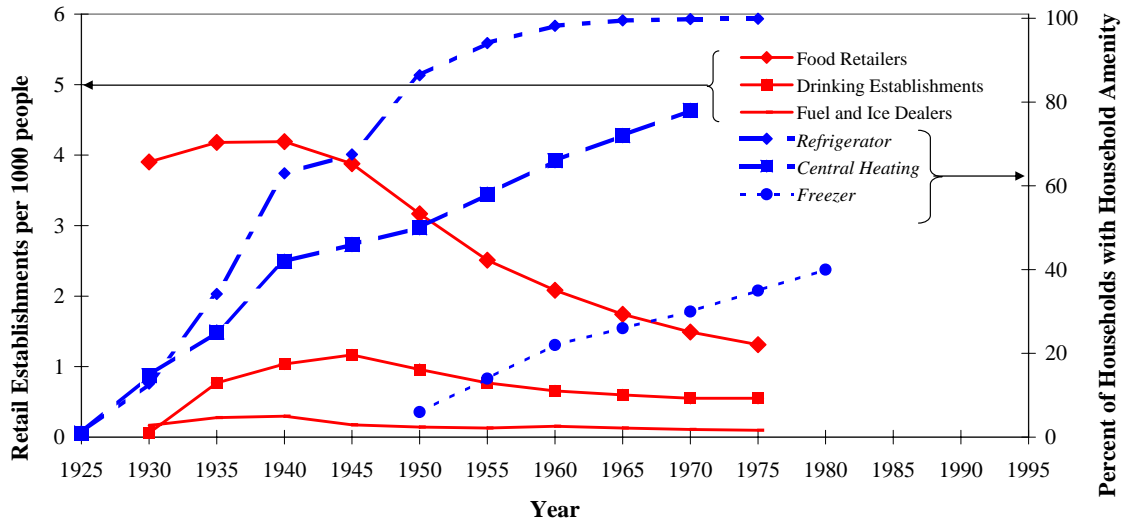
Sources: Historical Statistics of the U.S., (2006) [establishments, passengers, and registered vehicles]
Greenwood, Seshadri, and Yorukoglu (2001) [household appliances and amenities]

Figure 7: Important Examples of Product Cycles

	Item	Market Service	Alternative Home Production
1	Casual attire	Blue jeans rental	Blue jeans purchase
2	Formal attire	Tuxedo rental	Tuxedo purchase
3	Laundry	Laundromat/laundry service	Laundry machine purchase
4	Air transportation	Commercial airline	Private jet purchase
5	Changing oil	Oil change shop	Wrench, filter & oil purchase
6	Hair cut	Barber shop	Scissors/shears purchase
7	Surgery	Hospital	Scalpel purchase

Figure 8: Market Service vs. Home Production

of skilled labor? The examples in Figure 8 give immediate insight into the important driving factors. The next section develops a model of the market service vs. home production decision to formalize these issues.

In particular, understanding the service economy requires a theory of services, and the home production vs. market provision margin. This margin is vital in determing the size of the service sector and its late rise, but is also intimately related to technical change and the relative price of goods and services, the demand for goods, the demand for and relative wage of skilled labor, and the supply of labor.

3   Theory of Services: Simple Example

In this section, we model the home vs. market production decision for a single want of an agent with a demand for one unit. Following the examples in Figure 8, we assume that the production of services (y_s) requires the use of q units of manufactured goods (k_s) in combination with either low (l_s) and/or high-skill labor (h_s) to produce a maximum of $n > 1$ units of a service at a constant marginal cost:

$$y_s = \begin{cases} 0 & \text{if } k_s < q \\ \min\{n, A_l l_s + A_h h_s\} & \text{if } k_s \geq q \end{cases} \tag{1}$$

A simple example would be a washing machine that can do a maximum number of loads of laundry per day, with a certain amount of labor required for each load. Since the amount consumed by the agent is one unit, $1/n$ captures the utilization rate at home. A_l and A_h are low- and high-skilled labor specific productivities, respectively.

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We assume for simplicity that services can be produced either at home or on the market, while manufactured goods are only produced on the market. We also simplify by assuming that labor is the only input into manufactured goods production:[17]

$$y_m = A_l l_m + A_h h_m \qquad (2)$$

In equilibrium, $y_m = k_s$.

Given these production functions we focus on the cost differences in home and market production.

We assume that high-skilled labor is very specialized, so that high-skill workers are only high-skilled in the production of one type of services. For simplicity, we assume that agents have low-skilled productivity at the particular service in question. (In Section 4, we will assume a continuum of services on which any specialty has measure zero.) Whether a market service is produced using low-skilled workers or specialized high-skill workers will depend on comparative advantage as defined by the ratio of their wages w relative to their productivities A_h/A_l.

As long as the population is large relative to the efficient scale of production n, free entry will drive prices of market services to their minimum average cost. Using low-skilled labor as the numeraire:

$$p_s = \underbrace{\min\left\{\frac{1}{A_l}, \frac{w}{A_h}\right\}}_{\text{labor requirements}} + \underbrace{\frac{q}{n}\min\left\{\frac{1}{A_l}, \frac{w}{A_h}\right\}}_{\text{goods requirements}}$$

Similarly, for manufactured goods:

$$p_m = q\min\left\{\frac{1}{A_l}, \frac{w}{A_h}\right\}$$

In addition, agents face transaction costs of purchasing on the market that are proportionate to home labor time, $\frac{c}{A_l}$.[18]

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[17]This could be derived from a parallel treatment of manufacturing goods production:

$$y^m = \begin{cases} 0 & \text{if } k^m < q \\ \min\{n, Al^m + Bh^m\} & \text{if } k^m \geq q \end{cases}$$

Thus, (2) would arise as the limiting expression as $q, n \to \infty$ and $q/n \to 0$. We have implicitly assumed that the minimum scale of manufacturing is quite large, but the returns to scale in production are even larger.

[18]We assume that transaction costs for manufactured goods are negligible.

An agent with education e, $e \in \{l, h\}$, has one unit of potential labor, a wage w_e, and non-labor income y. The agent faces a discrete decision problem of whether to consume service, $\chi = 1$, and, if so, whether to home produce, $H = 1$, or to hire a service on the market, $H = 0$. In addition, agents have a constant marginal utility of unspent income x. Formally,

$$\max_{\chi, H \in \{0,1\}, \, x} \chi \left[H + (1 - H) \delta \right] + \mu x$$

s.t.

$$\chi \left[H \left(p_m + \frac{w_e}{A_l} \right) + (1 - H) \left(p_s + w_e \frac{c}{A_l} \right) \right] + x \leq w_e + y$$

where μ gives the marginal utility of income. A home produced service has two benefits over market produced. First, since $\delta \in (0, 1)$ home production yields more utility, perhaps because it avoids the disutility of public consumption (e.g., sitting next to others on the bus instead of driving your own car). Second, it avoids the transaction cost of going to the market. If a service is consumed at all, it will be provided by the market iff:

$$\mu [\underbrace{q \left(1 - \frac{1}{n} \right) p_m}_{\text{goods costs savings}} + \underbrace{\frac{w_e}{A_l} - \min \left\{ \frac{1}{A_l}, \frac{w}{A_h} \right\} - \mu c \frac{w_e}{A_l}}_{\text{labor costs savings}}] \geq 1 - \delta \tag{3}$$

Equation (3) shows the relevant trade-offs. On the left hand side are the cost savings typically associated with the market production of a service. The first term is the utility value of the difference in the costs of manufactured goods used in the production. This term will typically be positive because market production has the benefit of higher scale/utilization of specialized manufactured goods. The second term is the utility value of the difference in labor time costs devoted toward production of the service. The labor time cost of market consumption includes not only the service worker's time, but also the transaction time of the agent. The sign of this term depends on combinations of parameter values: the skill advantage of market production (if $w < \frac{B}{A}$), the opportunity cost w_e, and the transaction cost c. On the right hand side is the disutility cost associated with joint consumption of a market service.

One can also see the effect of technological progress leading to a decline in the price of the intermediate manufactured inputs. When the price of the intermediate manufactured inputs decline, any potential cost savings in the market is smaller, while the disutility cost associated with the joint consumption of a market service is constant. This makes home production relatively more attractive. Similarly, when income rises (and the marginal utility of income, μ, declines), the utility value of any given cost savings is less important relative to the disutility cost of joint consumption.

Simple comparative statics leads to the following proposition:

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Proposition 1 *The cost savings associated with market production of a service are:*

1. *increasing in the price of the manufacturing good p_m, the manufactured goods requirement q, and the efficient scale of production, n;*

2. *decreasing in the transaction costs c and the labor productivity A_l;*

3. *decreasing (increasing) in the agent's wage w_e if the home production time is greater (less) than the market transaction time;*

4. *decreasing in the wage of high-skilled workers (w) and increasing in their relative productivity (i.e., A_h/A_l) if high-skill workers have the comparative advantage in production of the service (i.e., $w < \frac{A_h}{A_l}$).*

This proposition is useful in organizing and understanding the items discussed earlier in Figure 8 . We have highlighted the role of technological progress in leading to a decline in the price of intermediate manufactured inputs. While this alone explains the market to home product cycle as productivity rises, one can see that the production decisions for particular items depend on different several relevant factors (i.e., disutility of market service consumption, the size/cost of required manufactured goods, returns to scale and utilization, the opportunity cost of time of the consumer, and the skill-intensity). Together, the many factors allow the model to explain a wide range of observations of home or market production of particular services.

In the remaining sections, however, our focus is not on the cross-sectional heterogeneity in consumption wants, but on the secular trends presented in the previous section. We therefore imbed a simplified version of the above model into a growth setting to explain the relevant facts. In particular, we set transaction costs $c = 0$, and normalize $q = 1$, and focus on the roles of n, δ, and A_h/A_l in generating product cycles and the rising importance and changing composition of services.

4   A Model of Services and Economic Growth

In this section, we extend the model by introducing a continuum of discrete wants or services indexed by their complexity z, $z \in \mathbb{R}$, in a continuous time overlapping generations model. For simplicity, we assume that generations live for an arbitrarily small interval of time. The continuum of wants and the preferences are similar to Matsuyama (2000, 2002).[19]

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[19]As discussed in Matsuyama (2002), an alternative interpretation of z is the place that a particular want occupies in the ordering of wants. Lower z corresponding to more basic wants that are satisfied first.

4.1 Preferences

Let the function $\chi(z) : \mathbb{R} \to \{0,1\}$ indicates whether a particular want is being satisfied. Wants can either be satisfied by procuring the service directly from the market, or by purchasing the required manufactured goods and providing the service at home. Define the function $H(z) : \mathbb{R} \to \{0,1\}$, which takes the value 1 if want z is satisfied by home production and 0 otherwise. Together the set of indicator functions mapping $\mathbb{R}$ into $\{0,1\}^2$ define the consumption set. Preferences over wants and the method of satisfying those wants (i.e., over indicator functions $(\chi(z), H(z))$) are represented by the following utility function:

$$\tilde{u}(\chi, H) = \int_{z_0}^{+\infty} [H(z) + \delta(1 - H(z))] \chi(z) \, dz + z_0$$

where wants $z \leq z_0$ correspond to basic needs that must always be satisfied and z_0 is an arbitrarily small constant and $H(z) \leq \chi(z)$.

For expositional purposes and without loss of generality (as will become clear when discussing the production technology), the consumer's problem can be restricted to the choice over the restricted consumption set defined by step functions of the type:

$$\chi(z) = \begin{cases} 1 \text{ if } z \leq \bar{z} \\ 0 \text{ if } z > \bar{z} \end{cases}$$

and

$$H(z) = \begin{cases} 1 \text{ if } z \leq \underline{z} \\ 0 \text{ if } z > \underline{z} \end{cases}$$

where $\bar{z}$ denotes the most complex want that is satisfied, and $\underline{z}$ denotes the most complex want that is home-produced.

Preferences over the restricted consumption set can then be represented as a utility function over two thresholds $\underline{z}$ and $\bar{z}$:

$$u(\underline{z}, \bar{z}) = \begin{cases} -\infty & \text{if } \bar{z} < z_0 \\ \underline{z}(1 - \delta) + \delta\bar{z} & \text{if } \bar{z} \geq z_0 \end{cases}$$

with $\underline{z} \leq \bar{z}$.

4.2 Technologies

We extend the technologies introduced in Section 3 by introducing skill neutral technological progress at the rate γ, and by allowing the productivity to decrease with the complexity of a want (z), i.e., $A_l(z)$ and $A_h(z)$ with $\frac{\partial A_l(z)}{\partial z} < 0$ and $\frac{\partial A_h(z)}{\partial z} < 0$. Formally:
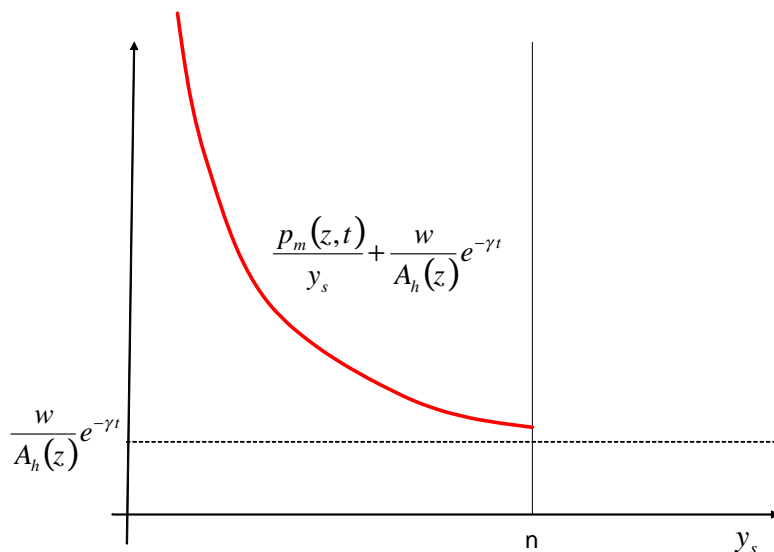
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Figure 9: Average Cost of High-Skill Services

$$y_s\left(z,t\right) = \begin{cases} 0 & \text{if } k_s < 1 \\ e^{-\gamma t}\min\left\{n, A_l\left(z\right)l_s + A_h\left(z\right)h_s\right\} & \text{if } k_s \geq 1 \end{cases}$$

Throughout the paper we restrict our attention to the case where high-skill labor has a (weak) comparative advantage in the production of more complex services, i.e., $\frac{\partial[A_h(z)/A_l(z)]}{\partial z} > (=) 0$. The exponential parameterization, $A_l\left(z\right) = \bar{A}_l e^{-\lambda_l z}$ and $A_h\left(z\right) = \bar{A}_h e^{-\lambda_h z}$, is of particular interest, and this assumption amounts to $\lambda_l \geq \lambda_h$.

Figure 9 illustrates the average cost function associated with this technology when skilled labor is employed.

Again, for simplicity, we assume that intermediate goods specific to the production of z services are manufactured on the market with a linear technology:

$$y_m\left(z,t\right) = e^{\gamma t}\left[A_l\left(z\right)l_m + A_h\left(z\right)h_m\right]$$

4.3   Schooling

Individuals can become specialized workers by spending a fraction θ of their time endowment acquiring skills. The population is heterogeneous with respect to the time required to acquire specialized skills. In particular, $\theta \in [0,1]$ is distributed according to the c.d.f. $F\left(\theta\right)$.

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As long as $F(0) = 0$, individuals can specialize in at most a finite number of services. Thus, given that individuals consume a continuum of them, only a measure zero of home-produced services will be done using high-skilled labor and, therefore, individuals will choose to specialize in at most one service.

4.4 Firms' Problem

Given wages, free entry of service and manufacturing firms implies that they will price at average cost:

$$p_s(z,t) = \frac{1}{n} p_m(z,t) + e^{-\gamma t} \min\left\{\frac{1}{A_l(z)}, \frac{w(t)}{A_h(z)}\right\} \tag{4}$$

and

$$p_m(z,t) = e^{-\gamma t} \min\left\{\frac{1}{A_l(z)}, \frac{w(t)}{A_h(z)}\right\} \tag{5}$$

Provided high-skilled workers have a comparative advantage in the production of more complex goods and services, and $\lim_{z\to-\infty} A_h(z)/A_l(z) < w$ and $\lim_{z\to+\infty} A_h(z)/A_l(z) > w$, there exists a cut-off service $\hat{z}$ above which all output is produced by high-skilled, specialized labor, and below which all output is produced by low-skilled labor. It is trivial to show that for the case with exponential productivities, the marginal service $\hat{z}$ is given by:

$$\hat{z} = \frac{1}{\lambda_l - \lambda_h} \log(w).$$

As the skill premium increases, more of the less complex services and manufactured goods are going to be produced with low-skilled labor.

4.5 Consumer's Problem

The demand for market services and manufactured goods of an individual with skill e, $e \in \{l, h\}$ solves:

$$V^e(\theta) = \max_{0 \le \underline{z}_e \le \bar{z}_e} (1 - \delta) \underline{z}_e + \delta \bar{z}_e$$

s.t.

$$\int_{-\infty}^{\underline{z}_e} p_m(z, t)\, dz + \int_{\underline{z}_e}^{\bar{z}_e} p_s(z, t)\, dz$$

$$= w_e \left(1 - \int_{-\infty}^{\underline{z}_e} \frac{e^{-\gamma t}}{A_l(z)} dz - \theta \mathcal{I}(e) \right) \tag{6}$$

where $\mathcal{I}(e)$ is an indicator function that equals one if $e = h$ and zero otherwise. Given prices satisfying (5) and (4), it can be shown that the budget set is strictly convex, implying that this is a strictly convex problem and, therefore, that the first order conditions are sufficient.

At an interior optimum, $\underline{z}_e$ and $\bar{z}_e$ solve the following first order conditions:

$$\mu \left[\left(1 - \frac{1}{n} \right) p_m(\underline{z}_e, t) + e^{-\gamma t} \left(\frac{w_e}{A_l(\underline{z}_e)} - \min \left\{ \frac{1}{A_l(\underline{z}_e)}, \frac{w}{A_h(\underline{z}_e)} \right\} \right) \right] \ge 1 - \delta \tag{7}$$

and

$$\mu p_s(\bar{z}_e, t) = \delta$$

where $p_s(z, t)$ has being substituted using (4) and μ denotes the marginal utility of income. Condition (7) is the counterpart to condition (3) in the simple example discussed in Section 3. This equation clearly shows the effect of technological progress that leads to a decline in the price of the intermediate manufactured inputs. When the price of the intermediate manufactured inputs decline, any potential cost savings in the market is smaller, while the disutility cost associated with the joint consumption of a market service is constant. This effect leads previously market provided services to be home produced, i.e., an increase in $\underline{z}_e$.

Figure 10 illustrates these optimality conditions for both a low-skilled individual and a high-skilled individual who is indifferent to becoming skilled, i.e., $\theta = \hat{\theta}$.

Given the value function associated with the agent's problem in (6), $V^e(\theta)$, $e = l, h$, we can solve for the decision rule to become a specialized, high-skilled worker. Individuals choose to specialize iff:

$$V^h(\theta) \ge V^l. \tag{8}$$

As is implicit in condition (8), the value of remaining low-skilled is independent of θ, while the value of becoming high-skilled is a strictly decreasing function of θ. Moreover,
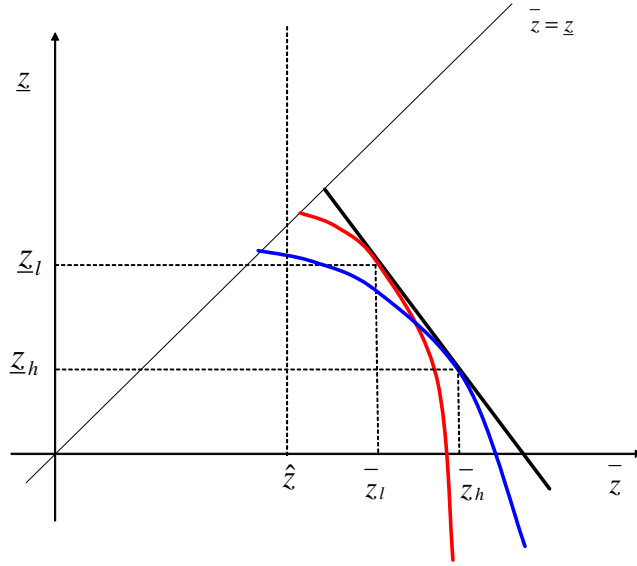
Figure 10: Optimality for Low and Marginal High Skilled ($\theta = \hat{\theta}$) Individuals

for $w > 1$, $V^h(0) > V^l$ and $V^l > V^h(1)$, implying that there exist a unique cost $\hat{\theta}$ such that individuals with schooling cost lower than $\hat{\theta}$ strictly prefer to become skilled.

>From the analysis of the consumer's problem, we obtain strong cross-sectional predictions for the consumption of market services by low- and high-skilled individuals, and for individuals of different ability.

High-skilled individuals have a high opportunity cost of their time, and therefore, face larger costs of home-producing services. This substitution effect implies that high-skilled workers consume more market services than low-skilled workers. At the same time, low θ high-skilled individuals have a higher net labor endowment, and therefore, they consume more of both market- and home-produced services. For the marginal high-skilled individual, $\theta = \hat{\theta}$, there is only a substitution effect, implying that $\overline{z}_h\left(\hat{\theta}, t\right) > \overline{z}_l$ and $\underline{z}_h\left(\hat{\theta}, t\right) < \underline{z}_l$ (see Figure 10). Among high-skilled workers with identical opportunity costs of time, high income workers consume more manufactured goods and a wider range of services overall, i.e., $\overline{z}_h\left(\theta', t\right) > \overline{z}_h\left(\theta, t\right)$ and $\underline{z}_h\left(\theta', t\right) > \underline{z}_h\left(\theta, t\right)$ for $\theta' < \theta$. In the case $A_l\left(z\right) = \bar{A}_l e^{-\lambda_l z}$ and $A_h\left(z\right) = \bar{A}_h e^{-\lambda_h z}$ the substitution effect dominates the income effect for all $\theta \leq \hat{\theta}$, i.e., $\underline{z}_l > \underline{z}_h\left(0, t\right)$.

These observations are summarized in the following proposition:

Proposition 2 *If the skill premium is positive, $w > 1$, there exist $0 < \hat{\theta} < 1$ such that*

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$V^h(\theta) \gtreqless V^l$ iff $\theta \lesseqgtr \hat{\theta}$. Moreover, high-skill workers $(\theta < \hat{\theta})$ consume some market services that low-skill workers do not consume, $\bar{z}_h(\theta, t) > \bar{z}_l(t)$ and the thresholds $\bar{z}_h(\theta, t)$ and $\underline{z}_h(\theta, t)$ are decreasing in θ. In addition, if $A_l(z) = \bar{A}_l e^{-\lambda_l z}$ and $A_h(z) = \bar{A}_h e^{-\lambda_h z}$, all high skill individuals home produce a smaller range of services than low-skill workers, i.e., $\underline{z}_h(\theta, t) < \underline{z}_l(t)$ for all $\theta \leq \hat{\theta}$.

Proof. See Appendix B. ∎

We finish this section by establishing that the exponential parameterization of productivity is a necessary and sufficient condition for the share of services in consumption to be constant as income grows. To simplify the exposition we restrict the analysis to an economy with a single skill.

Proposition 3 *Consider an economy with a single skill parametrized by constants n, δ, γ, and a strictly positive and strictly decreasing function $A(z)$. Then, the share of service in consumption (and value added) is a constant function of income for all n and δ if and only if $A(z) = \bar{A}e^{-\lambda z}$.*

Proof. See Appendix B. ∎

In the rest of the paper we restrict the analysis to this exponential parameterization of productivity, since we are interested in models that can explain the constant share of services for the early period.

4.6 Competitive equilibrium

A competitive equilibrium is given by price functions $p_m(z, t)$, $p_s(z, t)$, $w(t)$, schooling threshold $\hat{\theta}$, demand for manufactured goods and market services $\underline{z}_l(t)$, $\bar{z}_l(t)$, $\underline{z}_h(\theta, t)$, $\bar{z}_h(\theta, t)$, and the threshold of comparative advantage $\hat{z}(t)$ such that consumers' demands and schooling decisions solve (6) and (8); prices solve zero profits conditions (5) and (4); and labor markets clear.

Next, we characterize the dynamics of the model for the case where high-skilled labor has only an absolute advantage, i.e., $A_l(z) = \bar{A}_l e^{-\lambda_l z}$ and $A_h(z) = \bar{A}_h e^{-\lambda_h z}$ with $\lambda_l = \lambda_h$ and $\bar{A}_h > \bar{A}_l$ (Section 5), and the case where high-skilled labor has a comparative advantage in more complex goods, i.e., $\lambda_l > \lambda_h$ (Section 6).

5 Absolute Advantage: Product Cycle with Balanced Growth

In this section we briefly describe the equilibrium of an economy where high-skilled labor holds only an absolute advantage, i.e., $\lambda_l = \lambda_h = \lambda$. Beside yielding insightful closed-form

solutions, the study of this case is interesting in and of itself because it corresponds closely to the solution of the general case, $\lambda_l \geq \lambda_h$, for low t.

In this economy, the relative wage is pinned down by the relative productivity:

$$w = \frac{\bar{A}_l}{\bar{A}_h}.$$

The equilibrium allocation when $\lambda_l = \lambda_h = \lambda$ follows a balanced growth path and yields an analytic solution (see Appendix D). We briefly summarize some characteristics of the solution below:

Proposition 4 *The following is true about the balanced growth path allocation when $\lambda_l = \lambda_h = \lambda$:*

1. *The fraction of high-skilled workers $F\left(\widehat{\theta}\right) \in (0,1)$, is constant over time, increasing in their relative productivity, A_h/A_l, and increasing in the efficient scale, n.*

2. *The thresholds defining the demand of high- and low-skilled individuals for manufactured goods and services $\bar{z}_l(t)$, $\underline{z}_l(t)$, $\bar{z}_h(\theta, t)$, and $\underline{z}_h(\theta, t)$ all increase linearly with time with a slope γ/λ. Thus, the model yields a product cycle from not consumed to purchased on the market and finally produced at home for all consumers.*

3. *The share of services in output $\tilde{y}^s$ and consumption $\tilde{c}^s$ are constant, with $\tilde{c}_s = \frac{n+1}{n}\tilde{y}_s$.*

Proof. See Appendix D. ∎

To illustrate the product cycle it is useful to solve for the value added share of industries providing goods and services associated with a particular set of wants $[z, z+\Delta)$, i.e., $\tilde{y}_s(z, \Delta)$ and $\tilde{y}_m(z, \Delta)$, where z indexes the sector and Δ the level of aggregation. Similarly, we can solve for the share of consumption spent on goods and services of a particular industry. Figure 11 shows these product cycles for an economy with only low-skilled labor. (The general model requires an additional integration over θ, and the particular shape may depend on the distribution of θ). Value-added in both the service and corresponding manufacturing industry rises initially as more of the wants are satisfied (through market services), then falls with rising productivity/falling costs. Eventually costs fall enough to initiate direct consumption of the manufactured good and home production of the service (the dotted line). At this point, mass consumption of the manufactured good begins, and the manufacturing industry again rises, but the service industry declines even more sharply.

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Product Cycle: Value Added

$\widetilde{y}_s(z,\Delta)$

$\widetilde{y}_m(z,\Delta)$

t

Product Cycle: Consumption

$\widetilde{c}_s(z,\Delta)$
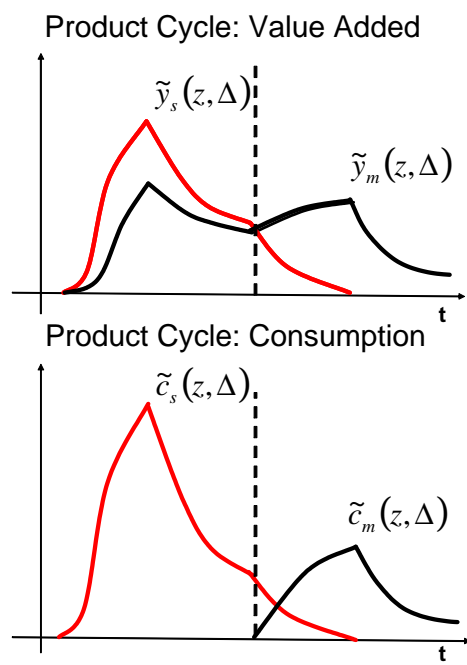
$\widetilde{c}_m(z,\Delta)$

t

Figure 11: Product Cycle for a Particular Industry $[z, z + \Delta]$. Single skill.

6 Comparative Advantage: The Rise of the Service Economy

In this section, we characterize the dynamics of the economy when skilled labor has a comparative advantage in the production of more complex goods, i.e., $\lambda_l > \lambda_h$. We show that the model generates a transition from an economy with unspecialized labor and a constant share of services to an economy with a rising skill premium, an increasing share of high-skilled, specialized labor, and a rising share of services in the economy. Moreover, the model generates both a rise in the relative price of services to manufactured goods and a rise in relative quantity of services to commodities that together contribute to the rising share of services in the economy. Thus, the model is consistent with the four facts of Section 2.

Figure 12.a illustrates the dynamics of services in the model economy. Both measured as a share of value added, consumption, and labor the model generates the transition from an economy with a stable services sector to one with a rising service economy. As illustrated by Figure 12.b and 12.c, the rise in the service economy is associated with a surge in specialized labor and a rising skill premium.[20] Intuitively, it is relatively more costly to home produce services for which high-skilled labor has a comparative advantage, since all home production is performed with low-skilled productivity. For this reason, the product cycle of skill-intensive services is substantially longer, and therefore, a larger fraction of services end up being provided in the market. At the same time, the rising skill premium makes it relatively more costly for high-skilled workers to home-produce services, further increasing the share of market services in the economy.

In the long run, the share of services in output asymptotes to a constant governed by the efficient scale parameter n, $\lim_{t \to \infty} \tilde{y}^s(t) = \frac{n}{n+1}$, and the share of service in consumption converges to one. The fraction of individuals who become high-skilled goes to one as the skill premium grows unbounded.

This discussion is formalized in the following proposition.

Proposition 5 *The following is true about the economy where high-skilled labor has a comparative advantage in more complex goods, i.e., $\lambda_l > \lambda_h$: i) There exists a threshold time t_0 marking the beginning of the service economy. For $t < t_0$, $w = 1$, $\hat{\theta} = 0$ (i.e., there is no specialized high-skilled labor), and the share of services is constant. ii) As t grows large: $\lim_{t \to +\infty} \tilde{y}_s(t) = \frac{n}{n+1}$, $\lim_{t \to +\infty} \tilde{c}_s(t) = 1$, $\lim_{t \to +\infty} w = +\infty$, and $\lim_{t \to +\infty} \hat{\theta} = 1$.*

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[20]The model does not require the fraction of schooling to be strictly zero before the rise, nor the skill premium/relative wage to be one, as illustrated in Figure (12). One could avoid this simply by defining $A^h(z) = \bar{A}^h \max(e^{-\lambda^h z}, e^{-\lambda^l z})$.
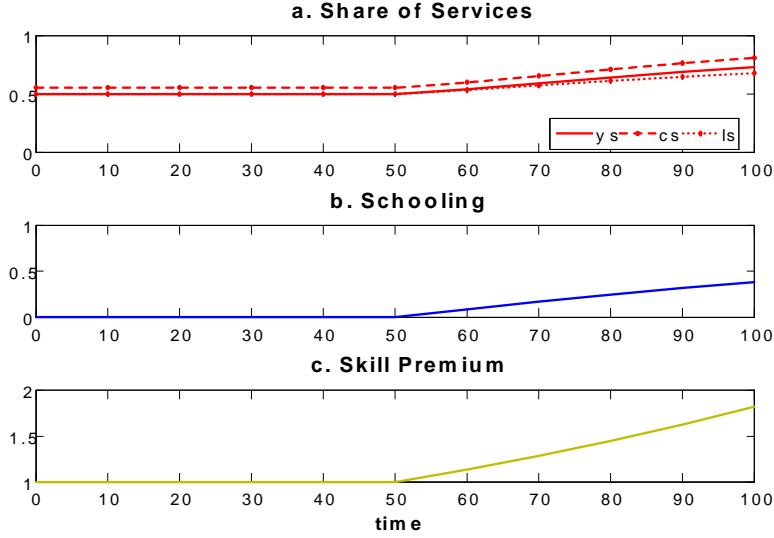
Figure 12: The Rise of the Service Economy and Related Stories

Proof. See Appendix E. ∎

Along the transition, the model generates a rising relative price of services to commodities, a fact that is often taken as exogenous by most theories of structural change.[21] In the model, as the skill premium rises, the relative price of services to commodities also increases, as the former are more skill-intensive. This is stated formally in the following proposition.

Proposition 6 $\frac{\partial P_s(t)/\partial t}{P_s(t)} - \frac{\partial P_m(t)/\partial t}{P_m(t)} > 0$ *for* $t \geq t_0$, *where* $\frac{\partial P_s(t)/\partial t}{P_s(t)}$ *and* $\frac{\partial P_m(t)/\partial t}{P_m(t)}$ *are the continuous-time changes in chain-weighted price indices for market services and manufactured goods, respectively.*

Proof. See Appendix E. ∎

As discussed before, the share of services in the economy also increases due to the lengthening of product cycles and the substitution away from home produced services by high-skilled workers. Thus, the model generates both a rise in relative price and relative quantities of services to manufactured goods.

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[21] A recent exception is given by Acemoglu and Guerrieri (2005).

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7 Extensions

We briefly review three extensions that might be considered potential alternative explanations for the rise in the service economy: 1) transaction costs for service purchases, 2) biased productivity across sectors (i.e., service vs. manufacturing), and 3) skill-biased technical change. These extensions also help clarify the intuition for results of the model analyzed in the previous section.[22]

7.1 Transaction Costs

We analyzed three interesting variations in which the inherent benefit of home production over market consumption is in avoiding market transaction costs, rather than the disutility of public consumption. That is, both home and market services provide one unit of utility, but the purchase of any service from the market requires a transaction cost of $Ce^{-\gamma_c t}$ units of time. Here γ_c captures potentially falling transaction costs over time. The simplified expression of the problem is:

$$V^e(\theta) = \max_{0 \leq \underline{z}_e \leq \bar{z}_e} \bar{z}_e$$

$$\text{s.t.}$$

$$\int_{-\infty}^{\underline{z}_e} p_m(z,t)\,dz + \int_{\underline{z}_e}^{\bar{z}_e} p_s(z,t)\,dz$$

$$= w_e \left(1 - \int_{-\infty}^{z_l} \frac{e^{-\gamma t + \lambda_l z}}{\bar{A}_l}\,dz - \int_{\underline{z}_l}^{\bar{z}_e} Ce^{-\gamma_c t}\,dz - \theta \mathcal{I}(e) \right)$$

The first variaton is the analog of the balanced case in which $\lambda_l = \lambda_h = \lambda$ and $\gamma_c = 0$. Thus, instead of a constant utility cost there is a constant time cost C. This model reproduces the balanced growth and product cycles, comparable to the balanced case examined above. The second variation is the case of comparative advantage, in which $\lambda_l > \lambda_h$ and $\gamma^c = 0$. This model produces the result that, asymptotically, market labor converges to zero, and all labor is used in either transaction costs, or home production. Despite its infinitesimal productivity relative to market production, home production is undertaken in order to avoid transaction costs.

A third variation, which produces the rise of the service economy, is $\lambda_l = \lambda_h = \lambda$, but $\gamma_c > 0$. In this case, the fall in transaction costs causes market production to be relatively more attractive. The share of the service sector in consumption (output) increases over time

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[22]Analysis of the extensions discussed is relatively straightforward and available upon request from the authors.

and converges to 1 $(n/(n+1))$ asymptotically. Furthermore, although the relative wage $w = \frac{\bar{A}_h}{\bar{A}_l}$ is constant, $\hat{\theta}$ increases over time, because of the reduced time in home production and coverges asymptotically to $1 - \frac{\bar{A}_l}{\bar{A}_h}$. Thus, this model produces the rising share of services and level of skill in the economy, but has no predictions about the skill-intensity of services (i.e., skills could be employed in manufacturing).

7.2   Biased Productivity Across Sectors

Instead of comparative advantage driving the rise of the service economy, one can produce the rise using differential rates of technological progress across services and manufacturing. To highlight this assume that $\lambda_l = \lambda_h = \lambda$, but productivity growth differs in services (γ_s) and manufacturing (γ_m). The model is therefore identical to the balanced growth case, except the production functions take the following form:

$$y_s(z,t) = \begin{cases} 0 & \text{if } k_s < 1 \\ \min\left\{n, e^{\gamma_s t}\left[\bar{A}_l e^{\lambda z} l_s(z,t) + \bar{A}_h e^{\lambda z} h_s(z,t)\right]\right\} & \text{if } k_s \geq 1 \end{cases}$$

$$y_m(z,t) = e^{\gamma_m t}\left[\bar{A}_l e^{\lambda z} l_s(z,t) + \bar{A}_h e^{\lambda z} h_s(z,t)\right]$$

Interestingly, in this model, the necessary assumption for the rise of the service economy is $\gamma_s > \gamma_m$, i.e., the service sector must have higher productivity growth. This is precisely the opposite of the required assumption in the standard model with biased sectoral productivity growth (e.g., Ngai and Pissarides, 2005). Intuitively, when manufacturing productivity growth is relatively slow, the service sector expands in order to save on manufactured goods costs through higher utilization on the market.

7.3   Skill-Biased Technical Change

Rather than assuming biased productivity across sectors, assume instead that productivity growth differs across high-skilled (γ_h) and low-skilled (γ_l) workers. Again focusing on the $\lambda_l = \lambda_h = \lambda$ case, the production functions are therefore:

$$y_s(z,t) = \begin{cases} 0 & \text{if } k_s < 1 \\ \min\left\{n, e^{-\lambda z}\left[\bar{A}_l e^{\gamma_l t} l_s(z,t) + \bar{A}_h e^{\gamma_h t} h_s(z,t)\right]\right\} & \text{if } k_s \geq 1 \end{cases}$$

$$y_m(z,t) = e^{-\lambda z}\left[\bar{A}_l e^{\gamma_l t} l_s(z,t) + \bar{A}_h e^{\gamma_h t} h_s(z,t)\right]$$

In this model, the relative wage is given by relative productivities:

$$w = \frac{\bar{A}_h}{\bar{A}_l} e^{(\gamma_h - \gamma_l)t}$$

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Since this relative productivity is common to all z, labor costs are equated for low- and high-skilled workers and there is indeterminacy about who works in which z. The model therefore does not predict increasing skill-intensity of services, nor the rising relative price of services, but otherwise looks very similar asymptotically to the comparative advantage model studied in the previous section. Namely, the relative wage goes to infinity, and $\hat{\theta} \to 1$, $\tilde{c}_s \to 1$, and $\tilde{y}_s \to n/(n+1)$. In this model, however, the longer product cycles are not the result of new goods being more skill-intensive. (They may be produced by low-skilled workers.) Instead, longer product cycles for skilled workers are driven by their rising opportunity cost w. As their relative wage rises, high-skilled workers stay with market services longer, transitioning them to home production at a slower rate. In contrast, the product cycles of low-skilled workers remain constant. The rise in the service sector is driven by the lengthening product cycles of high-skilled workers, and the rising fraction of high-skilled workers in the workforce.

This example highlights that there are two reasons for longer product cycles in the comparative advantage model in Section 6. The rising skill intensity of services lengthens product cycles for both low- and high-skilled workers, while the rising opportunity cost is an additional factor in the longer product cycles of high-skilled workers.

8 Conclusions

To explain the rise of the service economy in the U.S. over the last half century, we have focused on the household's decision between home production and market production in explaining the rise of the service economy. Modeling this margin has yielded insight into understanding the high-skill nature of the rising service economy.

As mentioned in the introduction, we conjecture that our model would have particular implications for several policy-relevant issues. First, the model has a rich theory of labor supply and its elasticity. We have avoided reference to female labor supply, which has strongly impacted the U.S. labor market over the period studied, is of great importance in considering the home production vs. market purchase decision, and has been linked to the growth in services (Lee and Wolpin, 2006). Trade is a second potentially important factor in understanding structural transformation, and the model may have important implications for the link between trade, home production and structural composition. A third issue relates to biased technological change and future growth prospects. Our theory can explain both the rising share of services and rising relative price of services without requiring slower productivity in services. Indeed, slower productivity growth in services would tend to lessen the quantitative implications of our theory for structural change. On the other hand, if productivity growth in services is understated, and comparable or

higher than that in manufacturing, then our model has greater potential in quantitatively reconciling structural change and the (smaller) increase in the relative price of services. A fourth question is whether the model's concepts of returns to scale of market services and mass consumption of manufactured goods in home production could also generate the observed expansion of manufacturing earlier in development, and the extent to which the theory can qualitatively and quantitatively account for the facts involving long run structural transformation. All of these questions are subjects of ongoing research.

Appendix A: Skill-Intensity and Labor Income Growth of Detailed Service Industries

	Declining Services			Growing Services	
Fraction College-Educated in 2000	**Change in Share of Labor Income (2000-1950)**	**Industry**	**Fraction College-Educated in 2000**	**Change in Share of Labor Income (2000-1950)**	**Industry**
0.301	-0.0366	Railroads and railway	0.766	0.0460	Educational services
0.274	-0.0092	Private households	0.652	0.0438	Medical and other health services, except hospitals
0.248	-0.0082	Laundering, cleaning, and dyeing	0.662	0.0428	Misc business services
0.362	-0.0055	Street railways and bus lines	0.743	0.0315	Hospitals
0.389	-0.0055	Food and related products	0.667	0.0259	Misc professional and related
0.324	-0.0049	Food stores, except dairy	0.831	0.0150	Security and commodity brokerage and invest companies
0.573	-0.0048	Postal service	0.687	0.0140	Banking and credit
0.468	-0.0045	Apparel and accessories stores, except shoe	0.816	0.0138	Legal services
0.279	-0.0043	Water transportation	0.822	0.0109	Engineering and architectural services
0.370	-0.0035	Electric-gas utilities	0.555	0.0088	Misc entertainment and recreation services
0.310	-0.0035	Gasoline service stations	0.630	0.0077	Real estate
0.640	-0.0035	Telephone	0.716	0.0061	Insurance
0.154	-0.0033	Dairy prods stores and milk retailing	0.659	0.0053	Household appliance and radio stores
0.352	-0.0029	Hardware and farm implement stores	0.813	0.0048	Accounting, auditing, and bookkeeping services
0.318	-0.0028	Auto repair services and garages	0.472	0.0043	Services incidental to transportation
0.411	-0.0027	Petroleum products	0.683	0.0039	Radio broadcasting and television
0.426	-0.0023	General merchandise	0.519	0.0039	Misc retail stores
0.377	-0.0022	Taxicab service	0.333	0.0036	Eating and drinking places
0.263	-0.0021	Fuel and ice retailing	0.651	0.0035	Air transportation
0.420	-0.0019	Dry goods apparel	0.680	0.0034	Telegraph
0.179	-0.0018	Five and ten cent stores	0.620	0.0024	Welfare and religious services
0.281	-0.0016	Farm prods--raw materials	0.502	0.0023	Misc wholesale trade
0.404	-0.0015	Gas and steam supply systems	0.676	0.0019	Advertising
0.511	-0.0014	Theaters and motion pictures	0.488	0.0014	Machinery, equipment, and supplies
0.341	-0.0014	Sanitary services	0.411	0.0013	Hotels and lodging places
0.420	-0.0012	Lumber and building material retailing	0.313	0.0012	Trucking service
0.460	-0.0012	Furniture and house furnishings stores	0.633	0.0012	Nonprofit membership organizs.
0.387	-0.0011	Shoe stores	0.432	0.0012	Motor vehicles and accessories retailing
0.451	-0.0007	Other and not specified utilities	0.542	0.0010	Not specified wholesale trade
0.554	-0.0007	Electric light and power	0.539	0.0007	Electrical goods, hardware, and plumbing equipment
0.398	-0.0007	Liquor stores	0.526	0.0005	Drug stores
0.470	-0.0007	Jewelry stores	0.388	0.0004	Motor vehicles and equipment
0.252	-0.0005	Bowling alleys, and billiard and pool parlors	0.452	0.0003	Misc personal services
0.149	-0.0005	Shoe repair shops	0.429	0.0000	Water supply
0.404	-0.0004	Misc repair services			
0.215	-0.0003	Real estate-insurance-law offices			
0.464	-0.0003	Not specified retail trade			
0.311	-0.0002	Warehousing and storage			
0.601	-0.0002	Drugs, chemicals, and allied products			
0.215	-0.0002	Dressmaking shops			
0.390	-0.0001	Petroleum and gasoline pipe lines			
0.392	-0.0001	Retail florists			

B Characterization of the Consumer's Problem

In this section we characterize the properties of the budget set for the case where skilled labor has a (weak) comparative advantage in the production of more complex wants: $\frac{\partial A_l(z)}{\partial z}\frac{1}{A_l(z)} \leq \frac{\partial A_l(z)}{\partial z}\frac{1}{A_h(z)}$. The budget set is given by the following inequality:

$$F\left(\underline{z}_e, \bar{z}_e\right) \leq 0 \tag{9}$$

where

$$
\begin{aligned}
&F\left(\underline{z}_e, \bar{z}_e\right) \\
&= \int_{-\infty}^{\underline{z}_e} p_m\left(z, t\right) dz + \int_{\underline{z}_e}^{\bar{z}_e} p_s\left(z, t\right) dz - w_e\left(1 - \int_{-\infty}^{\underline{z}_e}\frac{e^{-\gamma t}}{A_l\left(z\right)}dz - \theta\mathcal{I}\left(e\right)\right)
\end{aligned}
$$

The slope of the budget set equals:

$$
\begin{aligned}
\frac{d\underline{z}_l}{d\bar{z}_l} &= -\frac{F_{\bar{z}}\left(\underline{z}_e, \bar{z}_e\right)}{F_{\underline{z}}\left(\underline{z}_e, \bar{z}_e\right)} \\
&= -\frac{\min\left\{\frac{1}{A_l(\bar{z}_e)}, w\frac{1}{A_h(\bar{z}_e)}\right\}}{\frac{1}{A_l(\underline{z}_e)} - \frac{1}{n}\min\left\{\frac{1}{A_l(\underline{z}_e)}, \frac{w}{A_h(\underline{z}_e)}\right\}} \geq 0.
\end{aligned}
$$

Provided that the function $F\left(.,.\right)$ is convex, condition (9) defines a convex set. In the case $\underline{z}_e \geq \hat{z}$, The Hessian of $F\left(.,.\right)$ is given by:

$$
Hf = -\left(\begin{array}{cc}
\frac{1}{A_l(\underline{z}_e)^2}\frac{\partial A_l(\underline{z}_e)}{\partial\underline{z}_e} - \frac{1}{n}\frac{w}{A_h(\underline{z}_e)^2}\frac{\partial A_h(\underline{z}_e)}{\partial\underline{z}_e} & 0 \\
0 & w\frac{1}{A_h(\bar{z}_e)^2}\frac{\partial A_h(\bar{z}_e)}{\partial\bar{z}_e}
\end{array}\right)
$$

Clearly, as long as $\frac{1}{A_l(\underline{z}_e)}\frac{\partial A_l(\underline{z}_e)}{\partial\underline{z}_e} \leq \frac{1}{A_h(\underline{z}_e)}\frac{\partial A_h(\underline{z}_e)}{\partial\underline{z}_e}$ the budget set is guaranteed to be convex.
Proof of Proposition 2. Define $\bar{z}_h = \bar{z}_h\left(0\right)$, and $\underline{z}_h = \underline{z}_h\left(0\right)$. $\bar{z}_l$, $\underline{z}_l$, $\bar{z}_h$, and $\underline{z}_h$ solve the following system of equations for $e = l, h$:

$$
\left(1 - \delta\right) p_s\left(\bar{z}_e, t\right) = \delta\left[p_m\left(\underline{z}_e, t\right) + w_e\frac{e^{-\gamma t + \lambda_l \underline{z}_e}}{\bar{A}_l} - p_s\left(\underline{z}_e, t\right)\right]
$$

and

$$
\int_{-\infty}^{\underline{z}_e} p_m\left(z, t\right) dz + \int_{\underline{z}_e}^{\bar{z}_e} p_s\left(z, t\right) dz = w_e\left(1 - \frac{e^{-\gamma t + \lambda_l \underline{z}_e}}{\lambda_l \bar{A}_l}\right)
$$

In the case where there is a positive demand for skilled labor, i.e., $\hat{z} < \bar{z}_l < \bar{z}_h$,[23] and $\underline{z}_e > \hat{z}$ (a similar argument can be done for $\underline{z}_e < \hat{z}$), the first order condition and budget constraint can be written as:

$$\left(1 + \frac{1}{n}\right) w \frac{e^{-\gamma t + \lambda_h \bar{z}_e}}{\bar{A}_h} = \frac{\delta}{1 - \delta}\left[\frac{e^{-\gamma t + \lambda_l \underline{z}_e}}{\bar{A}_l}w_e - \frac{w}{n}\frac{e^{-\gamma t + \lambda_h \underline{z}_e}}{\bar{A}_h}\right]$$

and

$$\frac{e^{-\gamma t + \lambda_l \hat{z}}}{\lambda_l \bar{A}_l} + \frac{w}{\lambda_h \bar{A}_h}\left(e^{-\gamma t + \lambda_h \underline{z}_e} - e^{-\gamma t + \lambda_h \hat{z}}\right)$$
$$+ \left(1 + \frac{1}{n}\right)\frac{w}{\bar{A}_h \lambda_h}\left(e^{-\gamma t + \lambda_h \bar{z}_e} - e^{-\gamma t + \lambda_h \underline{z}_e}\right)$$
$$= w_e\left(1 - \frac{e^{-\gamma t + \lambda_l \underline{z}_e}}{\bar{A}_l \lambda_l}\right)$$

Solving for $e^{-\gamma t + \lambda_h \bar{z}_e}$ from the first order condition and substituting into the budget constraint we obtain an equation in $\underline{z}_l$:

$$w_e\left(\frac{e^{-\gamma t + \lambda_l \underline{z}_e}}{\bar{A}_l}\left(\frac{1}{\lambda_l} + \frac{\delta}{1 - \delta}\frac{1}{\lambda_h}\right) - 1\right)$$
$$= \frac{1}{n}\frac{e^{-\gamma t + \lambda_h \underline{z}_e}}{\bar{A}_h \lambda_h (1 - \delta)} + \frac{e^{-\gamma t + \lambda_l \hat{z}}}{\bar{A}_l}\left(\frac{1}{\lambda_h} - \frac{1}{\lambda_l}\right)$$

Notice that the left hand side and the right hand side of this equality define two increasing functions of $\underline{z}_e$. Moreover, the function defined by the left hand side intersects the function defined by the right hand side from below and at a point where $\left(\frac{e^{-\gamma t + \lambda_l \underline{z}_e}}{\bar{A}_l}\left(\frac{1}{\lambda_l} + \frac{\delta}{1 - \delta}\frac{1}{\lambda_h}\right) - 1\right) > 0$. Therefore, for $e = h$, $w_h = w > 1 = w_l$, the intersection occurs to the left, i.e., $\underline{z}_h < \underline{z}_l$. It is straightforward to show that $\bar{z}(\theta) > \bar{z}(\theta)$ and $\underline{z}_h(\theta) > \underline{z}_h(\theta')$ for $\theta > \theta'$, and that $\bar{z}_h(\theta) \geq z_l$ for $\theta > \hat{\theta}$. ∎

Proof of Proposition 3. We first show the sufficiency of $A(z) = e^{-\lambda z}$. If $A(z) = e^{-\lambda z}$ the problem of a consumer with neutral productivity $e^{\gamma t}$ simplifies to:

$$\max_{0 \leq \underline{z} \leq \bar{z}} (1 - \delta)\underline{z} + \delta\bar{z}$$
$$\text{s.t.}$$
$$\left(1 - \frac{1}{n}\right)\frac{e^{\lambda \underline{z}}}{\lambda} + \left(1 + \frac{1}{n}\right)\frac{e^{\lambda \bar{z}}}{\lambda} = e^{\gamma t}$$

---

[23]Since skilled individuals spend a positive amount on goods produced by unskilled individuals, trade balance between unskilled and skilled agents requires that $\hat{z} < \bar{z}_l$ whenever skilled intensive goods are produced.

>From the first order conditions of this problem we obtain:

$$\frac{\left(1-\frac{1}{n}\right)}{1-\delta}e^{\lambda\underline{z}} = \frac{\left(1+\frac{1}{n}\right)}{\delta}e^{\lambda\bar{z}} \tag{10}$$

Substituting (10) into the expression for the share of services in consumption, we obtain the desired results:

$$
\begin{aligned}
c^s &= \frac{\int_{\underline{z}}^{\bar{z}} p_s\left(z,t\right)dz}{\int_{-\infty}^{\underline{z}} p_m\left(z,t\right)dz + \int_{\underline{z}}^{\bar{z}} p_s\left(z,t\right)dz} \\
&= \frac{\left(1+\frac{1}{n}\right)\left(e^{-\gamma t+\lambda\bar{z}} - e^{-\gamma t+\lambda\underline{z}}\right)}{\left(1-\frac{1}{n}\right)e^{-\gamma t+\lambda\underline{z}} + \left(1+\frac{1}{n}\right)e^{-\gamma t+\lambda\bar{z}}} \\
&= \delta - (1-\delta)\frac{\left(1+\frac{1}{n}\right)}{\left(1-\frac{1}{n}\right)}.
\end{aligned}
$$

We next show the necessity. From the individual's decision problem we obtain the following two restrictions:

$$2\int_{-\infty}^{\underline{z}} \frac{dz}{A\left(z\right)} + \left(1+\frac{1}{n}\right)\int_{\underline{z}}^{\bar{z}} \frac{dz}{A\left(z\right)} = e^{\gamma t}, \tag{11}$$

and

$$\frac{\delta}{1-\delta} = \frac{1+\frac{1}{n}}{1-\frac{1}{n}}\frac{A\left(\bar{z}\right)}{A\left(\underline{z}\right)}. \tag{12}$$

An additional restriction is given by the condition that the share of services in consumption (a similar argument holds for value added) is constant:

$$\tilde{y}_s = \frac{\left(1+\frac{1}{n}\right)\int_{\underline{z}}^{\bar{z}} \frac{dz}{A(z)}}{\int_{-\infty}^{\underline{z}} \frac{dz}{A(z)} + \left(1+\frac{1}{n}\right)\int_{\underline{z}}^{\bar{z}} \frac{dz}{A(z)}} \tag{13}$$

Totally differentiating (13) gives:

$$\frac{d\underline{z}}{A\left(\underline{z}\right)}\left(1+\frac{1}{n}-\tilde{y}_s\frac{1}{n}\right) = \frac{d\bar{z}}{A\left(\bar{z}\right)}\left(1+\frac{1}{n}-\tilde{y}_s\left(1+\frac{1}{n}\right)\right). \tag{14}$$

Using (12) and (14) we obtain:

$$\frac{d\underline{z}}{d\bar{z}} = \frac{1+\frac{1}{n}-\tilde{y}_s\left(1+\frac{1}{n}\right)}{\left(1+\frac{1}{n}-\tilde{y}_s\frac{1}{n}\right)}\frac{1+\frac{1}{n}}{1-\frac{1}{n}}\frac{1-\delta}{\delta}$$

Thus,

$$\bar{z} = a + b\underline{z} \tag{15}$$

for a constant a and $b = \frac{1+\frac{1}{n}-\tilde{y}_s\left(1+\frac{1}{n}\right)}{\left(1+\frac{1}{n}-\tilde{y}_s\frac{1}{n}\right)}\frac{1+\frac{1}{n}}{1-\frac{1}{n}}\frac{1-\delta}{\delta}$. Furthermore, $\frac{dz}{d\bar{z}} = b = 1$ since otherwise $\tilde{y}_s$ equals zero for sufficiently large (if $b > 1$) or low (if $b < 1$) income. Together, (12), (15), and $b = 1$ imply:

$$\frac{A'\left(a+\underline{z}\right)}{A\left(a+\underline{z}\right)} = \frac{A'\left(\underline{z}\right)}{A\left(\underline{z}\right)}, \tag{16}$$

Since (16) must hold for any $a \geq 0$ (as we vary n and δ) and all $\underline{z}$ (as we vary t) we obtain the desired result. ■

C   Derivations Associated with the Balanced Case (i.e. No Comparative Advantage)

This section provides the analysis of the balanced case discussed in Section 5, and proves Proposition 3.

Proof of Proposition 4.   In the case $\lambda_l = \lambda_h = \lambda$ the consumer's problem becomes:

$$\max_{0 \leq \underline{z}_e \leq \bar{z}_e} (1-\delta)\underline{z}_e + \delta\bar{z}_e$$

s.t.

$$\left(1 - \frac{1}{n}\right)\frac{e^{-\gamma t + \lambda \underline{z}_e}}{\bar{A}_l \lambda} + \left(1 + \frac{1}{n}\right)\frac{e^{-\gamma t + \lambda \bar{z}_e}}{\bar{A}_l \lambda} = w_e\left(1 - \theta\mathcal{I}\left(e\right)\right)$$

>From the first order conditions we obtain:

$$\frac{\left(w_e - \frac{1}{n}\right)}{1 - \delta}e^{-\gamma t + \lambda \underline{z}_e} = \frac{\left(1 + \frac{1}{n}\right)}{\delta}e^{-\gamma t + \lambda \underline{z}_e} \tag{17}$$

implying that consumption expansion paths correspond to 45° lines with negative constant terms:

$$\underline{z}_e = \frac{1}{\lambda}\log\left(\frac{1-\delta}{\delta}\frac{1+\frac{1}{n}}{w_e - \frac{1}{n}}\right) + \bar{z}_e$$

The expansion path is illustrated in Figure 13. Substituting (17) into the budget constraint we obtain an expression for the frontier want satisfied by an individual of skill e at time t:

$$\bar{z}_e\left(t\right) = \frac{\gamma}{\lambda}t + \frac{1}{\lambda}\log\left(\frac{\delta\bar{A}_l\lambda w_e\left(1 - \theta\mathcal{I}\left(e\right)\right)}{1+\frac{1}{n}}\right) \tag{18}$$
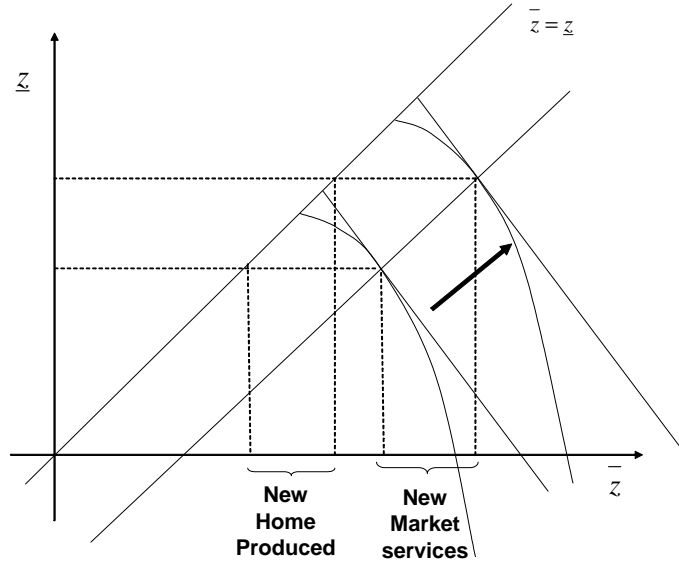
36

Figure 13: Expansion Path: Balance Case

Substituting (18) and (17) into the utility function we obtain an expression for the value function associated with different skill choices by an individual of talent θ:

$$
\begin{aligned}
V^e(\theta) \;=\;& (1-\delta)\ln\left[\frac{(1-\delta)\lambda\bar{A}_l w_e}{w_e - \frac{1}{n}}\right] + \delta\ln\left[\frac{\delta\lambda\bar{A}_l w_e}{1+\frac{1}{n}}\right] \\
& + \ln\left[(1-\theta\mathcal{I}(e))\right]
\end{aligned}
$$

The talent of the marginal specialized worker $\hat{\theta}$ then solves:

$$
V^l = V^h\left(\hat{\theta}\right)
$$

implying

$$
\widehat{\theta} = 1 - \frac{\bar{A}_l}{\bar{A}_h}\left(\frac{\frac{\bar{A}_h}{\bar{A}_l} - \frac{1}{n}}{1 - \frac{1}{n}}\right)^{1-\delta}.
$$

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For this economy aggregate output equals:

$$
\begin{aligned}
y(t) &= \left(1 - F\left(\hat{\theta}\right)\right) \left[\int_{-\infty}^{\bar{z}_l(t)} p_m(z,t)\, dz + \int_{\underline{z}_l(t)}^{\bar{z}_l(t)} p_s(z,t)\, dz \right] \\
&\quad + \int_0^{\hat{\theta}} \left[\int_{-\infty}^{\bar{z}_h(\theta,t)} p_m(z,t)\, dz + \int_{\underline{z}_h(\theta,t)}^{\bar{z}_h(\theta,t)} p_s(z,t)\, dz \right] dF(\theta)
\end{aligned}
$$

The aggregate value added of the service sector equals:

$$
\begin{aligned}
y_s(t) &= \left(1 - F\left(\hat{\theta}\right)\right) \left[\int_{\underline{z}_l(t)}^{\bar{z}_l(t)} \left(p_s(z,t) - \frac{1}{n} p_m(z,t) \right) dz \right] \\
&\quad + \int_0^{\hat{\theta}} \left[\int_{\underline{z}_h(\theta,t)}^{\bar{z}_h(\theta,t)} \left(p_s(z,t) - \frac{1}{n} p_m(z,t) \right) dz \right] dF(\theta)
\end{aligned}
$$

The aggregate consumption of services equals:

$$
\begin{aligned}
c_s(t) &= \left(1 - F\left(\hat{\theta}\right)\right) \left[\int_{\underline{z}_l(t)}^{\bar{z}_l(t)} p_s(z,t)\, dz \right] \\
&\quad + \int_0^{\hat{\theta}} \left[\int_{\underline{z}_h(\theta,t)}^{\bar{z}_h(\theta,t)} p_s(z,t)\, dz \right] dF(\theta)
\end{aligned}
$$

Using that $p_s(z,t) = \left(1 + \frac{1}{n}\right) p_m(z,t)$ it is clear from these equations that:

$$
\tilde{c}_s(t) = c_s(t)\,/y(t) = \frac{y_s(t)\,/y(t)}{1 + \frac{1}{n}} = \frac{\tilde{y}_s(t)}{1 + \frac{1}{n}}.
$$

∎

D Long Run Properties of the Case with Comparative Advantage ($\lambda_l > \lambda_h$)

Proof of Proposition 5. As long as

$$
\bar{z}_l = \frac{\gamma}{\lambda_l} t + \frac{1}{\lambda_l} \log\left(\frac{\delta \bar{A}_l \lambda_l}{1 + \frac{1}{n}} \right) < \frac{1}{\lambda_l - \lambda_h} \log\left(\frac{\bar{A}_l}{\bar{A}_h} \right)
$$

there is no demand for skills and the economy is in a balanced growth path with a constant share of services. This condition provides an equation to solve for t_0:

$$t_0 = \frac{\lambda_l}{\gamma} \frac{1}{\lambda_l - \lambda_h} \log\left(\frac{\bar{A}_l}{\bar{A}_h}\right) - \frac{1}{\gamma} \log\left(\frac{\delta \bar{A}_l \lambda_l}{1 + \frac{1}{n}}\right)$$

The share of services is given by the following equation:

$$
\begin{aligned}
y_s &= \frac{\int_{\underline{z}_l}^{\bar{z}_l} \frac{e^{-\gamma t + \lambda_l z}}{\bar{A}_l} dz}{\int_{-\infty}^{\underline{z}_l} \frac{e^{-\gamma t + \lambda_l z}}{\bar{A}_l} dz + \left(1 + \frac{1}{n}\right) \int_{\underline{z}_l}^{\bar{z}_l} \frac{e^{-\gamma t + \lambda_l z}}{\bar{A}_l} dz} \\
&= \frac{\frac{\delta}{1 + \frac{1}{n}} - \frac{1 - \delta}{1 - \frac{1}{n}}}{\delta - \frac{1 - \delta}{1 - \frac{1}{n}}} \\
&= \frac{n}{n + 1} \frac{\delta - \frac{n+1}{n-1}(1 - \delta)}{\delta - \frac{1-\delta}{n-1}}
\end{aligned}
$$

where the second equality uses the expression for $\underline{z}_l$ and $\bar{z}_l$ derived for the balanced case, i.e., equations (17) and (18).

To show the second part of Proposition 4 define $\bar{Z}_e(t) = e^{-\gamma t} e^{\lambda_h \bar{z}_e(t)}$, $\underline{Z}_e(t) = e^{-\gamma t} e^{\lambda_l \underline{z}_e(t)}$, $\hat{Z}_e(t) = e^{-\gamma t} e^{\lambda_l \hat{z}_e(t)}$, and $T(t) = (e^{-\gamma t})^{1 - \lambda_h/\lambda_l}$. After substituting for the equilibrium prices (5) and (4) the budget constrained can be written as:

$$
\begin{aligned}
\frac{\hat{Z}_e(t)}{\bar{A}_l \lambda_l} &+ w(t) \frac{T(t) \underline{Z}_e(t)^{\lambda_h/\lambda_l} - T(t) \hat{Z}_e(t)^{\lambda_h/\lambda_l}}{\bar{A}_h \lambda_h} \\
&+ \left(1 + \frac{1}{n}\right) \frac{w(t)}{\bar{A}_h \lambda_h}\left[\bar{Z}_e(t) - T(t)\underline{Z}_e(t)^{\lambda_h/\lambda_l}\right] \\
&\leq w_e(t)\left(1 - \frac{Z_e(t)}{\bar{A}_l \lambda_l} - \theta \mathcal{I}(e)\right)
\end{aligned}
$$

The first order condition is:

$$\frac{1 - \delta}{\delta} \geq \frac{\frac{w_e(t)}{w(t)} \frac{\bar{A}_h}{\bar{A}_l} \frac{Z_e(t)}{\bar{Z}_e(t)} - \frac{1}{n} \frac{T(t)\underline{Z}_e(t)^{\lambda_h/\lambda_l}}{\bar{Z}_e(t)}}{\left(1 + \frac{1}{n}\right)} (= if \underline{z}_e < \bar{z}_e)$$

Figure 14 illustrates the expansion path implied by the first order condition. Let $w = \lim_{t\to+\infty} w(t)$, using that $\lim_{t\to+\infty} T(t) = 0$, $\lim_{t\to+\infty} \underline{Z}_e(t) = \underline{Z}_e < +\infty$, $\lim_{t\to+\infty} \bar{Z}_e(t) = $

$\bar{Z}_e < +\infty$, and either $\lim_{t \to +\infty} \hat{Z} = 0$ or $\lim_{t \to +\infty} w(t) = +\infty$:

$$\left(1 + \frac{1}{n}\right) \frac{1}{\bar{A}_h \lambda_h} \bar{Z}_e$$

$$\leq \frac{w_e}{w} \left(1 - \frac{\bar{Z}_e}{\bar{A}_l \lambda_l} - \theta I(e = h)\right)$$

and the first order condition simplifies to:

$$\frac{1 - \delta}{\delta} = \frac{\frac{w_e}{w} \frac{\bar{A}_h}{\bar{A}_l}}{\left(1 + \frac{1}{n}\right)} \frac{\underline{Z}_e}{\bar{Z}_e}$$

These last two equations imply:

$$\bar{Z}_e = \frac{w_e}{w} \frac{\bar{A}_h (1 - \theta \mathcal{I}(e))}{\left(1 + \frac{1}{n}\right)\left(\frac{1}{\lambda_h} + \frac{1-\delta}{\delta} \frac{1}{\lambda_l}\right)}$$

and

$$\underline{Z}_e = \frac{1 - \delta}{\delta} \frac{\bar{A}_l (1 - \theta \mathcal{I}(e))}{\left(\frac{1}{\lambda_h} + \frac{1-\delta}{\delta} \frac{1}{\lambda_l}\right)}.$$

Substituting into the objective function:

$$\begin{aligned}
V^e(\theta) &= \frac{1-\delta}{\lambda_l} \log \underline{Z}_e(\theta) + \frac{\delta}{\lambda_h} \log \bar{Z}_e(\theta) \\
&= \frac{1-\delta}{\lambda_l} \log \frac{\bar{A}_l(1-\delta)}{\delta} + \frac{\delta}{\lambda_h} \log \frac{\bar{A}_h}{1 + \frac{1}{n}} \\
&\quad + \frac{\delta}{\lambda_h} \log \frac{w_e}{w} + \left[\frac{1-\delta}{\lambda_l} + \frac{\delta}{\lambda_h}\right] \log \frac{(1 - \theta \mathcal{I}(e))}{\left(\frac{1}{\lambda_h} + \frac{1-\delta}{\delta} \frac{1}{\lambda_l}\right)}
\end{aligned}$$

Thus, $\hat{\theta}$ solves:

$$\frac{\delta}{\lambda_h} \log w + \left[\frac{1-\delta}{\lambda_l} + \frac{\delta}{\lambda_h}\right] \log\left(1 - \hat{\theta}\right) = 0$$

or

$$\hat{\theta}(w) = 1 - w^{-\frac{\delta \lambda_l}{(1-\delta)\lambda_h + \delta \lambda_l}}.$$

Skilled labor market clearing implies:

$$
\begin{aligned}
F\left(\hat{\theta}\left(w\right)\right) &= \int_0^{\hat{\theta}(w)} \left[\left(1+\frac{1}{n}\right)\frac{\bar{Z}_h\left(\theta\right)}{\bar{A}_h\lambda_h} + \frac{\underline{Z}_h\left(\theta\right)}{\bar{A}_l\lambda_l} + \theta\right] dF\left(\theta\right) \\
&\quad + \left(1 - F\left(\hat{\theta}\left(w\right)\right)\right)\left(1+\frac{1}{n}\right)\frac{\bar{Z}_l}{\bar{A}_h\lambda_h} \\
&= \int_0^{\hat{\theta}(w)} dF\left(\theta\right) + \\
&\quad + \left(1 - F\left(\hat{\theta}\left(w\right)\right)\right)\frac{1}{w}\frac{1-\delta}{\delta\left(\frac{1}{\lambda_h} + \frac{1-\delta}{\delta}\frac{1}{\lambda_l}\right)}
\end{aligned}
$$

or

$$
F\left(\hat{\theta}\left(w\right)\right) = F\left(\hat{\theta}\left(w\right)\right) + \left(1 - F\left(\hat{\theta}\left(w\right)\right)\right)\frac{\delta}{w}
$$

Therefore, in the long run the skill premium goes to infinity and the entire population becomes skilled. ∎
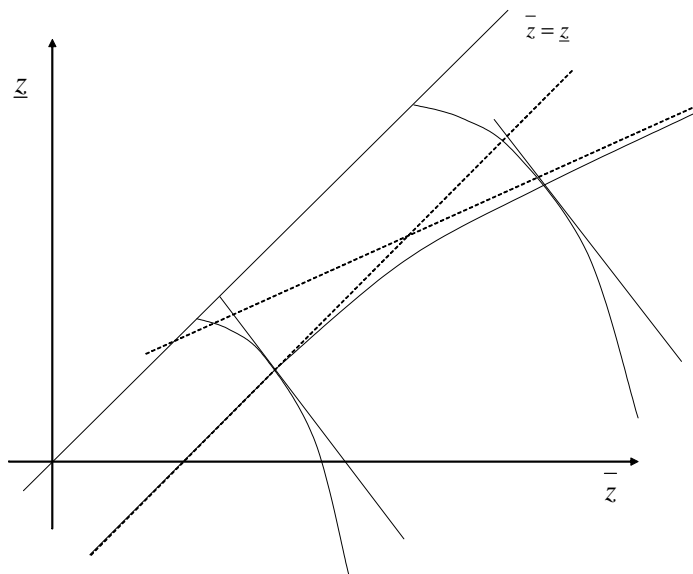

Figure 14: Expansion Path: Non-Balanced Case

Proof of Proposition 6. The evolution of the relative price of service to manufacturing equals:

$$\frac{\partial}{\partial t}\left(\frac{P_s(t)}{P_m(t)}\right) = \frac{1}{P_m(t)^2}\left\{\frac{\partial P_s(t)}{\partial t}P_m(t) - \frac{\partial P_m(t)}{\partial t}P_s(t)\right\}$$

or

$$\frac{\partial}{\partial t}\left(\frac{P_s(t)}{P_m(t)}\right)$$

$$= \frac{\partial w/\partial t}{P_m^2(t)}$$

$$\left\{\left[\left(1-F(\hat{\theta})\right)\int_{\underline{z}_l}^{\bar{z}_l}\frac{\partial p}{\partial w}dz + \int_0^{\hat{\theta}}\left[\int_{\underline{z}_h(\theta)}^{\bar{z}_h(\theta)}\frac{\partial p}{\partial w}dz\right]dF(\theta)\right]\right.$$

$$\left[\left(1-F(\hat{\theta})\right)\left[\int_{-\infty}^{\bar{z}_l}pdz + \frac{1}{n}\int_{\underline{z}_l}^{\bar{z}_l}pdz\right]\right.$$

$$+\left.\int_0^{\hat{\theta}}\left[\int_{-\infty}^{\bar{z}_h(\theta)}pdz + \frac{1}{n}\int_{\underline{z}_h(\theta)}^{\bar{z}_h(\theta)}pdz\right]dF(\theta)\right]$$

$$-\left[\left(1-F(\hat{\theta})\right)\left[\int_{-\infty}^{\bar{z}_l}\frac{\partial p}{\partial w}dz + \frac{1}{n}\int_{\underline{z}_l}^{\bar{z}_l}\frac{\partial p}{\partial w}dz\right]\right.$$

$$+\left.\int_0^{\hat{\theta}}\left[\int_{-\infty}^{\bar{z}_h(\theta)}\frac{\partial p}{\partial w}dz + \frac{1}{n}\int_{\underline{z}_h(\theta)}^{\bar{z}_h(\theta)}\frac{\partial p}{\partial w}dz\right]dF(\theta)\right]$$

$$\left.\left[\left(1-F(\hat{\theta})\right)\int_{\underline{z}_l}^{\bar{z}_l}pdz + \int_0^{\hat{\theta}}\left[\int_{\underline{z}_h(\theta)}^{\bar{z}_h(\theta)}pdz\right]dF(\theta)\right]\right\}$$

where $P_s(t)$ and $P_m(t)$ are the continuous time chain-weighted producers price deflators,[24] and $p(z,w)$ is such that:

$$p_m(z,t) = e^{-\lambda_t t}p(z,w),$$

---

[24] $P_s(t)$ and $P_m(t)$ also equal $Y_s(t)$ and $Y_m(t)$, respectively.

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where to save on notation we use $p(z, w) = p$. Simplifying:

$$\frac{\partial}{\partial t}\left(\frac{P_s(t)}{P_m(t)}\right)$$

$$= \frac{\partial w/\partial t}{P_m^2(t)}$$

$$\left\{\left[\left(1 - F(\hat{\theta})\right)\int_{\underline{z}_l}^{\bar{z}_l}\frac{\partial p}{\partial w}dz + \int_0^{\hat{\theta}}\left[\int_{\underline{z}_h(\theta)}^{\bar{z}_h(\theta)}\frac{\partial p}{\partial w}dz\right]dF(\theta)\right]\right.$$

$$\left[\left(1 - F(\hat{\theta})\right)\int_{-\infty}^{\bar{z}_l}pdz + \int_0^{\hat{\theta}}\int_{-\infty}^{\bar{z}_h(\theta)}pdzdF(\theta)\right]$$

$$-\left[\left(1 - F(\hat{\theta})\right)\int_{\underline{z}_l}^{\bar{z}_l}pdz + \int_0^{\hat{\theta}}\left[\int_{\underline{z}_h(\theta)}^{\bar{z}_h(\theta)}pdz\right]dF(\theta)\right]$$

$$\left.\left[\left(1 - F(\hat{\theta})\right)\int_{-\infty}^{\bar{z}_l}\frac{\partial p}{\partial w}dz + \int_0^{\hat{\theta}}\int_{-\infty}^{\bar{z}_h(\theta)}\frac{\partial p}{\partial w}dzdF(\theta)\right]\right\}$$

Notice that when t is such that $\underline{z}_l(t)$, $\underline{z}_h(\theta, t) < \hat{z}$ all θ:

$$\left(1 - F(\hat{\theta})\right)\int_{-\infty}^{\bar{z}_l}\frac{\partial p}{\partial w}dz + \int_0^{\hat{\theta}}\int_{-\infty}^{\bar{z}_h(\theta)}\frac{\partial p}{\partial w}dzdF(\theta)$$

$$= 0$$

It is also easy to see that when t is such that $\underline{z}_l(t)$, $\underline{z}_h(\theta, t) > \hat{z}$ all θ:

$$\left(1 - F(\hat{\theta})\right)\int_{\underline{z}_l}^{\bar{z}_l}\frac{\partial p}{\partial w}dz + \int_0^{\hat{\theta}}\left[\int_{\underline{z}_h(\theta)}^{\bar{z}_h(\theta)}\frac{\partial p}{\partial w}dz\right]dF(\theta)$$

$$= \left(1 - F(\hat{\theta})\right)\int_{\underline{z}_l}^{\bar{z}_l}pdz + \int_0^{\hat{\theta}}\left[\int_{\underline{z}_h(\theta)}^{\bar{z}_h(\theta)}pdz\right]dF(\theta)$$

In both case we have that:
$$\frac{\partial}{\partial t}\left(\frac{P_s(t)}{P_m(t)}\right) > 0.$$

To prove the general case it is useful to define $\tilde{\theta}$ such that $\underline{z}_h\left(\tilde{\theta}, t\right) = \hat{z}$, i.e., we have $\underline{z}_h\left(\theta, t\right) > \hat{z}$ for $\theta \in [0, \tilde{\theta})$ and $\underline{z}_h\left(\theta, t_0\right) < \hat{z}$ for $\theta \in (\tilde{\theta}, \hat{\theta}]$.

$$
\frac{\partial}{\partial t}\left(\frac{P_s\left(t\right)}{P_m\left(t\right)}\right)
$$

$$
= \frac{\partial w / \partial t}{P_m^2\left(t\right)}
$$

$$
\left\{ \left[\begin{array}{c} \left(1 - F(\hat{\theta})\right) \int_{\underline{z}_l}^{\bar{z}_l} \frac{\partial p}{\partial w} dz + \\ \int_0^{\tilde{\theta}} \left[\int_{\underline{z}_h(\theta)}^{\bar{z}_h(\theta)} \frac{\partial p}{\partial w} dz \right] dF(\theta) + \int_{\tilde{\theta}}^{\hat{\theta}} \left[\int_{\underline{z}_h(\theta)}^{\bar{z}_h(\theta)} \frac{\partial p}{\partial w} dz \right] dF(\theta) \end{array} \right] \right.
$$

$$
\left[\left(1 - F(\hat{\theta})\right) \int_{-\infty}^{\bar{z}_l} p\, dz + \right.
$$

$$
\left. \int_0^{\tilde{\theta}} \int_{-\infty}^{\bar{z}_h(\theta)} p\, dz\, dF(\theta) + \int_{\tilde{\theta}}^{\hat{\theta}} \int_{-\infty}^{\bar{z}_h(\theta)} p\, dz\, dF(\theta) \right]
$$

$$
- \left[\begin{array}{c} \left(1 - F(\hat{\theta})\right) \int_{\underline{z}_l}^{\bar{z}_l} p\, dz + \\ \int_0^{\tilde{\theta}} \left[\int_{\underline{z}_h(\theta)}^{\bar{z}_h(\theta)} p\, dz \right] dF(\theta) + \int_{\tilde{\theta}}^{\hat{\theta}} \left[\int_{\underline{z}_h(\theta)}^{\bar{z}_h(\theta)} p\, dz \right] dF(\theta) \end{array} \right]
$$

$$
\left[\left(1 - F(\hat{\theta})\right) \int_{-\infty}^{\bar{z}_l} \frac{\partial p}{\partial w} dz + \right.
$$

$$
\left. \left. \int_0^{\tilde{\theta}} \int_{-\infty}^{\bar{z}_h(\theta)} \frac{\partial p}{\partial w} dz\, dF(\theta) + \int_{\tilde{\theta}}^{\hat{\theta}} \int_{-\infty}^{\bar{z}_h(\theta)} \frac{\partial p}{\partial w} dz\, dF(\theta) \right] \right\}
$$

Using $\frac{\partial p}{\partial w} = \frac{1}{w}p$ for all high-skill goods:

$$\frac{\partial}{\partial t}\left(\frac{P_s(t)}{P_m(t)}\right)$$

$$= \frac{\partial w/\partial t}{P_m^2(t)}\frac{1}{w}$$

$$\left\{\left[\begin{array}{c}\left(1-F(\hat{\theta})\right)\int_{\underline{z}_l}^{\bar{z}_l} pdz+ \\ \int_0^{\tilde{\theta}}\left[\int_{\underline{z}_h(\theta)}^{\bar{z}_h(\theta)} pdz\right]dF(\theta) + \int_{\tilde{\theta}}^{\hat{\theta}}\left[\int_{\hat{z}}^{\bar{z}_h(\theta)} pdz\right]dF(\theta)\end{array}\right]\right.$$

$$\left[\left(1-F(\hat{\theta})\right)\int_{-\infty}^{\underline{z}_l} pdz +\right.$$

$$\left.\int_0^{\tilde{\theta}}\int_{-\infty}^{\underline{z}_h(\theta)} pdzdF(\theta) + \int_{\tilde{\theta}}^{\hat{\theta}}\int_{-\infty}^{\underline{z}_h(\theta)} pdzdF(\theta)\right]$$

$$-\left[\begin{array}{c}\left(1-F(\hat{\theta})\right)\int_{\underline{z}_l}^{\bar{z}_l} pdz + \int_0^{\tilde{\theta}}\left[\int_{\underline{z}_h(\theta)}^{\bar{z}_h(\theta)} pdz\right]dF(\theta) \\ + \int_{\tilde{\theta}}^{\hat{\theta}}\left[\int_{\underline{z}_h(\theta)}^{\bar{z}_h(\theta)} pdz\right]dF(\theta)\end{array}\right]$$

$$\left.\left[\left(1-F(\hat{\theta})\right)\int_{\hat{z}}^{\bar{z}_l} pdz + \int_0^{\tilde{\theta}}\int_{\hat{z}}^{\bar{z}_h(\theta)} pdzdF(\theta)\right]\right\}$$

Defining $A_1 = \int_0^{\tilde{\theta}}\int_{-\infty}^{\hat{z}} pdzdF(\theta)$, $B_1 = \int_0^{\tilde{\theta}}\int_{\hat{z}}^{\bar{z}_h(\theta)} pdzdF(\theta)$, $C_1 = \int_0^{\tilde{\theta}}\int_{\underline{z}_h(\theta)}^{\bar{z}_h(\theta)} pdzdF(\theta)$, $A_2 = \int_{\tilde{\theta}}^{\hat{\theta}}\int_{-\infty}^{\bar{z}_h(\theta)} pdzdF(\theta)$, $B_2 = \int_{\tilde{\theta}}^{\hat{\theta}}\int_{\underline{z}_h(\theta)}^{\hat{z}} pdzdF(\theta)$, $C_2 = \int_{\tilde{\theta}}^{\hat{\theta}}\int_{\hat{z}}^{\bar{z}_h(\theta)} pdzdF(\theta)$, $A_3 = \left(1 - F\left(\hat{\theta}\right)\right)\int_{-\infty}^{\hat{z}} pdz$, $B_3 = \left(1 - F\left(\hat{\theta}\right)\right)\int_{\hat{z}}^{\bar{z}_l} pdz$, $C_3 = \left(1 - F\left(\hat{\theta}\right)\right)\int_{\underline{z}_l}^{\bar{z}_l} pdz$, we can rewrite the previous expression in more compact form:

$$\frac{\partial}{\partial t}\left(\frac{P_s(t)}{P_m(t)}\right)$$

$$= \frac{\partial w/\partial t}{P_m^2(t)}\frac{1}{w}$$

$$\left\{\left[C_3 + C_1 + C_2\right]\left[A_3 + B_3 + A_1 + B_1 + A_2\right]\right.$$

$$\left.-\left[C_3 + C_1 + B_2 + C_2\right]\left[A_3 + B_3 + B_1\right]\right\}$$

$$\frac{\partial}{\partial t}\left(\frac{P_s(t)}{P_m(t)}\right)$$

$$= \frac{\partial w/\partial t}{P_m^2(t)}\left(1+\frac{1}{n}\right)\frac{1}{w}$$

$$\left\{\left[C_3+C_1+C_2\right]\left[A_1+A_2\right]-B_2\left[A_3+B_3+B_1\right]\right\}$$

Therefore,

$$\frac{\partial}{\partial t}\left(\frac{P_s(t)}{P_m(t)}\right) \overset{s}{=} \frac{C_1+C_2+C_3}{B_1+B_3}-\frac{B_2}{A_1+A_2+A_3}$$

Intuitively, the inflation of services is higher than the inflation of manufactured goods if and only if the output share of skilled services in total services is greater than the output share of skilled manufactured sectors in total manufacturing. Defining $\tilde{B}_1 = \int_0^{\tilde{\theta}} \int_{\hat{z}}^{\bar{z}_l} pdzdF(\theta)$, $\tilde{B}_2 = \int_{\tilde{\theta}}^{\hat{\theta}} \int_{-\infty}^{\hat{z}} pdzdF(\theta)$, $\tilde{C}_2 = \int_{\tilde{\theta}}^{\hat{\theta}} \int_{\hat{z}}^{\bar{z}_l} pdzdF(\theta)$ we have:

$$\frac{C_1+C_2+C_3}{B_1+B_3} > \frac{\tilde{C}_2}{\tilde{B}_1+B_3}$$

$$= \frac{\int_{\tilde{\theta}}^{\hat{\theta}} \int_{\hat{z}}^{\bar{z}_l} pdzdF(\theta)}{\int_0^{\tilde{\theta}} \int_{\hat{z}}^{\bar{z}_l} pdzdF(\theta)+\left(1-F\left(\hat{\theta}\right)\right)\int_{\hat{z}}^{\bar{z}_l} pdz}$$

$$= \frac{\int_{\tilde{\theta}}^{\hat{\theta}} dF(\theta)}{\int_0^{\tilde{\theta}} dF(\theta)+\left(1-F\left(\hat{\theta}\right)\right)}$$

and

$$\frac{B_2}{A_1+A_2+A_3} < \frac{\tilde{B}_2}{A_1+A_2}$$

$$= \frac{\int_{\tilde{\theta}}^{\hat{\theta}} \int_{-\infty}^{\bar{z}_l} pdzdF(\theta)}{\int_0^{\tilde{\theta}} \int_{-\infty}^{\bar{z}_l} pdzdF(\theta)+\left(1-F\left(\hat{\theta}\right)\right)\int_{-\infty}^{\bar{z}_l} pdz}$$

$$= \frac{\int_{\tilde{\theta}}^{\hat{\theta}} dF(\theta)}{\int_0^{\tilde{\theta}} dF(\theta)+\left(1-F\left(\hat{\theta}\right)\right)}.$$

Implying:

$$\frac{C_1+C_2+C_3}{B_1+B_3} > \frac{B_2}{A_1+A_2+A_3}.$$

■

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