

The Rise of the Service Economy

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This paper analyzes the role of specialized high-skilled labor in the disproportionate growth of the service sector. Empirically, the importance of skill-intensive services has risen during a period of increasing relative wages and quantities of high-skilled labor. We develop a theory in which demand shifts toward more skill-intensive output as productivity rises, increasing the importance of market services relative to home production. Consistent with the data, the theory predicts a rising level of skill, skill premium, and relative price of services that is linked to this skill premium.

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Two of the most salient, interesting trends in the post-1950 U.S. economy have been the rising importance of the service sector and the growth in the skill premium in wages despite a large expansion in the relative supply of high-skilled workers. The growth of the service sector and the relative demand for high-skilled workers have been well studied in independent literatures, but theorists have not formally linked the two phenomena.

This paper provides a theoretical framework for understanding the connection between skill accumulation and the growth of the service sector. Contrary to the conventional view, we argue that the growth in services is driven by the movement of consumption into more skill-intensive output. In doing so, we provide a new theory for the rise in the price and quantity of skilled labor, which is distinct from the common story of skill-biased technical change.

Several empirical trends involving services and skills motivate our analysis. First, the share of the service sector in value-added has grown steadily from 60 percent in 1950 to 80 percent in 2000, and it reflects disproportionate growth in both the price and real quantity of services. Second, this 20 percentage point increase is explained entirely by the growth of skill-intensive services: The output of high-skill industries increases by more than 25 percent, whereas the share of low-skill industries actually declines. Third, over the same period, the wages of college graduates rose from 125 percent to more than twice the wages of high school graduates, and the fraction of workers who were college educated rose from just 15 percent to over 60 percent.¹ Finally, the growth in college-

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¹Here we follow the methodology of Katz and Murphy (1992), constructing wages using men with 16 and 12 years of completed schooling, while constructing quantities using all workers with more than 12 or 12 or fewer years of education,

educated labor, the skill premium, the relative size of skill-intensive services, and the share of the service sector all accelerate around 1950.

Our key theoretical idea linking these three phenomena is that skills are specialized, and specialization plays an important role in the decision between home and market provision of services. Namely, the market allows the use of specialized skilled labor in production. This lowers costs relative to home production, since even high-skilled workers hold no specialty in most home production activities. This effect is greater, the larger the relative productivity of specialized high-skilled workers. With development, the increase in the consumption of more skill-intensive wants leads to a rise in the importance of market services, and an increase in the quantity and price of skills. The higher price amounts to a higher opportunity cost for home production, leading high-skilled workers to purchase an even wider range of services in the market.

We represent this idea using a stylized, static model in which a stand-in representative household faces a range of satiable wants that differ in their production costs. The household decides which wants to satisfy and whether to home produce or market purchase the services satisfying these wants. In addition, the representative household determines the fraction of members that are required to obtain specialized skills, and how high- and low-skilled members should allocate their time between home and market production. Market production has a cost advantage due to the use of more productive specialized skills, but home production is assumed to be more customized and therefore provides more utility. Furthermore, we assume that high-skilled workers have an increasing comparative advantage in the production of wants whose costs exceed a given threshold, and are therefore satisfied only at high incomes. Among the least complex wants, high-skilled workers have a constant absolute advantage.

To shed light on how these trade-offs shape the dynamics associated with development, we perform comparative statics with respect to a productivity parameter that is skill- and sector-neutral. At low levels of productivity, and hence income, only the wants for which high-skilled workers hold a constant absolute advantage are satisfied. Thus, the margin between home and market production is independent of productivity, and the skill premium, the fraction of workers becoming high skilled, and the share of services therefore remain constant in the face of productivity increases. Above a threshold level of productivity, however, demand begins shifting continually toward services for which high-skilled workers hold an ever-increasing productivity advantage. The expansion of consumption into these services changes the mix of services optimally produced in the market relative to the home.

Beyond this threshold, the higher is productivity, the greater is the importance of specialized high-skilled labor at high levels of productivity, which leads to the rise of the service economy. That is, it leads to growth in the range of services that are market produced relative to those home produced, and ultimately to growth in the relative quantity and relative wage of high-skilled workers. In the limit, as productivity increases, the share of services in consumption converges to one, though the share of services in value-added is bounded below one. Moreover, the growth in the real share of services

respectively. We refer to those with some college (more than 12 years of education) as college educated.

is also accompanied by growth in the relative price of services: the rising relative wage increases the cost and price of market services relative to goods, since the former are more skill intensive in equilibrium.

We relax the stylized assumption that home production is centrally produced by a stand-in household, and we highlight additional factors contributing to the growth in services by simulating an economy in which individual agents perform their own home production. In this case, the opportunity cost of home production is higher for high-skilled workers who therefore consume a higher fraction of their services on the market. Thus, when productivity grows, the rising fraction of high-skilled workers increases the overall share of services. Moreover, the rising relative wage resulting from productivity growth also increases the opportunity cost of home production, leading to an even greater shift toward market services.

We show, using a panel of nine countries with comparable data, that the rise in the skill premium is tightly related to increases in per capita income after controlling for time effects, which provides suggestive evidence in favor of our demand-driven story for the rise in the quantity and price of high-skilled labor.

The rest of the paper is organized as follows. We conclude this introduction with a review of related literature. Section I then establishes the facts that motivate our analysis. The model is laid out in Section II, while Section III describes the theoretical results and Section IV presents an alternative model. In Section V, we discuss the relationship between the theory and the motivating facts, together with additional testable implications. Section VI concludes.

A. *Related Literature*

Our paper is related to a vast existing literature on structural change, for which we provide a (very) incomplete summary in order to delineate our relative contribution.

Earlier discussions of the facts and explanations for the changes in the structure of production include Clark (1941), Stigler (1956), Kuznets (1957), Baumol (1967), Fuchs (1968), Kravis, Heston and Summers (1984), and Maddison (1987). These authors observed an early growth of the employment share of the service sector, and posited that a combination of biased productivity rates and nonhomothetic preferences were important in explaining labor shifts across sectors. A recent literature has adapted these ideas to explain long-run structural change within models that are consistent with Kaldor facts. Kongsamut, Rebelo and Xie (2001) posit neutral technological progress and non-homothetic preferences, while Ngai and Pissarides (2007) build a framework in which sector-biased technological progress drives structural change. In Acemoglu and Guerrieri (2008), sectoral differences in factor shares and capital deepening lead to changes in the structure of production. We complement this literature by modeling skill intensity differences between market and home production of services. We study the role of home production decisions, the growth of skill-intensive manufacturing and service industries, and neutral technological progress as driving forces of structural change. This approach helps address a series of empirical observations, including the late rise of the share of services in value-added, the skill composition of services, and the joint movement of

relative prices and quantities. We also focus on output and consumption rather than the allocation of raw labor.

There is also an existing literature on the role of home versus market production. Ngai and Pissarides (2008) and Rogerson (2008) are two recent contributions examining the role of home production in explaining the labor market shift toward services.² These authors model differential rates of productivity growth across market and home production sectors in order to explain labor movements. Greenwood, Seshadri and Yorukoglu (2005) also emphasize technological change in the home, but their focus is on the growth of the female labor force rather than the service sector. Locay (1990) analyzes the role of customization and scale in the home versus market decision. Finally, the work by de Vries (1994) emphasizes the changes between home and market production over development, including the importance of two-way movements, with market production rising in the early stages of the industrious revolution, and home production gaining importance with the decline in female labor supply in the latter phases of the Industrial Revolution. This paper complements these papers by analyzing the relationship between home production, human capital acquisition, and the service sector.

Our analysis of human capital is related to several other papers. Becker and Murphy (2007) examine the effect of general, rather than specialized, human capital on non-market productivity. Caselli and Coleman (2001) use human capital accumulation to explain discrepancies in labor and output trends in the decline of agriculture. Kaboski (2009) shows that human capital investments are often related to reallocations of labor across industries. Our paper's emphasis on the role of specialization, home versus market production, and the feedback on services is unique.

Our particular nonhomothetic preferences build on those of Matsuyama (2000), Matsuyama (2002), Murphy, Shleifer and Vishny (1989), and Zweimueller (2000) in their work on structural change. These preferences have shown to be a tractable way of modeling nonhomotheticities over disaggregated components of consumption. Our innovation is to introduce a decision between home and market production. Hall and Jones (2007) provide an important contribution in explaining the underlying nonhomotheticity for one important area of consumption: health care. Our model of disaggregated activities and nonhomothetic preferences is also closely related to Foellmi and Zweimueller (2008). Their analysis posits a direct preference explanation in which hierarchical wants are satisfied first as agriculture, then industry, and finally services. Our model has no direct exogenous nonhomotheticity toward services, but we emphasize how this can arise endogenously through the home production margin and a nonhomothetic shift toward skill-intensive wants. Given our focus on the consumption of heterogeneous services, with more complex, newer ones contributing to the rise of the service economy, our paper relates to the earlier work by Katouzian (1970).

Finally, our companion work Buera and Kaboski (forthcoming) uses identical preferences with a home production margin, but in that paper the focus is on the role of minimum scale rather than skill intensity in structural change. Moreover, its focus is on

²A related literature has emphasized the role of home production in less developed economies, including an emphasis on structural change out of agriculture (e.g., Gollin, Parente and Rogerson (2004), Buera and Kaboski (forthcoming)).

longer-run structural change including the rise of manufacturing.

I. Empirics

This section establishes several facts that motivate our theory.³ First, we show that the growth in the share of services accelerates at high incomes and involves disproportionate growth in the real quantity and price of services.⁴ Second, the growth of high-skill services accounts for the entire growth in the service share. Finally, we discuss the fact that the timing of the growth in services coincides with two well-known trends in the literature: the spread of college education and the rising return to skill.

A. Service Share

Figure 1 shows a strong mid-century break in the current-value shares of services in value-added in the United States. These data are from Martin (1939) from 1869 to 1920, the only source to give value-added in current values for the full service sector, and from national income and product accounts (NIPA) after 1929. The data include health, education, professional and personal services, transportation, FIRE (finance, insurance, and real state), wholesale and retail trade, as well as government and public utilities.⁵ We present value-added data, but we stress that all these facts hold for data on the share of final expenditures on services, as we show in our Web Appendix.

The growth in the share of services post-1950 has been driven by growth in both the relative real quantity of services and their relative price. Figure 2 illustrates this by decomposing the growth in the current-price value-added of services relative to commodities into the growth in the measured relative price of services and the relative real (i.e., deflated) quantities. Both show a positive trend, and both play a substantial role in the overall growth of the relative value of services.⁶

This decomposition is introduced with the caveat that changes in prices are measured imperfectly because of changes in quality over time. Quality improvements exist for both goods and services, but the rates of change and ability to control or adjust for quality may also vary across sectors. Moreover, many real quantities of services are only measured implicitly, and indeed Bosworth and Triplett (2007) and Griliches (1992) argue that growth in the real quantity of services is understated, and price growth is therefore overstated.

The growth of services in the U.S. is a late phenomenon, accelerating only post-1950. The acceleration of the share of services is a feature common to many countries, but across countries the break is more strongly tied to income per capita than chronological year. We show this using Buera and Kaboski (forthcoming)'s panel data assembled for 31 countries spanning six continents and constituting two-thirds of the world's population

³Our data, source documentation, and calculations are available at <http://XX>

⁴Kuznets (1957) noted the late acceleration in the value-added share of services for a small sample of countries, but it has nevertheless been overlooked in the literature (e.g., Maddison (1987)), probably because raw labor numbers tend to be more readily available.

⁵The same substantial trend exists when excluding government and public utilities.

⁶Lee and Wolpin (2006) established the same facts but over a shorter period of 1968-2000.

and 80 percent of global output.⁷ In 1950, the U.S. had an income per capita of \$9,200, in Gheary-Khamis 1990 international dollars. We divide the sample of country-year observations using this \$9,200 threshold, and then run the following regressions on the low- and high-income samples:

$$(1) \quad \text{services share of value-added}_{i,t} = \alpha_i + \beta \ln y_{i,t} + e_{i,t}$$

where $\ln y_{i,t}$ is log of per capita income of country i at time t , and α_i is a country i fixed effect. (We include fixed effects to control for level differences in the series, some of which are the result of differences in measurement across countries.⁸) Here β captures the effect of the within-country variation of income on the service share. In both samples, the estimate of β is positive and significant, but it increases more than three fold across samples: from just 0.06 (std. error of 0.01) for the $< \$9,200$ sample to 0.22 (0.02) for $\geq \$9,200$ sample. In contrast, splitting the sample by the year 1950 yields similar coefficients of 0.08 (0.01) before 1950 and 0.11 (0.01) from 1950 on.⁹ Thus, an acceleration of the share of services at higher incomes appears to be a common feature of structural transformation.

We should note that trends in the share of labor in services differ from those in the value-added (and consumption) shares. Rather than a delayed acceleration of services, the share of labor in services increases much more gradually with income per capita, both over time in the U.S. (Ngai and Pissarides (2008)) and in the cross section of countries (Kuznets, 1957).¹⁰ These numbers imply large differences in output per worker across sectors in the earlier period for the U.S. (Caselli and Coleman (2001); Buera and Kaboski (2009)). If skill levels differ across sectors, the numbers may reflect large discrepancies between raw labor and effective labor. Raw labor numbers may not be as informative for our purposes, especially given our emphasis on human capital. Still, the reason for the discrepancy between sectoral output and labor allocations pre-1950 is an open question, and not one that our theory will explain.

⁷These countries include Argentina, Australia, Austria, Brazil, Canada, Chile, China, Colombia, Denmark, Egypt, France, Germany, India, Indonesia, Israel, Italy, Japan, Korea, Mexico, Netherlands, Norway, Pakistan/Bangladesh, Spain, Sri Lanka, Sweden, Switzerland, United Kingdom, United States, Taiwan, and Thailand. Based on Maddison (2006), our data cover: 68 percent of world population and 81 percent of world GDP in 2000; 71 percent and 75 percent, respectively, in 1950; and 40 percent and 60 percent, respectively, in 1900. Although the numbers are lower for 1900, since the longer time series include Western Europe and its offshoots, we cover a much larger share of the population and economic activity undergoing large structural change at the time.

⁸For example, in several countries utilities cannot be separated from mining and so are excluded from services. Countries also differ to the extent that small-scale handicrafts are classified as services or manufacturing. Another interesting example is China, whose historical data show an extremely low share of services, probably because services were not viewed as producing value under Marxist ideology. After the Economic Census of 2004, the service share was revised upwards by 9 percentage points in the current official data.

⁹That is, the growth in services appears to be a feature of development rather than driven by a common shock to the world economy such as a commonly available new technology or adoption of a common policy.

¹⁰The difference between the labor and value-added trends in a small sample of developed countries was noticed quite early by Kuznets (1957).

B. *Composition of Services*

A second motivating fact is that the growth in services has been driven by skill-intensive services. Figure 3 decomposes the growth in services into the contributions of high- and low-skill industries. We rank industries according to their skill intensity as measured by the fraction of workers with more than 12 years of schooling in 1940 (the last available data preceding the acceleration) and partition the value-added of the service sector in half in 1950. High-skill industries are those industries with at least 12.5 percent of labor with more than 12 years of education in 1940.¹¹ We again see a breakpoint at 1950, and the rise of the service economy has been clearly driven by high-skill industries. The importance of low-skill service industries in value-added has actually declined. Again, an analogous partition using final expenditure data, available in our Web Appendix, yields a nearly identical picture, except that low-skill services stay constant rather than declining. In any case, growth patterns clearly differ across skill intensity.

We can look at a more disaggregated level if we focus on labor compensation data. Labor compensation numbers are nearly identical to value-added numbers in Figures 1 and 3, but are available at a more detailed level.¹² Figure 4 shows that there are many quantitatively important industries in the growth of high-skill services. It plots the absolute change in the share of different service industries in total labor compensation between 1950 and 2000 against the skill intensity of the industry (measured as the college-educated fraction of workers in 1940). Again, given available data, this positive relationship appears to be particular only to the high income, post-1950 period.¹³

The absolute importance of each industry to the total growth in services is its vertical distance from the zero growth line. The growing high-skill services include education (especially higher education), legal services, banking, real estate and accounting, broadcasting and television, air transportation, and health care. We emphasize that the growth in services is a broad increase in the demand for output that is intensive in specialized skills.

Of course, two important industries are health care and education, whose growth may be driven at least in part by growth in government subsidies or other policies. While important, however, these industries are simply not the full story. For example, medical services and hospitals together account for almost an 8 percentage point increase, but they constitute less than one-quarter of the total rise in high-skill services, and the 5 percentage point increase in education constitutes less than one-fifth.

Moreover, all the trends we highlight are robust to the exclusion of health care, education, and government from the data. Namely, the remaining service industries do not rise

¹¹These rankings are remarkably stable over time. We could have produced identical results if we had used data in 2000 to rank industries, but we would need a cutoff of 50 percent.

¹²Neither output nor final expenditure share data can be merged precisely with workforce education data at this detailed level. The detailed industry and education data come from the Integrated Public Use Microdata Series (IPUMS) censuses. After 1950, census labor and compensation numbers closely mirror NIPA numbers, except that census compensation does not include benefits. Using manhours instead of labor compensation yields a very similar picture.

¹³Although only a single decade of data is available, census data show no relationship between our measure of skill intensity and growth in the share of disaggregated services from 1940 to 1950. At an even more disaggregated level, it is clear that many high-skill services were not produced in earlier periods.

until after 1950, but then rise 16 percentage points thereafter, and growth of the remaining high-skill services (19 percentage points) again exceeds service growth overall.

More generally, we emphasize that the compositional change in services involves not only *what* is being consumed, but *how* it is being delivered. Indeed, even within the categories of health care and education, 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 in NIPA data, the share of services in health care final expenditures rose from 77 percent in 1950 to 84 percent in 2000. Similarly, if we combine educational services and books we see that the share of services in this broad educational final expenditure category increases from 73 percent in 1950 to 83 percent in 2000.

C. Market for High-Skilled Labor

The final motivating fact is the well-known increase in both the relative quantity and relative wage of high-skilled labor, the timing of which coincides with the growth in services. Using college-educated workers as a proxy for high-skilled workers, Figure 5 shows the growth in the relative price and relative quantity of skilled labor.¹⁴ The average wage of these workers rose from 125 percent of the average high school-graduate 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 15 percent to 60 percent. The rising disparity between high- and low-skilled workers is of great interest from a policy perspective.

Based on available evidence for the U.S., the timing of trends involving the service economy and the market for high-skilled labor is intimately connected. That is, the year 1950, or the \$9,200 threshold, appears to be a turning point for trends related to the schedule for the excess demand for skill. Wage and education questions were first introduced in the 1940 census, and so representative data are scant before that. There was a sharp decrease in premia to skill, including the college premium between 1940 and 1950. Broader returns to education, and other proxies for the skill premium such as white collar-blue collar occupation differentials, did not increase and most likely declined before 1940 (see Goldin and Katz (1999)).¹⁵

Levels of education and other measures of skill increased prior to this, and the growth in skills in the labor force is clearly part of a more continuous process. Still, as a dichotomous measure, college education appears to be an appropriate measure of the level of skills associated with the rise of the service economy.¹⁶ The college boom is overwhelmingly a post-1950 phenomenon, since college-educated workers accounted for just 11 percent of the labor force in the 1940 U.S. census. The college boom also coincides

¹⁴We focus on college education, but the trends hold for a broad range of “high-skilled” workers (see Juhn, Murphy and Pierce (1993)).

¹⁵Goldin and Katz’s story for the decline in the skill premium before 1950 is the increased supply of skills from the high school movement.

¹⁶Empirically, an increase in elementary and high school education precedes the college boom. From the point of view of a more general model with multiple levels of high-skill, these lower levels of education could be viewed as allowing individuals to be specialized in the production of less complex output, where skill has merely an absolute advantage.

with the \$9,200 threshold in other countries as well. Using data from Cohen and Soto (2007), the fraction of the adult (25+) population of a country that has some college education averages just 0.08 (std. dev. of 0.03) at real incomes near \$9,200. Split-sample regressions analogous to equation (1), but where the service share is replaced with the fraction of college-educated adults, yield a five fold increase in the coefficient on log income between the low- and high-income samples, from 0.04 ($< \$9,200$) to 0.23 ($\geq \$9,200$).¹⁷ That is, both growth in the service economy and investment in college education coincide with an income per capita of \$9,200.

A final indication that the market for services is related to the market for high-skilled labor is given in Figure 6. It plots the relative wage of college-educated workers along with the relative price of services over time for the United States. We have normalized the two to be equal in year 1940. There is a tight relationship between the two. In particular, the decade-to-decade fluctuations mirror each other, and the percentage movements are even of similar magnitude.

II. Environment

In this section, we model a stand-in household consisting of a measure one continuum of members/workers. Although members are ex ante identical, ex post they will be differentiated by their skill level e (for education), either specialized high-skilled workers ($e = h$) or low-skilled workers ($e = l$). The household chooses the fraction of workers that are high- and low-skilled (denoted f^h and $f^l = 1 - f^h$, respectively) and labor supply decisions. It also chooses what services to consume, and whether to purchase these services from the market or home produce them by acquiring the necessary manufactured inputs. The model is static, but comparative statics with respect to productivity will show how productivity growth leads to the relative growth of the service sector, the relative wage, and the quantity of high-skilled labor.

A. Preferences

The household holds preferences over a continuum of discrete, satiable wants indexed by the service that satisfies them, $z \in \mathbb{R}^+$. Thus, all final consumption takes the form of services.¹⁸ Let the function $C^e(z) : \mathbb{R}^+ \rightarrow \{0, 1\}$ indicate whether a particular want is being satisfied for household members of skill level e . Wants can be satisfied via market production or home production. Define the function $\mathcal{H}^e(z) : \mathbb{R}^+ \rightarrow \{0, 1\}$ to take the value 1 if want z is satisfied by home production for members with skill level e and 0 otherwise. Together the set of indicator functions mapping \mathbb{R}^+ into $\{0, 1\}$ ² defines the consumption set. The stand-in household holds preferences over wants and the method of satisfying those wants, i.e., over pairs of indicator functions $\mathcal{C} = \{C^l(z), C^h(z)\}$ and $\mathcal{H}(z) = \{\mathcal{H}^l(z), \mathcal{H}^h(z)\}$, which are represented by the following utility function:

¹⁷For each country, we use all countries with a year of income between \$8,500 and \$9,500 and choose the year closest to \$9,200. In comparison, at this income level, primary education is nearly complete (the fraction of the adult population averages 0.97), while secondary schooling is well under way (0.37).

¹⁸One could easily introduce a second continuum of wants that are directly satisfied by manufactured goods, but it would contribute little to the analysis.

$$(2) \quad u(\mathcal{C}, \mathcal{H}) = \sum_{e=l,h} f^e \int_0^\infty [\mathcal{H}^e(z) + \nu(1 - \mathcal{H}^e(z))] \mathcal{C}^e(z) dz$$

where $\mathcal{H}^e(z) \leq \mathcal{C}^e(z)$, $e = l, h$. The parameter ν represents the relative utility of having a want satisfied via market production instead of home production. We assume $0 < \nu < 1$ to capture the fact that home production of a service will be more customized to the specific wants of a household (e.g., driving precisely when and where you want rather than riding the bus on fixed schedules).¹⁹

In reality, increases in consumption typically reflect changes along both the intensive and extensive margin. Although our analysis assumes that increases in consumption occur entirely along the extensive margin, we want to stress that the key feature for our results is simply the presence of the extensive margin. Abstracting from the intensive margin serves only to better highlight the economic forces associated with changes along the extensive margin. Although this representation of preferences is somewhat nonstandard, similar preferences have been used by several other authors to model disaggregated nonhomotheticities.²⁰

B. Schooling

A worker can become high skilled by using a fraction θ of the worker's time to learn specialized skills for the production of a particular z . For simplicity we maintain that all workers are ex ante identical, rather than assuming a distribution over costs to become educated. Instead we adopt a very simple specification to generate an upward cost function for the production of educated workers by assuming that θ is a continuous, increasing, and strictly convex function of f^h , the fraction of workers who decides to acquire education, i.e., $\theta'(f^h), \theta''(f^h) > 0$.²¹ We assume that $\lim_{f \rightarrow 0} 1 - \theta(f) - f\theta'(f) \geq 1$ and $1 - \theta(1) - \theta'(1) < 0$, in order to ensure that $f^h \in (0, 1)$.²² A simple parameterization is the constant elasticity one, $\theta = \psi_0 (f^h)^{\psi_1}$, with $\psi_0, \psi_1 > 0$.

The stand-in household simply chooses the fraction of members to educate, f^h , with $f^h + f^l = 1$.

¹⁹Of course, in principle almost any level of customization could be market produced (e.g., a chauffeured limousine), but this is typically costly, so we do abstract from these.

²⁰See Murphy, Shleifer and Vishny (1989), Matsuyama (2000), Zweimueller (2000), and Matsuyama (2002), for example.

²¹One could motivate this in the typical way, where individual agents draw θ after choosing their skill level, but are completely insured against their draw. Thus, high- and low-skilled agents all receive the same utility in equilibrium. In this interpretation, $\theta(f)$ is the average cost of education as a function of the fraction of individuals that decide to acquire education.

²²Without loss of generality, we preclude agents from specializing in multiple z . In principle, we could relax this, but since agents can fully specialize on the market and skill does not increase productivity in home production, this would never be optimal.

C. Technologies

We model three production technologies: market production of goods, market production of services, and home production of services. Market goods are the foundation of production, since they are inputs into both market and home-produced services. The technology for producing type z goods $G(z)$ is linear in labor:

$$(3) \quad (\text{Market}) \text{ Goods: } G(z) = A_l(z)L_G(z) + A_h(z)H_G(z)$$

Here $L_G(z)$ and $H_G(z)$ are the amounts of low- and high-skilled labor, respectively, used in the market production of goods, and $A_l(z)$ and $A_h(z)$ are their respective productivities, discussed in more detail below.

The technology for type z market services $S_M(z)$ produces value-added with the identical linear labor technology, but this value-added is combined in Leontief fashion with type z inputs $G_M(z)$. One effective unit of labor and q units of type z manufactured inputs are combined to produce one unit of services:

$$(4) \quad \text{Market Services: } S_M(z) = \min \{A_l(z)L_G(z) + A_h(z)H_G(z), G_M(z)/q\}.$$

For each service z , an alternative nonmarket technology is available to home produce services. This technology differs in only one way; all labor has the identical, low-skilled productivity in home production:²³

$$(5) \quad \text{Nonmarket Services: } s_N(z) = \min \{A_l(z)n(z), g_N(z)/q\}$$

where $n(z)$ is the nonmarket time devoted to the home production of service z .

Note that the productivities are specific to the type of labor and also the complexity of the good z . For simplicity, they are also common across sectors. We assume that $A_l(z) = Az^{-\lambda_l}$ and $A_h(z) = A\phi \max \{z^{-\lambda_l}, z^{-\lambda_h}\}$. Three parametric assumptions dictate productivity:

- $\phi > 1$, so that high-skilled labor has an absolute productivity advantage over low-skilled labor in all market production,
- $\lambda_l > 0$, $\lambda_h \geq 0$, so that high z goods are more complex in the sense that they require more resources to be produced,
- $\lambda_l \geq \lambda_h$, so that high-skilled labor has a (weak) comparative advantage in more complex output (i.e., $z > 1$) on the market.

The parameter $A > 0$ is common across technologies and skill levels and therefore captures neutral labor-augmenting productivity.

²³We justify the assumption that high-skilled workers have low-skilled productivity at home by the argument that they are highly specialized. One can derive this directly from a technology that explicitly incorporates this specialization. Since an agent consumes a continuum of z , any specialty would be measure zero of overall consumption. Thus, the implicit assumption is that within the stand-in household, home services are produced in relatively small units.

D. Equilibrium

We define a competitive equilibrium and then characterize the prices and allocations. Since production functions are constant returns to scale, we model representative firms for each z in the market services and goods sectors. The representative firms in the market services and goods sectors maximize profits taking as given wages w_e , prices of goods output/intermediate $p_G(z)$, and prices of services output $p_S(z)$. We normalize the price $p_G(1) = 1$ as the numeraire.

DEFINITION

A competitive equilibrium is given by price functions $p_G(z)$, $p_S(z)$ and wages w_h and w_l ; the fraction of people who attain schooling f^h (and $f^l = 1 - f^h$); (skill-specific) consumption decisions $C^e(z)$ and $\mathcal{H}^e(z)$; (skill-specific) home production labor allocations n^e ; and market labor allocations $L_G(z)$, $L_M(z)$, $H_G(z)$, and $H_M(z)$, such that

- schooling, consumption decisions, and home production labor allocation of low and high-skilled members maximize (2) subject to a common budget constraint and the home production constraints:

$$(6) \quad \sum_{e=l,h} f^e \int_0^\infty C^e(z) \mathcal{H}^e(z) \frac{z^{\lambda_l}}{A} dz = \sum_{e=l,h} f^e n^e;$$

- firms maximize profits taking prices as given;
- labor markets clear:

$$(7) \quad \int_0^\infty [L_G(z) + L_M(z)] dz + n^l = f^l$$

$$(8) \quad \int_0^\infty [H_G(z) + H_M(z)] dz + n^h = f^h [1 - \theta(f^h)];$$

and

goods and services markets clear:

$$\begin{aligned} \forall z \quad G(z) &= \sum_{e=l,h} f^e C^e(z) \mathcal{H}^e(z) q + G_M(z) \\ \forall z \quad S(z) &= \sum_{e=l,h} f^e C^e(z) [1 - \mathcal{H}^e(z)]. \end{aligned}$$

CHARACTERIZATION OF EQUILIBRIUM PRICES

Given market production technologies (3) and (4), we can easily solve for prices using zero profit conditions for firms:

$$(9) \quad p_G(z) = \min \left\{ \frac{w_l}{A_l(z)}, \frac{w_h}{A_h(z)} \right\}$$

$$(10) \quad p_S(z) = qp_G(z) + \min \left\{ \frac{w_l}{A_l(z)}, \frac{w_h}{A_h(z)} \right\}.$$

The first term in the minimizations above indicates per unit labor costs using low-skilled labor, while the second term corresponds to the unit labor costs associated with high-skilled labor. Setting the numeraire so that $p_G(1) = 1$, we have $w_l = A$. For simplicity, we then define the (gross) skill premium as the relative wage of high-skilled workers, $w = w_h/w_l$.

When there is no comparative advantage, i.e., $\lambda_h = \lambda_l$, the skill premium equals $w = \phi$, and producers are indifferent between high- and low-skilled workers for all z . When $\lambda_l > \lambda_h$, high-skilled labor has a strict comparative advantage in the production of complex goods and services. Given any relative wage $w \geq \phi$, there will exist a threshold complexity \hat{z} such that for all $z > \hat{z}$ the cost of production using high-skilled workers is strictly lower than that using low-skilled workers. Given (9) and (10), and substituting in for the productivities, it is straightforward to see that

$$\hat{z}(w) = \left[\frac{w}{\phi} \right]^{\frac{1}{\lambda_l - \lambda_h}}.$$

This threshold is an increasing function of the skill premium, as a larger w increases the set of goods and services for which low-skilled workers are more cost effective. Indeed, for $w > \phi$, low-skilled workers have a strict comparative advantage in the least complex goods and services, $z < \hat{z}(\phi) = 1$.

E. The Household Problem and Preliminary Characterization

The symmetry of the problem with respect to the consumption allocation clearly implies that the stand-in household assigns the same consumption for high- and low-skilled individuals, so we introduce the simplified notation $\mathcal{H}(z) \equiv \mathcal{H}^l(z) = \mathcal{H}^h(z)$ and $\mathcal{C}(z) \equiv \mathcal{C}^l(z) = \mathcal{C}^h(z)$.²⁴

In order to write down the representative household's problem, we define the total expenditure on goods and services as

$$(11) \quad C_G \equiv \int_0^\infty \mathcal{C}(z) \mathcal{H}(z) qp_G(z) dz$$

$$(12) \quad C_S \equiv \int_0^\infty \mathcal{C}(z) [1 - \mathcal{H}(z)] p_S(z) dz.$$

²⁴This result relies on the assumption that the stand-in household face the single home production constraint (6). In Section IV, we relax this assumption and highlight additional factors contributing to the growth in services.

The optimal policy functions f^e , n^e , $e = l, h$, $\mathcal{H}(z)$, and $\mathcal{C}(z)$, and the associated expenditure in goods and services, C_G and C_S , maximize:

$$(13) \quad \int_0^\infty [\mathcal{H}(z) + v(1 - \mathcal{H}(z))] \mathcal{C}(z) dz$$

subject to

$$(14) \quad C_G + C_S = \sum_{e=l,h} f^e w^e [1 - \theta(f^h) \mathcal{I}(e) - n^e]$$

and

$$(15) \quad \int_0^\infty \mathcal{C}(z) \mathcal{H}(z) \frac{z^{\lambda_l}}{A} dz = \sum_{e=l,h} f^e n^e.$$

Equation (14) is the household budget constraint. Market expenditures are on the left-hand side of the constraint, with the first integral capturing expenditures on goods used in home production (C_G), and the second integral capturing expenditures on market services (C_S). The right-hand side of the budget constraint is labor income. Labor income is the product of the wage w^e and labor supplied to the market, both of which depend on the educational decision e . $\mathcal{I}(e)$ is an indicator function that equals one if $e = h$ and zero otherwise. Labor supply is net of the amount of time used for schooling $\theta(f) \mathcal{I}(e)$ and home production time. Note again that home production, which follows from (5), is performed using the low-skilled productivity, regardless of educational decision e .

Condition (15) requires that the total labor needed to home produce services equals the available supply of home production labor.²⁵ This constraint only has to hold at the level of the household, not the member. We consider an alternative specification, in which each type of labor produces its own services, in the simulations of Section IV.

The following proposition characterizes the consumption and home production policies in terms of simple threshold rules.

PROPOSITION 1: *Equilibrium consumption decisions are characterized by thresholds $\underline{z} \leq \bar{z}$ such that*

$$\mathcal{C}(z) = \begin{cases} 1 & \text{if } z \leq \bar{z} \\ 0 & \text{if } z > \bar{z} \end{cases} \quad \text{and} \quad \mathcal{H}(z) = \begin{cases} 1 & \text{if } z \leq \underline{z} \\ 0 & \text{if } z > \underline{z} \end{cases}.$$

The above result is quite natural in this setting since wants enter utility symmetrically but costs increase in complexity z . Hence, consumers will satisfy and home produce the least complex wants first. Thus, \bar{z} denotes the most complex want that is satisfied, and \underline{z} denotes the most complex want that is home produced, and the household's consumption decision is simplified into choosing these thresholds.

²⁵ Additionally, we require that $n^e \geq 0$ for both e .

Given the symmetry of the consumption decisions, the household simply chooses f^h to maximize income. The first-order condition for f^h is

$$(16) \quad w [1 - \theta(f^h) - f\theta'(f^h)] = 1.$$

where our assumption on $\theta(f^h)$ ensures an interior solution, $f^h \in (0, 1)$.

Two further results regarding the allocation of home production time are immediate. First, since high-skilled workers have the same productivity in home production as low-skilled workers, but a higher opportunity cost of time, no high-skilled workers will be employed in home production. That is, $n^h = 0$. Second, since low-skilled workers' productivity in the market is the same as their productivity at home, but home-produced services yield more utility, no low-skilled workers will ever produce market services. That is, $\hat{z} \leq \underline{z}$.

III. Analytical Results

This section characterizes the equilibria of the model analytically, yielding the central results of the growth in services, schooling, the return to schooling, and the relative price of services.

We assume the condition below, which guarantees that low-skilled workers supply positive labor to the market:

$$(17) \quad \frac{\phi f_0^h (1 - \theta(f_0^h))}{1 - f_0^h} < q,$$

where f_0^h solves $\phi [1 - \theta(f_0^h) - f_0^h \theta'(f_0^h)] = 1$.

This condition requires that the effective supply of skilled workers is not too large relative to the manufacturing requirements, q . For instance, this condition will hold if skilled workers are not too productive, or if it is sufficiently costly to acquire skills. This assumption greatly simplifies the analysis, but it also leads to no market services in equilibrium at low levels of productivity. Other relatively minor modifications to the model could ensure a positive value of market services, however, and so this assumption on high-skilled productivity is not strictly necessary.²⁶

A. Rise of Services, the Skill Premium, and the Supply of Skills

In what follows we present comparative statics results of our model with respect to productivity. We focus on the case of strict comparative advantage $\lambda_l > \lambda_h$, since the results for $\lambda_l = \lambda_h$ can be illustrated as a special case. Recall that even when $\lambda_l > \lambda_h$, high-skilled workers have no comparative advantage for $z \leq 1$. Thus, the results at low

²⁶For instance, following Buera and Kaboski (forthcoming), we could assume that the technology for producing services in the market has a scale advantage relative to home-production. A similar assumption would simultaneously allow for market services *and* low-skilled labor employed in the market. The analysis of this extension of the model, while less clean, is available from the authors upon request.

values of productivity, when there is no production of goods with $z > 1$, are identical to those when $\lambda_l = \lambda_h$ except that the results for the latter hold at all productivity levels.

We start by showing how the key objects involving the service share change in response to an increase in productivity, then discuss their implications for the share of services and relation to the facts of Section I.

As productivity A increases, it crosses two critical thresholds, A_1 and A_2 . The first threshold, A_1 , is the highest productivity for which only $z \leq 1$ goods are produced in equilibrium, i.e., the point at which comparative advantage becomes relevant. It is the point at which increases in A increase the range of market services at a faster rate than the range of home-produced services. The second threshold, A_2 , is the productivity at which the labor used to produce wants with a strict comparative advantage for the high-skilled, $z \geq 1$, equals the supply of high-skilled labor for the price $w = \phi$. It is at this point that the fraction of high-skilled and their relative wage begin to increase with productivity. We state this characterization formally below.²⁷

PROPOSITION 2: *There exist productivity thresholds A_1 and A_2 , such that:*

- (i) *Consumption thresholds satisfy $\frac{\partial \underline{z}}{\partial A} \frac{1}{\underline{z}} = \frac{\partial \bar{z}}{\partial A} \frac{1}{\bar{z}}$ for $A < A_1$, and $\frac{\partial \bar{z}}{\partial A} \frac{1}{\bar{z}} > \frac{\partial \underline{z}}{\partial A} \frac{1}{\underline{z}}$ for $A \geq A_1$.*
- (ii) *The supply and price of skills satisfy $\frac{\partial f^h}{\partial A} = \frac{\partial w}{\partial A} = 0$ for $A < A_2$, and $\frac{\partial f^h}{\partial A} > 0$, $\frac{\partial w}{\partial A} > 0$ for $A \geq A_2$.*

Proposition 2 contains a great deal of content. In our discussion below, we focus on the case in which $A_1 < A_2$, a sufficient condition for which is given in the Web Appendix. This case is of most interest because simple modifications to the model that yield strictly positive market services at low levels of productivity (see, e.g., Footnote 26) would lead to this case more generally.

The case of $A_1 < A_2$ yields three distinct regions: low productivity, $A < A_1$, intermediate productivity, $A_1 \leq A < A_2$, and high productivity, $A_2 < A$. Point (i) of Proposition 2 states that at productivities below A_1 , the thresholds increase with productivity at an equal rate. Since $A_1 < A_2$, point (ii) implies that schooling decisions and relative wages are also independent of productivity in the $A < A_1$ range. As A increases above A_1 , there is an intermediate region in which the importance of strict comparative advantage is evident. Here the market service upper threshold increases with productivity at a faster rate than the home production threshold. This happens because comparative advantage makes the cost of \bar{z} produced with high-skilled work increase with z at a lower rate than the cost of producing the marginal service at home \underline{z} , which is produced with low-skilled work. At the same time, the fraction of high-skilled individuals and their relative wage remain constant in this intermediate region.²⁸ For $A < A_2$, high-skilled workers are used to produce a positive measure of wants for which they do not have a strict comparative advantage. In this region the increase in the demand for high-skilled workers is met by lowering their employment in unskilled wants, $z \leq 1$. Therefore, the

²⁷The proofs are in the Web Appendix.

²⁸It is straightforward to show that home production time n^e is also constant.

relative price for skills equals ϕ , and the supply of high-skilled workers is a constant determined by equation (16). Above A_2 , the labor needed to produce wants for which high-skilled workers have a strict comparative advantage exceeds the supply at the skill price ϕ . An increase in productivity leads to an increase in both the fraction of high-skilled individuals and their relative wage. This simultaneous increase in the fraction of high-skilled workers and relative wages maps into the empirical increase in both the fraction of college-educated workers and the relative wage of college-educated workers relative to high school-educated workers presented in Figure 5.

We now turn to the behavior of the service share. Aggregate expenditures on goods and services, C_S and C_G , were defined in equations (11) and (12). Since the technology to produce services requires the use of q units of manufacturing goods, and services are not used as intermediate inputs, aggregate value-added for goods and services can be expressed in terms of the respective consumption expenditures as $Y_G = C_G + \frac{q}{1+q}C_S$ and $Y_S = \frac{1}{1+q}C_S$. We can similarly define the real analogs to these measures.²⁹

In the low productivity region, $A < A_1$, it is trivial to show that the shares of services in consumption $C_S/(C_S + C_G)$ and value-added $Y_S/(Y_S + Y_G)$, both current value and real, are invariant to A . Hence, in the range $A < A_1$, the model is consistent with the constancy of the service share in value-added in the pre-1950 U.S. shown in Figure 1, and the behavior of consumption reported in the Web Appendix. The results for the case of $\lambda_l = \lambda_h$ are analogous to the $A < A_1$ characterization at all levels of productivity.

The results for the share of services in the region where comparative advantage is relevant, $A \geq A_1$, are of more interest but also require somewhat more explanation.³⁰ Over the range $A \in [A_1, A_2)$, both f^h and w are constant, and so it is easy to show that both the current-value and the real consumption share of services relative to goods is increasing in A . For $A \geq A_2$, the interaction of the changes in the relative wage (point (ii)) and the changing thresholds (point (i)) complicates the analysis, making the algebra intractable. Notwithstanding this, the particular case of $\lambda_h = 0$ buys sufficient tractability to explicitly prove that the current-value and constant-value share of services in consumption increases for all $A \geq A_1$.³¹

Thus, the onset of comparative advantage leads to an increase in the share of services, the fraction of high-skilled individuals and the relative wage, consistent with the evidence presented in Section I. It does so by changing the cost of high-skilled labor relative to low-skilled labor in producing marginal services, and the relative cost of producing services in the market with this high-skilled labor relative to producing at home with low-skilled labor.

As A goes to infinity, the limiting behavior of the economy underscores these results and the importance of comparative advantage. For high values of A , the fraction of high-

²⁹We define real aggregate consumption analogously using individual consumptions and schooling decisions for technology A , and valuing these using prices at a base level of technology A_0 . For example, $C_S^{real}(A, A_0) = \int_0^\infty C(z; A) \mathcal{H}(z; A) q p_G(z; A_0) dz$.

³⁰These results are available explicitly in our Web Appendix.

³¹While we are not able to prove the result more generally, we suspect it holds nonetheless as confirmed by extensive simulations for a wide range of parameter values.

skilled workers approaches the maximum feasible rate and the relative wage increases without bound.³² As A increases, households consume services for which high-skilled workers have an ever-higher productivity advantage, and so the relative rate of change of the thresholds and also the relative wage depend on the extent of comparative advantage, $\lambda_l - \lambda_h$.³³ Thus, the range of services that are market consumed increases more rapidly with productivity than the range of services that are home produced. Simply put, the model predicts an increase in the share of services because the marginal services that are consumed at high productivity, such as brain surgery, legal services, and now spaceflight, are produced more effectively in the market using high-skilled labor, and this productivity advantage increases without bound.

The limiting impact on the service share can also be proven more generally, and indeed follows immediately from the above discussion. In the limit, the share of services in consumption converges to one. Given the need to produce high-skilled manufacturing intermediates, the share of services in value-added converges to $1/(1+q)$. Finally, in the limit aggregate home production time converges to the fraction of low-skilled individuals $1 - \bar{f}^h$.

We state and prove these limiting results formally in the Web Appendix.

B. Implications for Relative Price of Services

Here we evaluate the model's implications for relative price movements.

Recall that Proposition 2 states that the relative wage is constant for $A < A_2$. Relative prices are therefore also constant in this range, as is clear in equations (9) and (10).

For $A > A_2$, Proposition 2 implies $w > \phi$, resulting in a strict sorting of workers defined by \hat{z} . Increases in w therefore change relative prices. The sorting of workers leads to market services being more skill-intensive than goods in the sense that both low z (unskill-intensive) and high z (skill-intensive) goods will be produced in the market, but only high z (skill-intensive) services will be market produced. Consequently, the aggregate relative price of market services will also be increasing in w . This increasing relative price is an additional channel through which higher productivity leads to a higher *current value* share of services. We state this formally below.

We start by defining our price indices $P_S(A, A_0)$ and $P_G(A, A_0)$ as the values of baskets of services and goods consumed when productivity is A_0 , evaluated at prices corresponding to productivity A .³⁴

PROPOSITION 3: *Assume $A > A_2$ and $A_0 = A$. Then*

³²The maximum feasible fraction of high-skilled workers is implicitly defined by the following equation: $1 - \theta(\bar{f}^h) - \bar{f}^h \theta'(\bar{f}^h) = 0$.

³³In the case of $\lambda_h = 0$, the differential rate of change of the thresholds is also increasing in the extent of comparative advantage, captured by λ_l .

³⁴Formally, we define them generally as $P_S(A, A_0) = \int_{\bar{z}(A_0)}^{\bar{z}(A)} p_S(z; A) dz$ and $P_G(A, A_0) = \int_0^{\bar{z}(A_0)} p_G(z; A) dz$. One can easily transform this into the time domain by a law of motion for A . Changes in P_S/P_G would then correspond to changes in a relative price index constructed from continuous time chain-weighted price indices, where the indices are continuously chained.

$$\partial [P_S(A, A_0) / P_G(A, A_0)] / \partial A > 0.$$

The major point is that the model leads to growth in both the relative real quantity of services and the relative price of services, and the increase in relative prices is a direct implication of the sorting that occurs through comparative advantage. This result is consistent with the evidence on the relative price of services and its relationship with the skill premium, presented in Section I.

C. Alternative Representation of Preferences

To build further intuition and insight into these results, we present an alternative representation of the consumption choice problem in the spirit of Benhabib, Rogerson and Wright (1991). Specifically, given the optimal interior choice of f^h , the household's problem can be written in terms of quasi-preferences over total market expenditures on final services and goods, C_S and C_G , respectively. These preferences are "quasi" in that the preference parameters depend on underlying preferences *and* technology, as well as the (endogenous) relative positions of the thresholds. For the case of $A < A_1$ and positive purchases of market services, this problem is

$$\max_{c_m, c_s} b_1 C_G^{\sigma_l} + b_2 [C_S + b_3 C_G]^{\sigma_l}$$

s.t.

$$(18) \quad \tilde{P}_G C_G + C_S \leq A [f^h w (1 - \theta(f^h)) + (1 - f^h)]$$

with preference parameter $\sigma_l = 1/(\lambda_l + 1)$.³⁵ Here, $\tilde{P}_G = 1 + \frac{1}{q} \frac{\phi}{w}$ represents the full (shadow) price of goods consumption which includes both the market purchases and the nonmarket labor used to ultimately home produce services.³⁶ The above quasi-preferences are clearly homothetic, and so a pure increase in income leads to no change in the share of services in market expenditures.

The aggregated quasi-preferences themselves are not stable, however, but instead change with technology. To show this, we contrast the homothetic preferences above with those for the simplest case, when $1 < \hat{z} = \underline{z} < \bar{z}$. Given the optimal choice of f^h , the household problem can be expressed

$$\max_{c_m, c_s} b_1 C_G^{\sigma_l} + b_2 [C_S + b_3 C_G]^{\sigma_h}$$

s.t.

³⁵The preference weights are $b_1 = (1 - v) \left[\frac{\lambda_l + 1}{q} \frac{A\phi}{w} \right]^{\frac{1}{\lambda_l + 1}}$, $b_2 = v \frac{\lambda_h + 1}{1 + q} \frac{A\phi}{w}$, and $b_3 = v \frac{\lambda_h + 1}{q} \frac{A\phi}{w}$.

³⁶Here we have used the optimality condition for f^h (16), together with the result that $n^h = 0$ and $n^l = 1$, to combine the budget constraint on market expenditures (14) and the constraint on home production time (15) into a single constraint.

$$\tilde{P}_G C_G + C_S \leq A [w f (1 - \theta (f^h)) + (1 - f^h)]$$

The quasi-preferences are quite similar to those in (18), except that the exponent on the term containing service expenditures, $\sigma_h = 1 / (1 + \lambda_h)$, now exceeds the exponent on the goods expenditures alone, $\sigma_l = 1 / (1 + \lambda_l)$. Thus, the marginal utility of service expenditures falls at a lower rate, the quasi-preferences are no longer homothetic, and the Engel curves are biased toward services.

This example also helps to emphasize that our model cannot be replicated by a simple model with stable preferences over goods and service aggregates, since the representation changes as productivity increases.³⁷

IV. An Alternative Model

In the previous analysis, we assumed that a stand-in household chooses allocations for low and high-skilled individuals subject to a common constraint for home labor time (see equation (15)). This common constraint implies that high-skilled individuals specialize in market production and only low-skilled labor is used in home production. It also implied symmetric consumption allocations for low and high-skilled individuals. While this captures some tendency of households in the world, another aspect of reality is that high-skilled individuals as well as low-skilled individuals must use some of their own time in home production.³⁸ When agents can only home produce for themselves, two additional forces contribute to the rise of the service economy: (1) as the wage increases, high-skilled individuals demand more market services as the opportunity cost of home producing services increases; (2) as the quantity of high-skilled individuals increases, the demand for market services increase as high-skilled individuals consume more market services relative to low-skilled individuals. In this section, we present numerical simulations for a model with single individual households.³⁹

Specifically, we consider an economy where individuals face a discrete educational choice, $e = l, h$, together with choice of consumption bundles characterized by skill-specific thresholds \underline{z}^e and \bar{z}^e , $e = l, h$. The problem of an individual is almost identical to that of the stand-in household, equations (13)-(15), with the only difference being that instead of choosing fractions, individual educational choices are restricted to be discrete. We denote these individual decisions $f_i^h = 1 - f_i^l \in \{0, 1\}$. In equilibrium, the fraction $f^h (= \int_0^1 f_i^h di)$ will be interior, $f^h \in (0, 1)$. The step function aspect of decision rules from Proposition 1 continues to hold. Given that the equilibrium fraction of high-skilled individuals is interior, homogeneity of individuals requires that individuals be indifferent between the two educational choices:

³⁷Indeed, when \hat{z} is less than both thresholds \underline{z} and \bar{z} , the quasi-preferences have a constant term subtracted from manufacturing expenditures, similar to the “subsistence” term in Stone-Geary preferences. Moreover, the pricing term on goods, \tilde{P}_G , becomes nonlinear.

³⁸At least this would be the case if both low- and high-skilled individuals consume home-produced services, and there is positive sorting of individuals to households in terms of their skills.

³⁹In addition, the numerical examples discussed in this section illustrate that, as productivity increases, the share of services tends to increase monotonically for the case $\lambda_l > \lambda_h > 0$, suggesting that the monotonic dynamics found for the case $\lambda_h = 0$ hold more generally. Indeed, this was found to be the case for all the numerical simulations that we ran.

$$(1 - v) \underline{z}_l + v \bar{z}_l = (1 - v) \underline{z}_h + v \bar{z}_h.$$

This economy shares all other technologies and market-clearing conditions from our benchmark economy, including an upward-sloping (aggregate) cost of transforming low-skilled individuals into high-skilled, as a function of the fraction of individuals becoming high-ed.

As hinted at before, in this economy low- and high-skilled agents choose different consumption bundles. There are two possible configurations for the four consumption thresholds:

$$\underline{z}^h < \underline{z}^l < \bar{z}^h = \bar{z}^l$$

or

$$\underline{z}^h < \bar{z}^h < \bar{z}^l = \underline{z}^l$$

The fact that $\underline{z}^h < \underline{z}^l$ in both cases stems from the fact that high-skilled agents face a higher opportunity cost of home production ($w \geq 1$). Both cases imply that the household's ratio of services to goods in market expenditures will be higher for high-skilled agents than for low-skilled agents. Since $\underline{z}^h < \underline{z}^l$, it is now possible that some market services will be produced by low-skilled workers (for high-skilled consumption, i.e., $\underline{z}_h < \hat{z} \leq \underline{z}_l$).⁴⁰

The simulations also show that the consumption of services produced by low-skilled labor will decline with A , whereas consumption of market services produced with high-skilled labor will increase with A . The model is therefore consistent with the changing composition of the service industry presented in Figure 3.

For ease of presentation of the simulations, we transform the level of technology A into a time axis by assuming a 2 percent annual growth rate in total factor productivity (TFP) and choose the time-0 level of A to equal A_1 , now defined as the point at which $\bar{z}^h = 1$. We then assign other parameter values so that the time-0 economy resembles the U.S. economy in 1950. Specifically, the relative productivity of high-skilled workers, ϕ , is chosen to match a relative wage of 1.24 (the college/high school relative wage in 1950), and the relative value of market-produced output v is chosen to yield $f^h=0.16$ (the fraction of college-educated workers in 1950).⁴¹ Finally, we have set $\lambda_l = 1$ which is effectively a normalization, and $\lambda_h = 0.5$ in order to get trends that are easy to discern.⁴²

Figure 7 shows the evolution of the service share in consumption (top panel), the relative wage of high-skilled labor (middle panel), and the fraction of high-skilled individuals (bottom panel). All of these increase monotonically.

Three endogenous threshold conditions are of particular interest in these simulated equilibria (illustrated by vertical lines in Figure 7). The first condition is $\bar{z}_h > 1$, when

⁴⁰Recall, only high-skilled workers produced market services (i.e., $\hat{z} \leq \underline{z}$) in our benchmark model. Services produced by low-skilled workers were always home produced, providing more utility at the same cost.

⁴¹We do not try to match the aggregate share of services in consumption, since our model abstracts from other dimensions that are important in explaining the level of market services at a point in time, e.g., the indivisibility of specialized goods and the efficient scale of production that market services offer (see Buera and Kaboski (forthcoming)).

⁴²This is not strictly so, but quantitatively the larger the absolute difference between λ_l and λ_h , the more responsive are the service share, f , and w to A . For a given absolute difference, a larger relative difference has very little effect.

comparative advantage becomes relevant for the high-skilled consumption set, and therefore the equilibrium. By construction, this occurs after year 0. (Before that the equilibria are identical to an economy with $\lambda_l = \lambda_h$.) The second condition is $w > \phi$, which first occurs in year 8, once $A \geq A_2$. Between year 0 and 8, the share of services and the fraction of high-skilled workers increase slowly, although this is difficult to see. After year 8, the share of services rises steeply. The third condition is $\bar{z}_l > \underline{z}_l$, when low-skilled workers purchase market services, which occurs starting in year 37. Beyond this threshold, as the relative wage rises, the fraction high-skilled increases more steeply, while the share of services rises less steeply.

We emphasize that the simulations are representative of all simulations we have run. In particular we have varied each parameter independently, as well as combinations of parameters, and we always find monotonically (weakly) increasing relationship between A and the share of services, relative wage, and fraction of high-skilled workers.⁴³

In this version of the model, in which both low- and high-skilled agents supply labor for home production, we have two additional forces that lead real service expenditures to increase with A faster than real goods expenditures. First, the service consumption of high-skilled agents increases with the opportunity cost of their time (i.e., relative wage of high-skilled workers, w). Second, as f^h increases more sharply, the share of market expenditures for high-skilled agents also increases. Since high-skilled agents' consumption is weighted toward market services, this compositional effect also increases the share of services. To illustrate these separate effects, Figure 8 decomposes the increase in the service share of the household's problem into four components. The counterfactuals are constructed by relaxing market-clearing conditions and merely solving the household problem for exogenously given paths for prices, wages, and (in the first counterfactual) the fraction of high-skilled individuals f^h . These paths are either (a) the paths of the market-clearing, unconstrained equilibrium or (b) fixed at their initial values.

The lowest line in Figure 8 shows the response of the real share of services given the market-clearing, unconstrained equilibrium prices, but where w (affecting the relative income and the opportunity cost of home production for high-skilled individuals) and f^h are kept constant at their initial levels. The second line shows the analogous response of the real share of services, where only f^h is kept constant, but w follows the equilibrium path. The difference between the first and second lines measures the change in the real share of services in response to a change in the opportunity cost of the home production time of high-skilled individuals. The third line shows the full real effect, i.e., the path of services in the market-clearing, unconstrained equilibrium. Therefore, the difference between the second and third lines measures the contribution of compositional effects, as the share of high-skilled individuals who consume relatively more market services increases. These three counterfactuals have focused on real consumption in that they have valued consumption bundles at the initial prices, when $w = \phi$. The top line shows

⁴³The larger the difference between λ_l and λ_h , the more responsive are the service share, f , and w to A , and this responsiveness depends strongly on the absolute difference and only slightly on the relative difference. Increasing q raises the level of the share of services, and the share of services is more responsive to A , when the pre-1950 level is near 0.5, but has no effect on schooling or the relative wage. Lowering v has similar effects except that it also leads to an earlier increase in w .

the full effect on the current-value share that includes the rising relative price of services, which is slightly larger than the full effect in real terms.

V. Discussion

This section reviews the implications of the model in light of our motivating data. We also discuss additional evidence consistent with the theory.

The basic implications of the model are consistent with the motivating facts of Section I. Namely, the service share is constant at low levels of income/productivity, increasing only after a sufficient level of income is attained (Proposition 2), which is consistent with the patterns discussed in Section I.A. In the simulated model, low-skilled workers produce market services, and the model leads to a growth in the share of services produced by high-skilled workers and a decline in the share produced by low-skilled workers, which is consistent with the facts in Section I.B. Finally, the growth of the service share coincides with a period of rising wages and rising schooling, which is consistent with the motivating facts in Section I.C.

The model also leads to growth in services that is characterized by an increase in both relative quantities and relative prices as observed in the data presented in Figure 2. It is also consistent with the tight link between relative prices and relative wages (Proposition 3), which we showed in Figure 6.⁴⁴ In our comparative advantage model, the increase in demand for services stems from an increase in the demand for complex output. Again, the reason why relative prices increase in the comparative advantage story is that the sorting of workers causes market services to be more skill intensive. The rising relative wage therefore leads to a greater increase in the relative price of services.

Our theory also implies a novel explanation for the observed growth in the skill premium that is distinct from skill-biased technical change. Namely, our theory predicts that the skill premium should be tightly linked to demand patterns associated with income per capita rather than to time-specific technological change patterns. We evaluate this implication using the available panel data from nine countries (Canada, Germany, Italy, Mexico, Russia, Spain, Sweden, U.S.A, and U.K.) that include measures of the college-high school skill premium over time that are computed comparably across the countries.⁴⁵

The skill premium data show a substantially strong relationship with income that is independent of any relationship with time. In particular, a regression of the skill premium on log real income per capita, controlling for country and year fixed effects, yields a significant coefficient of 0.84 (standard error=0.24, t-statistic=3.49). The coefficient is

⁴⁴The growth in the skill premium after 1970 coincides with the well-known slowdown in measured productivity growth. Our model may not be consistent with a rapidly rising skill premium during a time of slower productivity growth, though this will certainly depend on the particular form of $\theta(f)$. In any case, the literature has proposed several explanations (e.g., Hornstein and Krusell (1996), Greenwood and Yorukoglu (1997)) for these joint phenomena, including mismeasurement of productivity growth, and our model is consistent with a rising share of services and relative price of services during a period of rising skill premium.

⁴⁵The panels are of varying length between 1967 and 2002 and are from the series of special issue papers summarized in Krueger et al. (2010).

sizable; the 0.4 log point increase in income between 1980 and 2001 would account for 84 percent of the increase in the skill premium in the U.S. over the same period of time. Moreover, the income variable has as much explanatory power as the full set of 34 time dummies. Dropping these year dummies lowers the coefficient on log income to 0.47, but it remains quantitatively important and highly significant (standard error=0.05, t-statistic=9.04). A simple comparison of time versus income effects alone shows that the two do a roughly equal job of accounting for the data. We conclude that a simple look at the data is consistent with demand forces playing an important role in the dynamics of the skill premium. A more thorough comparison of the two explanations is left for future work.

A final novel implication of the model is our prediction of rich product cycles, i.e., movements of activities both in and out of home production. The simulations in Section 4 allow for movement of productive activities out of the home as the opportunity cost of time rises. This marketization of home production and its effect on the service sector has been modeled by Ngai and Pissarides (2008) and Rogerson (2008). Examples of such activities include child care, elderly care, lawn care, and meal preparation, all of which are plausibly driven by rising opportunity costs of time among high-skilled workers. The more novel and surprising implication, however, is the prediction that as the costs of production fall, the preference for the benefits associated with home production will move activities from the market to the home. The model predicts that the higher the productivity advantage of high-skilled labor, the longer the product cycle, which could make many product cycles difficult to discern. Still, there are numerous examples of this product cycle, even among skill-intensive activities such as medicine and education. For example, in health care, patients now do home dialysis, check blood sugar levels, and give insulin shots.⁴⁶ In education, self-guided foreign language instruction now exists, and home schooling is a small but rapidly growing segment of the education market, particularly in primary schooling.⁴⁷ Again, for these examples the utility benefit of home production appears to play a role.

VI. 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. Modeling this margin has yielded insight into understanding the high-skill nature of the rising service economy.

We conjecture that our model would have particular implications for several policy-relevant issues. First, the model features 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 and is of great importance in considering the home production versus market purchase margin. Indeed, labor supply decisions have been recently linked to the growth in services (Lee and Wolpin (2006)). Second, we have

⁴⁶See Blagg (1997) for a discussion of home dialysis.

⁴⁷Princiotta, Bielick and Chapman (2006) document the recent growth in the prevalence of home schooling in the U.S..

mentioned government subsidies that exist in important growing service industries such as education and health care. More broadly, 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 aforementioned subsidies to the service sector (relative to Rogerson (2008)). Third, our theory can explain both the rising share of services and the 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. All of these questions are subjects of ongoing research.

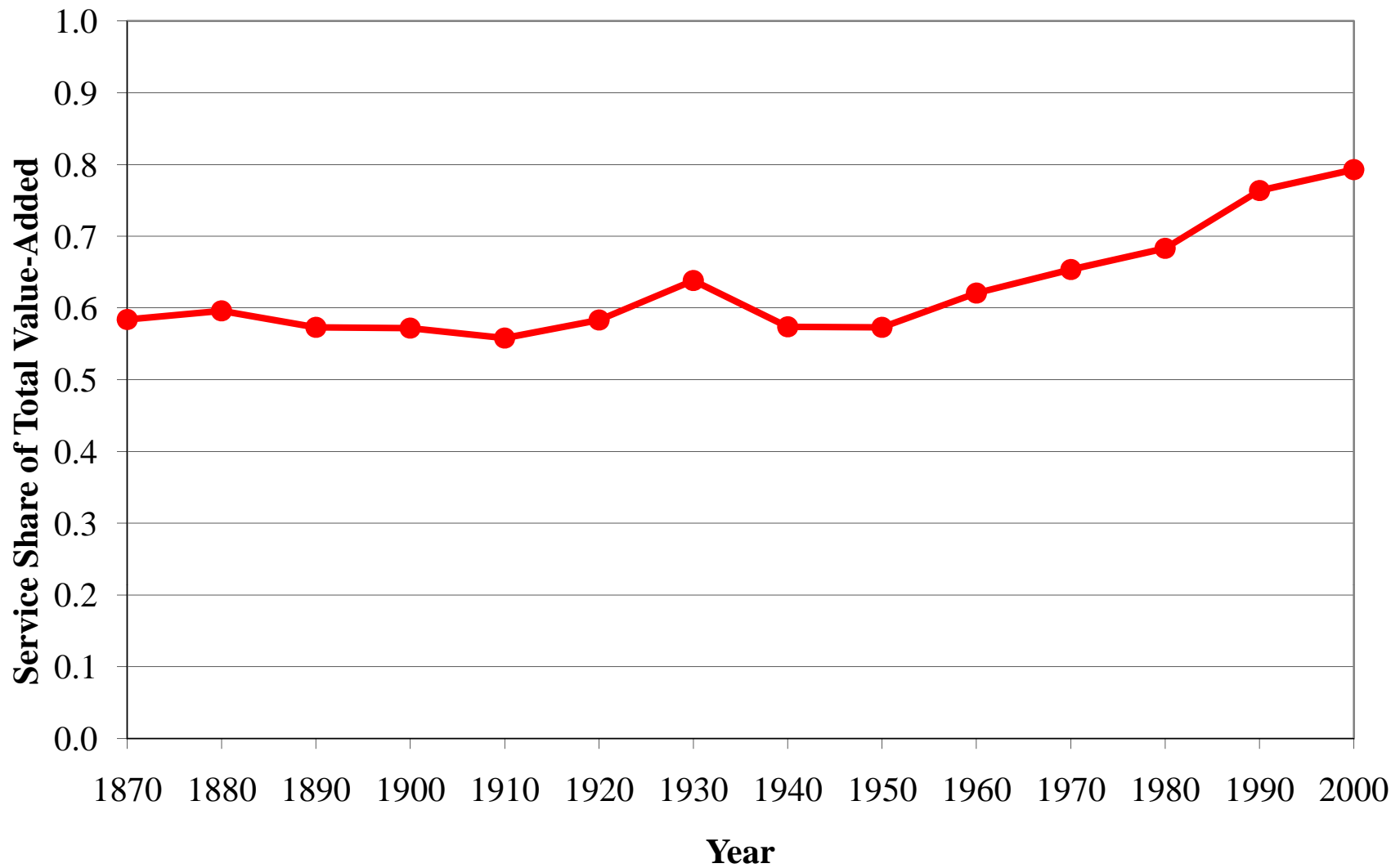
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Note: The category of services includes services, retail and wholesale trade, public administration, utilities, and transportation.

Figure 1: Growth of Share of Services in Value-Added (Current Prices)

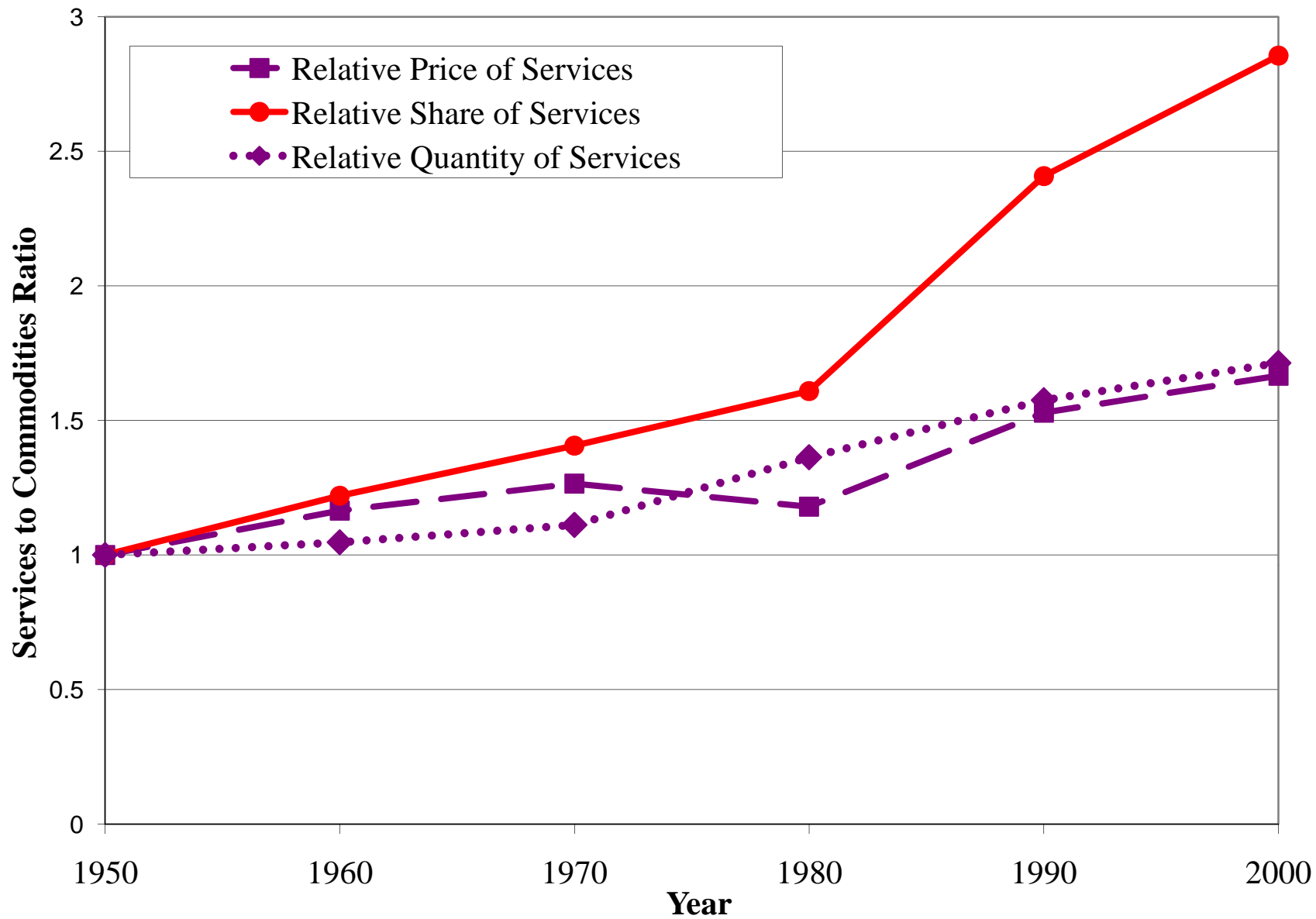
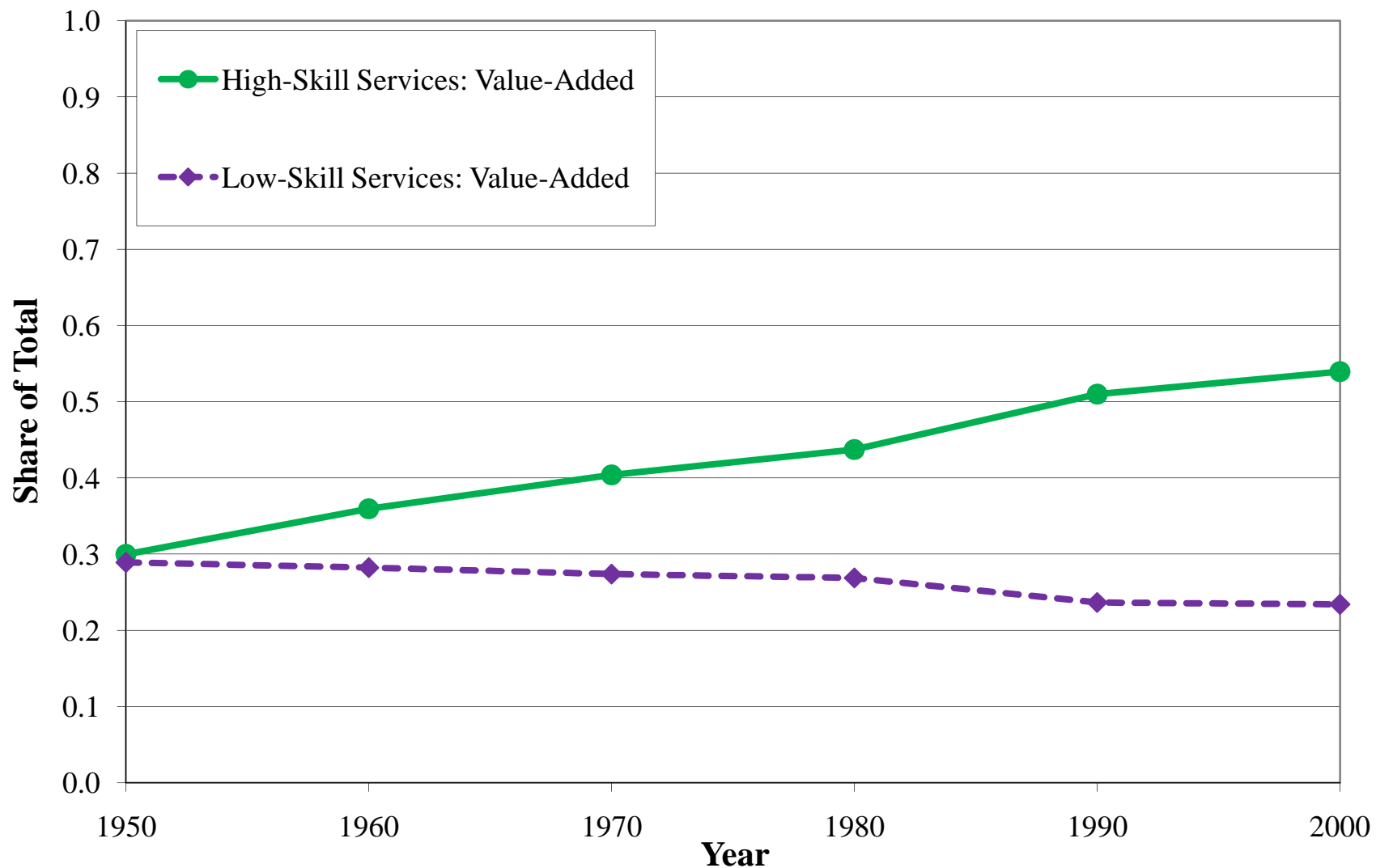


Figure 2: Growth of Relative Price and Quantity of Services



Note: The category of high-skill services includes all industries with at least 12.5% of workers college-educated in 1940.

Figure 3: Growth of Low- and High-Skill Service Shares

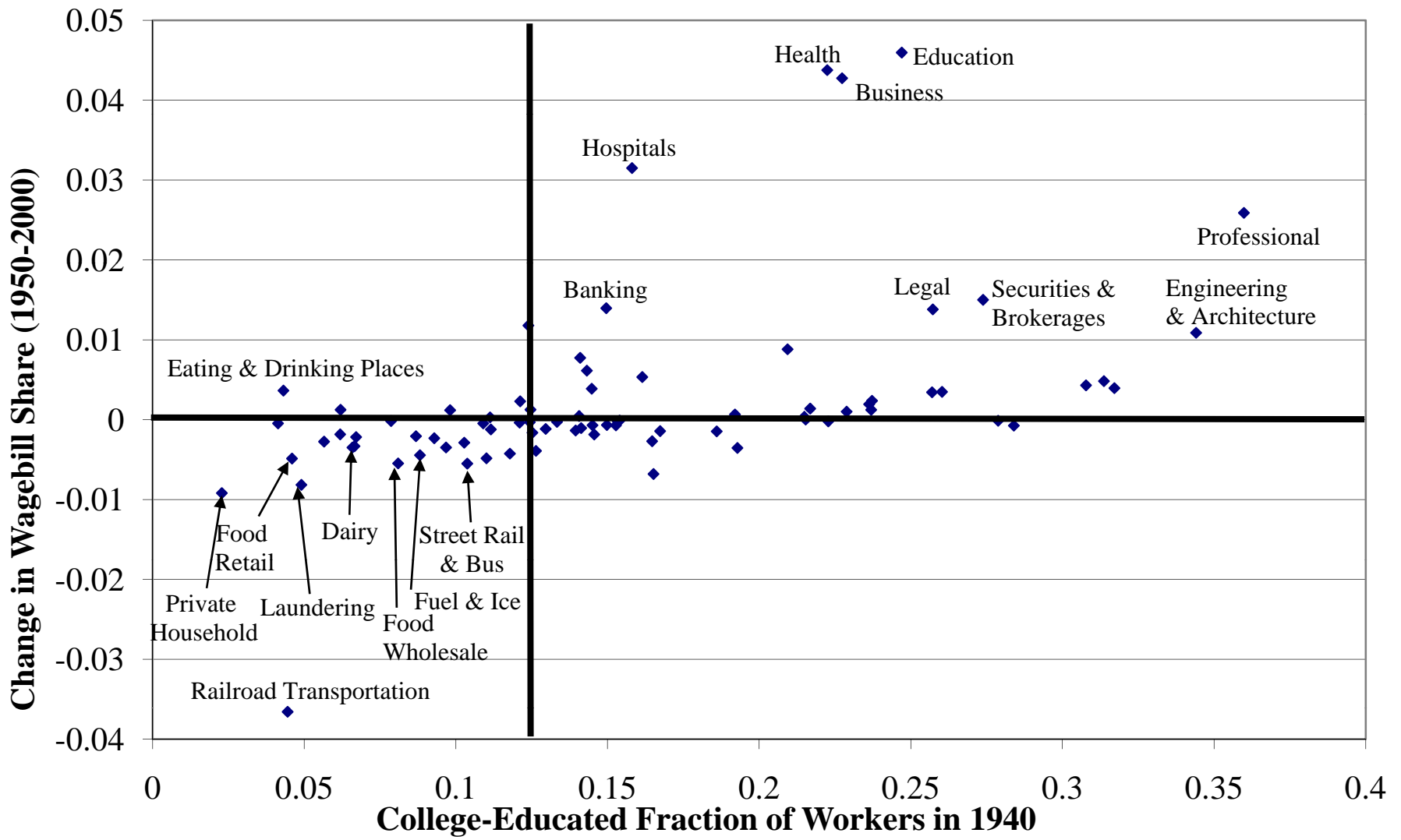


Figure 4: Growth vs. Skill Intensity of Disaggregate Service Industries

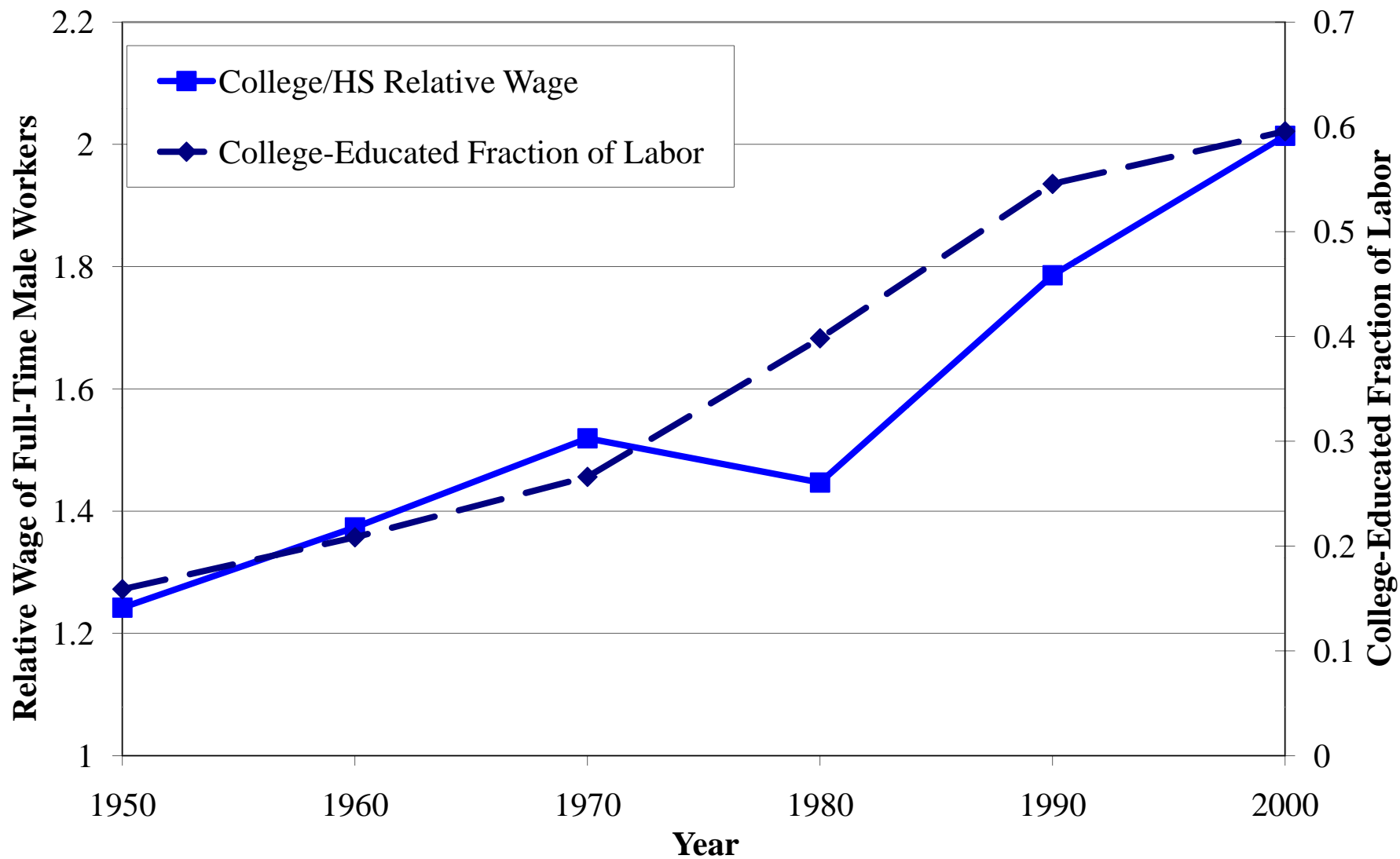


Figure 5: Growth of College Premium and Fraction College-Educated

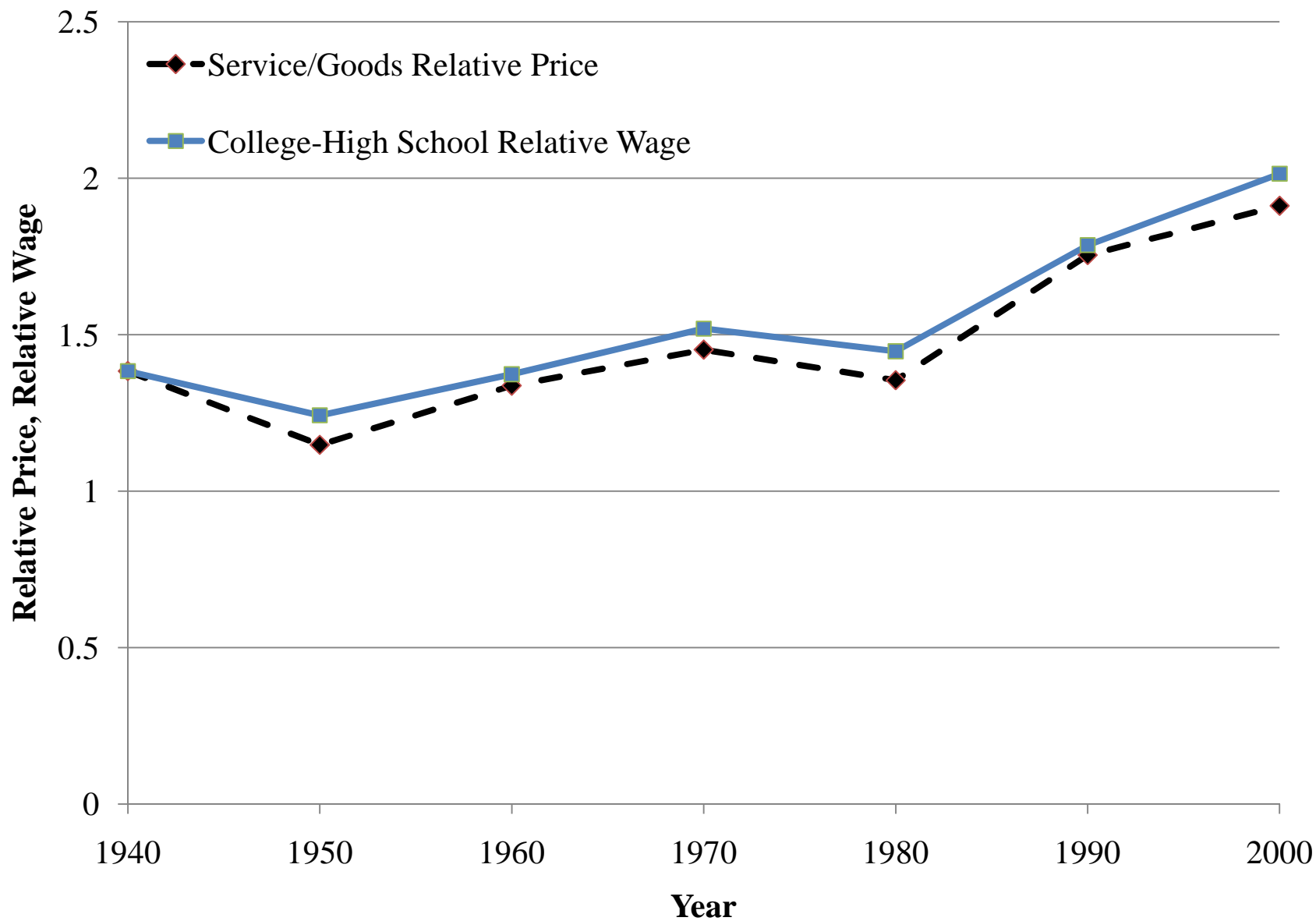


Figure 6: Correlation of Skill Premium and Relative Price of Services