Productivity growth in personal services from lagging to leading: how motion pictures industrialised entertainment[1]

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[1] Insert acknowledgements.

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Abstract

Motion pictures constituted a revolutionary new technology that transformed entertainment—a rival, labour-intensive service—into a non-rival commodity. Combining growth accounting with a new output concept, we show that *productivity growth in entertainment surpassed that in any manufacturing industry between 1900 and 1938*. This suggests that productivity growth in personal services was not per definition stagnant, as current understanding has it. Instead it was unparalleled in some cases. The pictures' contribution to aggregate US GDP- and TFP-growth was smaller, but still not insignificant compared to general purpose technologies such as railways, steam and electricity. Valuing entertainment output by consumers' opportunity costs, following Becker (1965), we also find that motion pictures' welfare impact was far larger still than their growth contribution, but was hidden in the conventional accounting by a phenomenal fall in prices in combination with the 24-hour day, an exogenous limit to demand. An observer in 1938 might very well have remarked that 'motion pictures are everywhere except in the productivity statistics'.

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> So long as the number of persons who can be reached by a human voice is strictly limited, it is not very likely that any singer will make an advance on the £10,000 said to have been earned in a season by Mrs. Billington at the beginning of the last century, nearly as great as that which the business leaders of the present generation have made on the last.
>
> Alfred Marshall[2]

When Charlie Chaplin was eight years old, he performed in three large music halls a night at most. Less than ten years later, in 1915, he performed in thousands of halls a night across the entire world. The remarkable transformation of his performance into a non-rival service was made possible by motion pictures that industrialised entertainment by automating it, standardising it and making it tradable.

While in 1900 almost all spectator entertainment was provided by live performers, in 1938 the share of live entertainment had fallen to less than three percent of all entertainment, and in absolute terms it was only two-thirds its previous size. Also, in 1900 most live entertainment was of the popular, sometimes perhaps vulgar type, such as popular theatre, vaudeville and burlesque. Opera, for example, probably constituted less than four percent of all live entertainment provided in 1900.[3] The vast majority of popular live entertainment, however, was substituted away by motion pictures in several step-changes in technology that made motion pictures an

[2] 1947: 685-686; as quoted in Rosen (1981).
[3] See table 1.

ever closer substitute. By 1938, the live entertainment that had survived was more the elite high-brow entertainment heavily subsidized and supported by charities, or high value added, high-concept commercial entertainment such as musicals and Broadway plays. In other words, the entertainment that survived the onslaught of motion pictures had done so by dynamically differentiating itself from motion pictures.

By 1938 motion pictures provided entertainment even at marginal hours and in marginal places, offered an unprecedented variety of performances, especially for smaller towns, offered sound and colour, close-ups and speakers that equalised the experience in the auditorium. They gave every consumer the chance to see a top superstar like Charlie Chaplin instantly in his or her own town.

While it is not difficult to grasp the enormous step-change in entertainment provision motion pictures constituted intuitively, no attempt has been made to quantify the productivity growth in this personal service. We aim to do just that, and find that *TFP-growth in the US entertainment industry was higher than in any manufacturing industry* and higher than in any other well-measured industry.

We show that productivity in personal services does not necessarily have to be stagnant if the proper industry and market definition are used. Often final-year elasticities of substitution are implicitly assumed for preceding periods, leading to the argument that the industrialised service was an entirely different product. William Baumol and William Bowen (1966), for example, found that productivity growth in the US performing arts was stagnating, although they did not specifically measure TFP-growth. While they acknowledge the massive productivity increase enabled by audiovisual delivery technologies, Baumol and Bowen assumed that the 'performing arts' formed an entirely different market. This was probably less accurate before

1940 than in the 1960s, when, as noted above, the surviving live entertainment was far more differentiated, and that was precisely how it survived.

The issue of industry and market definition also relates to the debate in the economics of new goods literature on the extent to which innovations can be considered new goods or substitutes (see for example the introduction and essays in Bresnahan and Gordon (1997)). Using the hedonic approach and regarding quality as multidimensional, the extent to which an innovation is substitute can be assessed. In the words of Kelvin Lancaster (1966), looking at cross-price elasticities allows in principle shoes and ships to be just as close substitutes as margarine and butter, while the hedonic approach is closer to the intuitive understanding of many consumers about what constitute close substitutes. In longitudinal processes rather than comparative statics, multidimensional quality is even more important, as innovations are often further improved through incremental innovations that make the original innovation an ever closer substitute.

We will first present historical evidence showing that it is reasonable to assume that motion pictures were a close substitute for live entertainment. We will then estimate productivity growth in the industry between 1900 and 1938, estimate its contribution to US economic growth and, finally, assess its welfare impact.

The first part will estimate sectoral TFP-growth through primal and dual growth accounting following Jorgenson and Griliches (1967). It introduces the spectator-hour—one consumer consuming one hour of spectator entertainment, as output measure. Previous works often have used inputs as a proxy for outputs. Baumol and Bowen (1966) for example mention the person-hours the members of a string quartet use to perform, to suggest that such a quarter's productivity must be stagnant. This underestimates productivity growth, because it disregards the additional spectator-hours the quartet could sell through, for example, larger-scale auditoriums or audiovisual technologies.

We find that 1938 output was 28 times larger than 1900 output, a phenomenal growth of over nine percent annually, almost double the that implied by existing studies on recreation services (Lebergott 1996, Bureau of Economic Analysis 1977) that do not use the spectator-hour as output measure and whose estimates range from 3.8 to 5.4 percent per annum. Only one third of the nine percent output growth could be accounted for by a growth in inputs. The rest was caused by a phenomenal TFP-growth that was not achieved in any other measured industry during the time.

This one single finding falsifies the notion that personal services almost by definition show stagnant productivity growth. It nuances, for example, the assumptions of the Baumol (1967, 1985) model, which divides an economy in a stagnant sector (certain services) and a progressive sector (such as manufacturing). The model makes four assumptions: the difference between ‘progressive’ and ‘stagnant’ activities are inherent in their technological structures; all outlays other than labour costs are ignored; wages in the stagnant and the progressive sector move up and down together; wages in both sectors increase when productivity in the progressive sector increases.

This paper suggests that, inherent technological differences were limited, given the sharp increase in the live capital/labour ratio in the face of competition by cinema (i.e. the ‘stagnant’ sector was not stagnant); that given the former, capital costs can not be ignored; and that wages in the ‘stagnant’ sector probably were substantially lower than in progressive one (although their distribution might have been different). The fourth assumption can not rejected by this paper’s findings. Baumol also makes four propositions: in the stagnant sector costs will rise without limit; in the progressive sector they remain constant; the stagnant sector will tend to vanish in competitive circumstances; if output shares are held fixed, all labour goes to the stagnant sector eventually; if so then growth rates decline. This paper's findings show that, in this period, costs per unit of output declined in both sectors; and that the 'stagnant' sector indeed tends to vanish in competitive circumstances. They do not contradict the last two propositions, although they did not happen in spectator entertainment before 1940.

The paper is also related to the literature on the economics of superstars (such as Rosen 1981; Adler 1985), in that it does suggest that performers' services becoming non-rivalrous lead to sharp productivity growth (and that secondly the market for entertainment also grew); that the shift from a rivalrous to a non-rivalrous product was the shock that forever changed the industry, although here we do not aim to measure its effect on star income distribution, but instead to quantify the effect on productivity growth. As Rosen (1981) remarked, a more skewed income distribution for talent was not inconsistent with an increase in total welfare given new non-rivalrous delivery technologies, and this paper empirically corroborates that notion.

The second question that we try to answer is: did the sharp productivity growth in entertainment make any difference for aggregate economic growth? Using established growth accounting techniques (such as those applied historically to steam in Crafts (2003)), we find that motion pictures' growth contribution was far lower relative to other industries than its absolute TFP-growth, but that it was *not* insignificant. They accounted for about two percent of US GDP-growth and three percent of aggregate TFP-growth between 1900 and 1938. Disaggregating this contribution (following Nordhaus 2002), we find that over 90 percent was driven by intensive growth, of which 60 percentage points were due to the pure productivity effect, 25 percent to the share effect and 7 percent to the input-shift effect.

These findings relate to the literature that tries to quantify the contribution of general purpose technologies (GPTs) to aggregate growth such as Fogel (1962), Crafts (2004a) and Lipsey, Bekar and Carlaw (1998). Motion pictures did not constitute a GPT, but their growth contribution was high, only slightly lower than that of many GPTs, such as steam, railways and electricity. The findings are also consistent with the recent reinterpretation of US economic growth in the early twentieth century as being more driven by services. Broadberry shows how services, not manufacturing can explain the productivity lead of the US relative to Britain and Germany, and Field (distri, AER, JEH) shows how mass-services like utilities, transport and distribution played a key role in US productivity growth. We find that the US productivity lead and the US growth surge also extended to some personal services.

The implications of these findings are, first, that certain service industries are not per definition stagnant, but, in the face of market forces, can adopt new technologies and potentially be subject to similar or even higher productivity growth than in agriculture and manufacturing. Second, inadequate output measurement may leave a substantial part of this growth unmeasured, and the current productivity estimates may therefore understate both national productivity growth as a whole as well as the part due to certain services. Angus Maddison (2001: 138), for example, showed how the Bureau of Economic Analysis' use of an annual chain index and of hedonic indices to adjust for quality changes resulted in an upward revision of U.S. economic growth by a third, from 2.63 to 3.48 percent per annum between 1929 and 1950. The current paper suggests that we still are understating the wealth the twentieth century has brought us, and that improved measurement of service output may lead to significant further upward revisions.

The third question we try to answer is: given the decent, but not large growth contribution above can we estimate the welfare impact of motion pictures in a way that is consistent with their ubiquity in the 1930s? Most of those below the age of 40 went to the cinema more than once a week (Bakker 2001, 2003). The pictures played an incredibly important role in the leisure time and social life of most consumers. Yet an observer in 1938 could very well have remarked that 'motion pictures everywhere except in the productivity statistics'.

Following Becker (1965) we assume that consuming motion pictures costs an amount of time in a fixed, inseparable proportion to the ticket, that the time can be expressed in opportunity costs, and that therefore the time/money trade-off collapses into a single constraint, so that we can add the ticket price and the opportunity costs.[4] We argue that the opportunity costs, the time that a consumer is willing to give up to watch pictures, form a good proxy for the welfare benefit. Setting opportunity costs at the wage rate, we find that while the overall ticket price decreased by 80 percent between 1900 and 1930, opportunity costs rose by 300 percent, making the 1938 full cost roughly identical to the 1900 full cost. While in 1900 for the average consumer watching spectator entertainment cost a great deal of money and a little time, by 1938 it cost a little bit of money and a great deal of time.

Valuing all 1938 entertainment output by its full cost yields a total of $6.2bn, or almost 9 times the monetary costs alone. Although this amount says little about the contribution to GDP and TFP-growth noted above, it does show that motion pictures had a large welfare impact, and that this impact was probably far larger than the

[4] Goolsbee and Klenow (2006) use a different set-up discussed in note 29 below. But note that cinema ticket is almost worthless without the entire block of time, and that that block of time is worthless for watching movies without the cinema ticket. So you cannot change the quantities and hours outside the fixed proportions.

modest monetary expenditure share would suggest. It corroborates what we already knew intuitively: that motion pictures were everywhere in the 1930s.

These findings relate to the growing literature that attempts to quantify the welfare benefits from services such as healthcare and transportation. Time-savings of new highways, for example, are routinely compiled at the micro-level before they are built, but do not show up in national accounts (Fernald 1999). The railways' contribution to economic welfare between 1850 and 1912, for example, as measured by their social savings, was over three times as high if we factor in the opportunity-costs of travel time (Leunig 2006). Likewise, conventionally valued, the contribution of medical services to overall productivity growth seems negligible at best, but when changes in outcomes are examined, it could be substantial. William Nordhaus (2005: 386) finds that between 1900 and 1950 the value of improvements in life expectancy where substantially above the increase in the value of all other goods and services put together, and Cutler and Richardson (1997), find that between 1970 and 1990 the increase in quality-adjusted health capital per capita was about five times the increase in medical spending per capita. French and Miller (1999) show that doubling drug expenditure at age 40 increases life expectancy by two percent (about a third of the effect of doubling GDP), implying again that the welfare benefits generated by healthcare inputs may not be properly reflected in national accounts. These studies suggest that the twentieth century has brought us much that has gone unmeasured.

This paper also relates to the history of new goods through the twentieth century, such as the work of Brad de Long (2000) and the essays in Bresnahan and Gordon (1997), in that it corroborates that economic growth in the 20^{th} century has been a fountain of wealth and pleasure, and still harbours unmeasured aspects. If we measure these, we may find that 20th century economic growth has generated even more welfare benefits than currently thought.

The rest of this paper is structured as follows. In the next section we show why it is reasonable to assume that motion pictures formed a close substitute to live entertainment. Section II discusses the underlying data. The subsequent two sections estimate TFP-growth and the contribution to aggregate growth. Section V compares these findings with previous estimates and with TFP-growth in other industries. Section VI estimates the welfare impact valuing output by the time people spent using the services. Section VII concludes.

I. Motion pictures as a close substitute

During the nineteenth century stand-alone entertainment venues made way for theater circuits and local stock companies for traveling companies, helped by the railways. Central booking offices on Union Square in New York routed creative inputs efficiently across the nation. Innovations such as the steel frame and reinforced concrete enabled a sharp increase in theater size as well as price differentiation, with cheaper tickets for the galleries. The demand for entertainment was boosted by falling working hours, rising disposable income, urbanization, rapidly expanding transport networks and strong population growth.

At the turn of the century, when the existing industry faced decreasing returns to further process innovations, cinema was adopted. It industrialized live entertainment by automating it, standardizing it and making it tradable (Bakker, 2001). This industrialization may have been not unlike the way in which information and communication technology (ICT) would automate, standardize and make tradable certain services after 1945 (Freeman and Soete, 1997: 403-408).

Actors needed only to make one performance, which was reproduced infinitely. This standardized the public's viewing experience; they were guaranteed they would see the entertainment as advertised, without understudies, second-rank sets, reduced musical support or actors having a bad night. Before cinema, only creative inputs were mobile and relatively permanent in time, now the performances themselves became tradable. They were not produced anymore at the time and place of consumption, usually one of the characteristics of a service. Tradability increased competition among creative inputs for the audience's attention and integrated entertainment markets. Until the emergence of cinema, the number of actors and actresses per 100,000 inhabitants increased sharply (figure 1). It stagnated subsequently, while real revenue per performer increased sharply.

By 1938 the spectator entertainment industry was 28 times its 1900 size, and that live entertainment only constituted seven percent of this. A whole industry had gone with the wind and was replaced by an industrialized service.

This paper's key underlying assumption is that motion pictures provided a close substitute for live entertainment. This assumption enables us to assess the impact of motion pictures on industry growth and on US GDP- and TFP-growth.

Below we will argue that the historical evidence suggests that motion pictures and live entertainment were close substitutes because motion picture demand and prices increased simultaneously, because initially live and motion pictures were often shown intermittently, because old live venues were used for cinema, because live entertainment fell sharply a distinct step-improvements in the substitutability of motion pictures, and, following the hedonics approach starting with Lancaster (1966) because the two products inherently shared many characteristics. These points will be discussed in turn below.

First, between the mid-1900s and the mid-1910s, prices for film increased three- to fourfold—from 5 cents to between 10 and 20 cents—while demand grew rapidly (Bowser 1990: 213-14). The main way in which such a phenomenon can be explained is unmeasured quality change and a process of substitution. Second, vaudeville and variety theatres often showed motion pictures intermittently with live acts, literally substituting some acts for celluloid. Third, many venues that provided live entertainment were converted into cinemas, as careful studies by theatre historians note (Moore, 1968). Jack Poggi (1968: 79, 43), for example, writes:

> First the movies created a new audience, many of whom had never been to the theater; but the desertion of the galleries in theaters in all the large cities indicates that they also began to lure away that part of the theater audience with the lowest income. Then, as the movies improved in quality and respectability, people from the business and professional classes might be expected to change their entertainment habits. (...) Possibly the habitual New York theatergoers went to both theater and films for a time and then gradually limited their attendance at live theater to special occasions. This theory would explain why the less popular plays began closing more quickly, causing a drop in the number of theater weeks. (...)
>
> The motion pictures could not have crushed the legitimate theater if there had been a real preference for live drama. Theater managers would never have turned their buildings over to the movies if they could have made more money by booking plays; a few might have been satisfied if there had been equal profit, or even a little less, in live theater. Again we come back to the same point: people were simply not willing to pay the price necessary to maintain live theater, except in the largest cities. If they could get what they wanted from the movies, why should they look elsewhere?

It follows that the quality-adjusted price of those disappearing plays must have been higher than that of motion pictures.

Fourth, after each step-improvement in the substitutability of motion pictures, demand for live entertainment fell sharply. Production data (figure 2) suggest a two-staged process: from the mid-1900s onwards, motion picture theatres replaced small-town live entertainment and from 1927 talking pictures replaced much of the high-value-added metropolitan entertainment (proxied by 'Broadway'). During the emergence of fixed cinemas from the late 1900s, demand for small-town live entertainment (proxied by 'road productions') decreased rapidly (figure 2). In the late 1920s sound films constituted a major jump in substitutability by automating away most of the remaining live acts.[5] Before their introduction, Americans spent $1.33 per capita on theater, versus $3.59 on movies, while in 1938 the figures were $0.45 vs. $5.11 (figure 2).

As Bresnahan and Gordon (1997) noted, any innovation usually has characteristics of a new good and of a substitute. Quality improvements are generally achieved over a vector of quality dimensions, some of those being very close to existing products, some offering a far higher quality, and some new products also offer additional, previously unavailable dimensions. (Although usually it is always possible to find a substitute).

Bresnahan and Gordon (1997), for example, argue that on the one hand the car was an entirely new product, on the other a substitute for the horse, the cart, public transport, walking or cycling. To capture the full welfare benefits one would need to take the passenger-miles travelled, with their cost in money and time, and correct for the changing economic geography because of the car.

Using this approach, it can be argued that both cinema and live entertainment had multiple quality dimensions, and that the differences between the shared

[5] Kraft (1994a, 1994b) and Ehrlich (1986: 197-210) analyze talkies' disastrous effect on musicians' employment for the US and Britain. Ehrlich discusses one-person cinema organs (replacing whole orchestras) as an important labor-saving innovation before the coming of sound.

dimensions were not always in the same direction. Each form of entertainment would constitute a bundle of quality dimensions that could differ in magnitude and would not entirely overlap.[6] Consumers could only buy these bundles of entertainment, not the individual quality dimensions, implying that the market prices we observe for different forms of entertainment may not be directly comparable. On most of the quality dimensions one can informally identify, intuitively motion pictures appear to dominate live entertainment (diagram 1).

Diagram 1. *Examples of comparative quality dimensions of live entertainment and cinema.*

	Live	Silent cinema	Talking pictures
Availability of time slots throughout the day	Lower	High	High
Availability close to the home / at distant places	Low	high	High
Consistency of quality conforming to expected quality	Lowest	lower	High
Probably of performance taking place as planned with actual cast	Lower	higher	Highest
Performers talking in dialogue	High	lowest	High
Interaction with audience	High	lower	Lowest
Existing performance can be adjusted to take into account recent news events	High	Low	Low
Close-ups	Low	High	High
Uniformity of viewing experience across seating area	Lower	Higher	Higher
Number of set-ups	Low	High	High
Availability one particular (star) performer to any consumer	Low	high	High
Consumer can come in any time	Low	highest	Higher
Consumer needs to understand the language	Higher	lowest	Higher
Availability of most successful shows	Low	high	High
Colour	Higher	lower	Lower (before 1937)
Price	High	Lowest	Low

[6] Or, on an overarching vector of entertainment quality dimensions, for each form of entertainment there would be some dimensions with a zero value, and the vector would differ in at least one but probably far more of the shared dimensions, in order for it to be a distinct form of entertainment.

Detailed entertainment price and quantity data for Boston in 1909 give a frozen snapshot of one moment in the process of substitution, one moment frozen in time. Particular good data for Boston in 1909 (Jowett, 1974) show that local consumers could chose between at least eight forms of theatrical entertainment, ranging from opera at a $2 ticket price to moving pictures at ten cents (figure 3). These figures form a static, early snapshot of a dynamic process of creative destruction. Three years after their emergence, cinemas supplied half of Boston's capacity. Given the low prices, however, it took in only a sixth of expenditure. Although figure 3 does not formally show a demand curve, one could informally observe that the rapid diffusion appeared to be reflected in the increasing 'price elasticity of demand' at lower prices, as tentatively suggested by the evidence (table 1). The cheapest vaudeville reacted by interspersing live performances with films. The radical new technology not only swept away the traditional entertainment delivery technology, but also opened up new markets, supplying consumers that had never seen theatrical entertainment before. Gradually, cinema would automate away more and more lower-priced live entertainment, leaving standing only the most differentiated and expensive forms.

A critic might argue that many motion pictures are of lower quality than one of the few top live shows that survived the onslaught of the pictures. However, comparing a B-film to opera might not make a lot of sense. The point confuses the marginal use of entertainment with the inframarginal value. As entertainment became cheaper, consumers started to use it far more, and as the quantity increased, the marginal value decreased as well of course. But this does not contradict that the inframarginal value of the (filmed) entertainment consumed can be very high. Bresnahan and Gordon (1997: 13) make this point as well, and illustrate this with the example of water, which in developed economies has now a very low marginal value but a very high inframarginal one.

To proxy output growth in services, often employment or capital is used. As these are inputs, this inevitably leads to observing limited TFP-growth.[7] This paper proposes a common measure for output for both live and filmed entertainment, the ‘spectator-hour’. Spectator-hours produced, not unlike passenger-miles, are the seats in a venue times the performance duration constitute the spectator-hours produced, the proportion filled the hours actually sold.

The above does not take into account changes in the quality of a spectator-hour. Given the massive increase in production expenditures and new product characteristics—such as cinema itself, the feature film, talking pictures, air-conditioned venues—quality change was probably positive.[8] Robert Lamson (1970), for example, studied the quality of motion picture theatres between 1947 and 1964, including dimensions such as crowding, parking spaces, and theatre age. Quality change was substantial and not captured in the national accounts; it would lower the admission price series with about two-thirds, and increase total factor productivity from zero to 2.7 percent. This suggests that the current paper’s assumptions understate actual productivity growth.

II. Data

Spectator entertainment is defined as theatrical entertainment such as opera, theater, concerts, vaudeville, burlesque and cinema. Two benchmark years have

[7] The TFP-figures below show capital is a better proxy than labor growth, as Millward (1990) suggested, although far from perfect.
[8] Initially, pictures’ lack of audience-interaction and sound were inferior characteristics. Live entertainers provided both aspects during and between pictures, before the talkies.

been selected for the growth estimate: 1900, the first census year before cinema's take-off, and 1938, when the industrialization was complete. Since 1927 sound had driven out most live entertainment, and television had still to arrive.[9] Reliable and exact data sources could not be obtained easily. Especially for 1900, sometimes estimates had to be made based on indirect indicators. Appendices A and B explain each estimate in detail.[10] Yet, we do not need to quantify everything perfectly to make the point that the entertainment's impact on GDP-growth was substantial. Following Fogel's (1964) approach, we bias our estimates against the idea that entertainment's growth contribution was large. If we then still find a significant growth contribution, data imperfections are unlikely to change our findings. It is not our aim to get the exact value of entertainment's contribution, something that is hardly possible given data imperfections, but merely to show that given the available evidence, its impact must have been big.

For the primal growth accounting, data on the capital stock, the labor quantity and output (in spectator-hours) have been collected. Labor quantity is measured in hours using industry full-time employment estimates linked with data on national average working hours from Huberman and Minns (2007). Labor quality has been proxied by the average number of years of education for the population from Maddison (1995). For dual growth accounting, prices and factor prices have been estimated. The 1900 estimates are based on the census, the Historical Statistics of the United States (U.S. Department of Commerce 1975), a household expenditure survey, Owen (1970), and on studies in theatre and film history. No reliable industry wage data were available; the national average has been used. Capital is GDP-

[9] The other major new media—recorded music and radio—were partially different products. The phonograph had remained an elite product. Although in the 1920s radio expanded rapidly, it would only reach its peak during the 1940s and early 1950s. Choosing 1938 makes the estimates more conservative because motion picture and live entertainment expenditure grew rapidly from 1940 onwards.

[10] These are attached and also available from the authors.

deflated and other values are deflated by the consumer price index to make them comparable with 1938.

The data for 1938 is slightly more reliable, as most estimates are based on the National Income and Product Accounts, supplemented by data from industry studies such as Greenwald (1950) and Conant (1960). Wage data were only available for film and 'amusements and recreation'. Combined with other sources, the latter only gives an indication of live entertainment wages. An upper bound estimate of accumulated welfare benefits, using Fogel's (1964) social savings method, was made with (the more reliable) 1938 data only.[11] It is a good test to assess whether the TFP-estimates are in the right ballpark.

III. The Growth in Total Factor Productivity

Traditional growth accounting captures the contribution of technological change to growth through the Solow residual (TFP). With the standard Cobb-Douglas production function and competitive assumptions:

$$Y = AK^{\alpha} L^{1-\alpha} \tag{1}$$

the Solow residual is computed as:

$$\frac{\Delta A}{A} = \frac{\Delta Y}{Y} - s_k \frac{\Delta K}{K} - s_l \frac{\Delta L}{L} \tag{2}$$

With Y = output (in spectator-hours), K = capital, L = labor, A = the Solow residual, and s_k and s_l are the factor income shares.

[11] Social savings estimate the cost-savings of a new technology compared with the next-best alternative:

$$SS = (p_c - p_a)q_a$$

Where p_c is the price of the next best alternative (live entertainment), p_a the actual price at the current technology, and q_a the actual quantity consumed. Assuming the actual quantity remains unchanged at the counterfactual price yields the upper bound. The key advantage compared to TFP is that only final-year (1938) quantity data is needed; the only initial year (1900) data needed is the price.

A term for changes in labor quality has been added in table 2. At nine percent annually for almost forty years, output growth was remarkably high.[12] A third was explained by increases in capital and labor, the rest was due to TFP-growth. Growing over five percent annually, the latter was significantly higher than in other industries.[13]

Using the average share of motion pictures in all spectator entertainment, it is possible to disaggregate total TFP-growth into the contribution of live and film technology:[14]

$$g_{film} = \frac{g_{live+film} - s_{live}g_{live}}{s_{film}} \tag{3}$$

Where g denotes the annual average growth rate between 1900 and 1938 and s the share of the respective technology in output.

Live entertainment showed substantial negative output growth of 1.24 percent annually (table 2). However, inputs where shrinking far faster than output, mainly driven by an exodus of the labor force, resulting in moderately positive TFP-growth.[15] Cinema output grew thirteen percent annually, sixty percent of it driven by TFP-growth. By 1938 it was 13 times as productive as live entertainment.

The Solow residual can also be computed as

$$\frac{\Delta A}{A} = \frac{\Delta(Y/L)}{Y/L} - s_k \frac{\Delta(K/L)}{K/L} \tag{4}$$

This shows entertainment labor productivity increasing with 7.5 percent per annum (table 3). Only slightly more than a tenth was explained by capital deepening, and slightly more by increased education of the workforce. Live labor productivity grew

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[12] For the estimation of factor elasticities, value of human capital and the effect of international trade, see Appendix A.
[13] See section VI.
[14] This assumes that live technology accounted for all 1900 output, because Nickelodeons emerged only in 1905 and film TFP-growth is extremely sensitive to imprecisions in a 1900 size estimate. Live's share was 0.263, the geometric average of the assumed 1900 (1) and 1938 share. Interpolating geometrically from benchmark estimates for 1909, 1914, 1919, 1921, and so on, using US Department of Commerce (1975), combined with industry growth indicators (Bakker, 2005: 344-347) yields an 0.224 share. To keep the TFP-growth estimate for cinema technology conservative, the higher live share is used.
[15] Increasing efficiency in a declining technology is not unusual. Utterback (1996), for example, shows gas lighting's efficiency improved remarkably, and prices fell concurrently, when faced with electric light competition.

2.3 percent annually, largely driven by capital deepening and increased education of the work force, while film labor productivity grew over nine percent annually, mostly because of TFP-growth. In 1900, one hour of labor produced 1.3 spectator-hours, by 1938 this had increased to 19.5 hours.[16]

By 1938, the industry level of TFP was over eight times what it had been in 1900, and for the film industry alone it was over seventeen times as much. The changes in the industry production structure were significant. The industry doubled the capital/labor ratio (figure 4). Even the declining live entertainment's ratio was only a fifth lower than that of cinema by 1938 (table 4). The capital/output ratio declined sharply, from \$0.71 to \$0.15 per spectator-hour.[17] The technical rate of substitution at least doubled. By 1938, about \$16,000 of capital was needed to replace one worker.[18]

Although the underlying Cobb-Douglas function is probably not a perfect model of actual production, sensitivity tests comparing the wage/rental ratio, factor costs and income shares with their Cobb-Douglas values suggest that it is a good approximation in this case.[19]

A dual method to estimate of TFP growth was used Zvi Griliches and Jorgenson (1967) and has been applied to economic history by Antras and Voth (2003) and Crafts (2003). The decline in price of a good, all factor prices remaining the same, must be the result of an increase in efficiency. The dual highlights the welfare interpretation of TFP through real cost reduction (Hulten 2001, Harberger 1998), including unconventional benefits. The dual of expression (2) thus becomes:

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[16] Arrived at by multiplying Y/L (table 3) with the average years of education (6.38 in 1900, 10.03 by 1938). The increase was driven by both rising labour and leisure productivity, as reflected in rising real wages and falling ticket prices.
[17] This is partially responsible for the large 'shift-effect' (input transfer effect), discussed in section IIIc.
[18] Arrived at by taking 1756 hours * 10.03 years of education * 0.90 (the TRS).
[19] Using:

$$|TRS| = \frac{w}{r} = \frac{1-\alpha}{\alpha}\frac{K}{L}\,;\; r = \frac{w}{|TRS|} = \frac{\alpha}{1-\alpha}\frac{L}{K}w\,;\; w = r \cdot |TRS| = \frac{1-\alpha}{\alpha}\frac{K}{L}r\,;\; \alpha = \frac{rK}{rK + wL}$$

Wage/rental ratios for total, live and film varied between 1.02 to 1.15 of the CD TRS. Actual rental rates were between 1.03 to 1.21 of CD-rates, and actual wages 1.03 to 1.15 of CD-wages.

$$\frac{\Delta A}{A} = s_k \frac{\Delta r}{r} + s_l \frac{\Delta w}{w} - \frac{\Delta P}{P} \qquad (5)$$

The results are more tentative than for primal TFP, because rough estimates had to be made for wages and rentals in 1900.[20] Most productivity gains were passed on to consumers: real prices fell phenomenally, with over four percent per annum for nearly forty years, before television had even arrived (table 5). Because live entertainment prices fell by ‘only’ 1.3 percent annually, film technology had the largest downward force on prices, decreasing them with about six percent per annum over almost forty years.[21] The dual estimates give confidence that our TFP-estimates are in the right ballpark.

IV. The Impact on Aggregate Economic Growth and Productivity

Entertainment’s growth contribution can be calculated following traditional growth accounting (Crafts, 2004a). Multiplying the growth of capital by entertainment’s profit share, we arrive at the extensive contribution, which was very small (table 6). The intensive growth contribution, that is producing more outputs without increasing any inputs, consists of three effects.[22] The pure productivity effect captures entertainment’s contribution if its GDP-share had remained the same; it is the 1900

[20] See Appendix B. Sensitivity tests comparing estimated wages or rentals with those of the Cobb-Douglas production function, show that the dual results for total and film TFP are not very sensitive, but that dual live TFP and all markups are sensitive to small estimation errors.
[21] The difference between primal and dual TFP-growth should reflect changes in markups (Crafts and Mills, 2005) using:

$$\frac{\frac{P_t}{MC_t}}{\frac{P_0}{MC_0}} = \left(1 + (g_{primal} - g_{dual})\right)^t \qquad (6)$$

Where P and MC denote price and marginal cost, and g denotes primal or dual TFP-growth as a fraction.Although markups are very sensitive to estimation imprecisions, our data suggests they did not increase, and probably declined (table 7). Thus, dynamic efficiency did not happen at the expense of allocative efficiency in the long run, consistent with Nordhaus’ (2004) findings for US industries between 1948 and 2001.
[22] Nordhaus (2002), who names the share effect the Baumol effect and the shift effect the Denison effect.

share times TFP-growth.[23] The share effect captures the contribution caused by increased relative spending on entertainment. It is TFP-growth times the average additional GDP-share. The input transfer, or 'shift', effect, takes into account that inputs were used more efficiently in entertainment than elsewhere; it is the growth of inputs times the difference between entertainment's GDP-share and input-share.

It turns out that 1.87 percent of GDP-growth can be explained by entertainment.[24] This growth contribution was large compared to the industry's size. It was 2.5 times its average GDP-share and over two-thirds of steam's intensive contribution in Britain between 1870 and 1910 (Crafts, 2004a). Only eight percent of entertainment's contribution was due to extensive growth (embodied in new capital), sixty percent to pure productivity, a quarter to the share effect and as much as seven percent to the input transfer effect. Entertainment's growth contribution was achieved almost without adding new inputs.

Motion pictures' share of aggregate TFP-growth, therefore, was even larger (table 7).[25] It amounted to as much as three percent of TFP-growth, over five times its GDP-share. Another way of reassuring ourselves that there is a real welfare gain is to use the concept of social savings popularized in the economic history literature following Fogel (1964). This is simply the difference in the resource cost of supplying a given volume of output using old and new versions of the technology. The previous section showed how TFP-growth can be interpreted as the rate of real cost reduction. Social savings from reductions in the cost of spectator entertainment as a proportion

[23] Entertainment's expenditure share in GDP is its so-called Domar weight. Economy-wide these weights sum to greater than 1. For an algebraic justification see Hulten (1978).
[24] An alternative method, dividing GDP in entertainment and a composite good and then correcting entertainment prices, suggests entertainment accounted for 1.59 percent of GDP-growth, slightly less (possibly because it is innocent of the shift effect) but still in the same ballpark, suggesting our findings are not unreasonable.
[25] Angus Maddison (1995: 255). For the U.S. private non-farm economy Field (2003) finds a growth rate of 1.70, Abramovitz and David (1999) 1.40 and Gordon (2000) 1.43 percent per annum. Rates for various intervals were converted into 1900-1938 equivalents, using weighted geometric averages. Maddison's estimate is used because it encompasses the whole economy. Other estimates leave entertainment-TFP-growth still several times general TFP-growth.

of GDP can therefore give an upper bound estimate of the welfare gains of real cost reduction.[26]

Motion pictures' social savings in 1938 relative to a world where they did not exist are obtained by taking all film spectator hours produced (7 billion) times the price difference with live entertainment. These turn out to be almost $2 billion, or 2.2 percent of 1938 GDP. Being an upper bound estimate, this is slightly higher than the accumulated TFP-growth (real cost reduction) between 1900-1938, as reported in table 7 line 20), giving confidence that our growth accounting results are not unreasonable.

V. Discussion of the industry's productivity growth and growth contribution

Comparing this paper's findings with existing growth data on recreation suggests that our current understanding of GDP-growth in this period may seriously underestimate the contribution of certain services. Existing pre-1929 GDP series are based on benchmark-year estimates, which do not include entertainment separately before 1909.[27] Using the price relative to all other goods and services, however, combined with the expenditure for 1900 and 1938 yields an output growth of 4.2 percent and a price increase of 1.4 percent annually, and a TFP growth of 0.90 percent (table 8).

From 1929 onwards the national accounts contain price indices for live and filmed entertainment, from which we can estimate TFP-growth in two ways. First, if we link them to our 1938 estimates, and then weigh the output by price rather than

[26] The upper bound arises because the technique in its simplest form, used by Fogel (1964), assumes that demand is inelastic, and thus that consumers keep consuming the same quantity at old technology prices. Social savings are innocent of international trade, but motion picture exports were small compared to domestic expenditure (see Appendix A) and cannot materially alter our findings. The TFP/social savings comparison follow Crafts (2004a: 344-345).

[27] See Lebergott (1996), and *Historical Statistics of the United States*, Millenial Edition, pp. xx-xx.

spectator-hours (the method traditionally applied), this reveals an annual output decline of -0.47 percent per annum between 1929 and 1938. If we assume that the growth of inputs calculated for 1900-1938 was not much different during the 1930s, this yields a negative TFP-growth of -3.76 percent.

Second, if we use the Bureau of Economic Analysis (1977) NIPA indexes to estimate the number of spectator hours for 1929 and then value output by those, output grows with 0.15 percent, and TFP is still sharply negative. Even if input growth would have been a fraction of the 1900-1938 trend rate, TFP-growth would still be negative. In short, the national accounts appear to underestimate entertainment's growth contribution.

We can also compare motion pictures to Lebergott's (1996) growth estimates for all recreation services, which amount to 4.2 percent annually for 1900-1938, yielding TFP-growth of 0.9 percent. If we combine Lebergott's price series for 1900-1929 with entertainment's share in recreation services and our output and price data, all recreation services grew with just 0.16 percent per annum, and their price with 13.7 percent per annum. Both are highly improbable and suggest entertainment is currently not well-measured. Detailed estimates by Owen (1970) for all recreation services as well as goods between 1901 and 1938 show an output growth of 4.3 percent annually. If spectator entertainment output grew at the same rate, TFP would have been just one percent.

On average, the above existing estimates imply output, price and TFP growth of 3, 0.2 and - 0.33 percent per annum, respectively (table 8). They underestimate output growth by at worst - 5 percent and at best 58 percent of that measured in this paper, leading to an underestimate of TFP-growth of at worst - 63 percent and at best 35 percent of actual TFP-growth.

No well-measured industry surpassed entertainment's TFP-growth during the first half of the twentieth century (table 9). Only rubber products and electric utilities came close, but had 10 and 13 percent lower TFP-growth. If we compare other industries' thirty-year intervals with entertainment's 38-year, only rubber exceeded entertainment's TFP-growth by nine percent. If we take twenty and ten year intervals, more industries surpass entertainment, showing that its TFP-growth was not unheard of, but that *no other industry experienced it for so long*. Over shorter intervals, entertainment TFP-growth was in the same league as transport, electricity and their supply sectors oil and gas and rubber, but its growth contribution lower because sharply falling prices, together with low exports and a demand elasticity bounded by the 24-hour day, kept its GDP-share lower. Motion pictures thus led the big league in TFP-growth, but lagged in impact because of its small GDP-share.

The fact that entertainment accounted for about 3 percent of over-all TFP-growth suggests that it was part of the broad-based U.S. shift to accelerated TFP-growth, and of the TFP-surge outside manufacturing during the 1930s identified by Field (2003, 2006). Compared to TFP-growth in other service industries, motion pictures remained exceptional. TFP-growth, for example, was 'only' 1.8 percent per annum between 1919 and 1938 in the telephone industry, 3.9 percent in electric utilities and 2.2 percent for the railroads (Kendrick, 1961).[28]

High TFP-growth has been associated with General Purpose Technologies (GPTs), technologies that initially have 'much scope for improvement and eventually come to be widely used, to have many uses, and to have many Hicksian and technological complementarities' (Lipsey, 1998; Crafts, 2004a). GPT's initial productivity impact is typically minimal; it may take 40 to 120 years to become

[28] Derived from 1919-1929 and 1929-1941 intervals. Only 'Trucking and warehousing' and 'Transportation by air' had higher TFP-growths than film (13.6 and 13.7 percent annually) for 1929-1941 (Field, 2006: 219).

substantial. Film technology possessed some GPT-properties: initially it needed many improvements and became widely used nationally and internationally, in almost every town. Motion pictures probably had their largest productivity impact only after thirty to forty years, with the coming of sound in 1927. Their uses, however, as well as complementarities, remained largely constrained to spectator entertainment, and this limited their growth impact compared to GPTs.

Entertainment's GDP-share was much lower than that of GPTs, except early British steamships (table 10). Yet its TFP-growth and intensive growth share were higher than most other GPTs. Only fin-de-siècle British railways experienced growth more intensively, and only because passenger time savings have been included in output (Leunig 2006). Because of its small size, cinema's total growth contribution was smaller than that of GPTs.

Its accumulated *intensive* growth contribution was in the same ballpark as many GPTs and higher than British railways, steam and steamships before 1870 (table 10).[29] The high contribution was possible because the extreme intensiveness of growth compensated for entertainment's small expenditure share. Without the plunge in prices resulting from the efficiency increase, this share might have been far higher.

To assess an industry's growth impact, its accumulated growth contribution (real cost reduction) can be expressed as a fraction of the national accumulated

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[29] Calculated using

$$G_t = 1 - \left\{ 1 - \frac{s_y \left[\left(\frac{A_t}{A_0} \right)^{\frac{1}{t}} - 1 \right]}{\left(\frac{GDP_t}{GDP_0} \right)^{\frac{1}{t}}} \right\}^t \quad (7)$$

Where G_t = the 'growth impact', the accumulated intensive growth as fraction of GDP, s_y = the share of spectator entertainment expenditure in GDP and t = the number of years. This is a formalization of the methodology used by Crafts (2004b) and Foreman-Peck (1991).

intensive growth (using expression (7)) (Table 10, column 12). The latter was 37 percent of GDP in 1938 relative to 1900: using only technologies available in 1900, the US would have needed additional inputs to the value of a third of actual GDP to produce the same output. A technology's share in national real cost reduction can potentially quantify the extent to which it is a GPT. This growth impact assessment takes account of both intensive growth and industry size and scales this to economy-wide efficiency gains. Motion pictures accounted for 3.8 percent of national real cost reduction, a growth impact lower than that of any GPT except early British steamships because of entertainment's low GDP-share and high national intensive growth during its emergence.[30]

VI. Motion pictures' welfare impact

As noted above, while in TFP-growth spectator entertainment was in the big league, its growth contribution was more moderate. Consumption had multiplied 28-fold in quantity terms, but its price had decreased so much that the resulting GDP-share remained limited. Yet anyone alive in the 1930s would notice the ubiquity of the pictures. Most young consumers would go more than once a week to the pictures, many magazines and books centred around the pictures and a big share of the hit songs were derived from the pictures. An observer in the 1930s could have noted that 'motion pictures are everywhere, except in the productivity statistics'.

It is clear, however that the time consumers spent watching entertainment had increased far more rapidly than the expenditure. In 1900, the expenditure share was

[30] If national intensive growth was the average of that during the emergence of other GPTs, entertainment's growth impact would be 7.3 percent. If its GDP-share equaled the GPT-average, its growth impact would be 11.1 percent. Combined, the impact would be 16.4 percent, lower only than ICT and British railways before 1870. (National intensive growth, GDP-share and the joint effect account for 28, 59 and 13 percent of growth, respectively).

0.73 percent and the time share 0.67 percent, by 1938, the expenditure share was 0.63 percent and the time share 3.1 percent (table 12). In other words, while in 1900 the time share was 0.9 times the expenditure share, by 1938 this had increased to 5 times.

If we take into account the value of time consumers spent watching entertainment, we will be able to make an estimate of the (welfare) impact of motion pictures that comes closer to what we would intuitively expect. This approach follows that of Gary Becker (1965) who showed how the full costs of consumption consist of monetary and opportunity costs, and that these combine into an overall constraint.[31] In the case of entertainment this approach is especially relevant because of two reasons. First, the service delivered and the time to consume it are inextricably linked in fixed proportions: a ticket is worthless without the fixed amount of time needed to watch a film, and this amount of time cannot be used watching a film without a ticket.[32] Second, entertainment is a consumptive service, because it cannot be delegated to a third person, just as going to the dentist, hairdresser, listening to music (Reid 1934).[33] If a service can be delegated, it constitutes household production. Activities such as childcare, cooking and doing the laundry can be produced in the market in different ways and at different prices, which can be compared to household production. Consumptive activities like cinema-going do not have this delegation option. The only way other activities can compete is for the time they involve. This suggests that time is the most fundamental output of the entertainment sector, and that therefore it is useful to value its output by the time consumers spent watching it.

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[31] [Following Becker (1965) 'full costs' is used rather than 'total costs' to emphasize they include opportunity costs and relate to 'full income'.]

[32] Goolsbee and Klenow (2006) use an alternative approach, using a utility function in which they separate out time and money. This is not necessary in the case of motion pictures, as they were produced in fixed proportions, leaving consumers no choice. Also the historical data does not enable the estimation of an utility function. Nevertheless, Goolsbee and Klenow reach similar conclusions for internet-access services. For a general analysis of time allocation dynamics between 1965 and 2005, see Krueger (2007).

[33] The 'third person criterion', is often used in household satellite accounts that supplement national accounts (Murgatroyd and Neuburger 1997).

We will assume here that the opportunity costs equaled the wage rate. We also assume this for the unemployed, following Nordhaus and Tobin (1972), who estimate leisure time in the 1930s. Alternatively, the unemployed could have opportunity costs proportionate to unemployment duration, following, for example, Layard (1981) and Crafts (1987). The unemployed then needed low prices because they had little income, the employed because their opportunity costs were so high.[34] Below we will show that our findings are not very sensitive to using this latter approach. Some might interject that valuing leisure time at the wage rate is counterintuitive, given that people do not appear to take into account their wage rate when making each individual leisure decision, and could not be able to easily obtain the opportunity for working another hour. In the longer run, however, consumers can easily chose to work a day or an evening more or less, can work over time, can take on second jobs---so it seems perfectly sensible to take the wage rate as the opportunity costs, because in the medium term consumers can easily fill those hours with work at the prevailing (market) wage rate.[35]

We use opportunity costs here as a proxy for the welfare impact of motion pictures, following the approach by Becker (1965) and not unlike empirical work such as Hausman (1997) or Goolsbee and Klenow (2006). This welfare impact is of course conceptually different from the production perspective of the TFP-growth and growth contribution estimated in the preceding part.

The results of valuing entertainment output by its opportunity costs are presented in table 11. While total expenditure grew by 4.2 percent a year, total

[34] Assuming linear proportions and a 26-week average duration, and taking the unemployment rates of 5 percent and 12.47 percent for 1900 and 1938 (Barber 1976), our findings hardly change: opportunity-cost output- and TFP growth (table 3, line 3) decline by 0.12 and 0.10, and total-costs output- and TFP growth both by 0.14 percentage points. The ratio of total consumption costs for the employed to those for the unemployed then increased from 1.25 to 8.8 between 1900 and 1938. Valuing everyone's leisure hours at a different proportion of wages obviously only affects total-costs growth rates. Valuing leisure time at half the wage rate, for example, reduces output- and TFP growth from 9.2 to 6.9 and from 5.9 to 3.6 percent.

[35] Issues that affect long-run versus short-run substitution include the clumpedness of labour opportunities (there is not always a spot market), transaction costs (contract signing, vetting, getting worked-in etc.), and economies of scale (to-work transport and work preparation spread out over more work-hours).

opportunity costs grew by 12.3 percent annually. When expenditure and opportunity costs are summed, it becomes clear that opportunity costs increased from 31 percent of full costs in 1900 to as much as 88 percent in 1938.

The full cost per hour remained constant at $0.88 an hour, because coincidentally, the sharp rise in opportunity costs was compensated for by a sharp fall in price (table 11). While price fell by 4.6 percent a year (from $0.61 to $0.10), opportunity costs rose by 2.8 percent annually (from $0.27 to $0.78; table 11). This also explains why the annual growth in total full costs of 9.2 percent equaled the annual output growth measured in spectator-hours.

Although the full costs per hour remained constant, per capita consumption nevertheless increased sharply, by 7.6 percent per annum. The question remains how this was possible. Becker (1965) notes how during the first half of the twentieth century the productivity of both labor and leisure increased. The increasing productivity of leisure led people to change labor into leisure hours (substitution), or vice versa (the income effect).[36] Likewise, rising labor productivity (and thus rising wages) would lead to changing leisure for labor hours (substitution) and labor for leisure hours (the income effect). If both productivities increased at the same rate, which Becker suggests was likely, then the respective substitution and income effects cancelled each other out. With an income elasticity of time-intensive activities greater than unity, however, labor hours fall and leisure hours rise, and this is what happened in the early twentieth century, according to Becker (see diagram 2). So the story is not simply one of increasing labor productivity with the income effect dominating a substitution effect, but of the effects of labor and leisure productivity growth offsetting each other, with at the higher full income a larger demand for time-intensive activities.

[36] Owen (1970) notes substantially falling prices of leisure goods and services as evidence of rising productivity of leisure time.

Diagram 2: *Potential effects of labour and leisure productivity growth on the number of leisure hours.*

		Leisure productivity	
Labour		**Constant**	**Growing**
productivity	**Constant**	No change	lh↑ or lh↓
	Growing	lh↑ or lh↓	lh ↑ if e_y>1

Notes: lh = leisure hours, e_y = the income elasticity of time-intensive activities

The historical evidence indeed suggests a sharp increase of both market and household productivity, even if both cannot always be measured perfectly (Owen 1970). Moreover, the income elasticity of time-intensive activities was high in this period. Bakker (2007), for example, finds an income elasticity for motion pictures of 2.3 in 1918 and 1.5 in 1935, and for live entertainment of 4.4 and 8.2 respectively.[37] Mincer (1963) and Becker (1965) note that these income elasticities would be higher still if the full costs were taken into account, since opportunity costs increase with income.

The constant full cost of a spectator-hour suggests that Becker's conjecture held for the case of spectator entertainment. The effect of an increase in productivity of leisure time (the falling price per spectator-hour) was off-set by the increase in labor productivity (rising real wages). Thus, entertainment demand per capita did not increase because of falling ticket prices, but because rising leisure and labor productivity increased full income, which led to more expenditure on entertainment, as its income elasticity was far above unity.

[37] In 1889-1890 the income elasticity of 'amusements and vacations' ranged between 1.2 and 1.4 for families with positive expenditure and was 2.1 for all families. Estimates for Britain and France reach similar or higher elasticities (Bakker 2007).

With constant full costs, any per capita consumption increase between 1900 and 1938 must have been due to the long-run full-income elasticity of demand. Using the wage rate to reflect the change in full income, we get a long-run full-income elasticity of demand of 3.96.[38]

Historical evidence suggests that in an earlier place and time—during the British Industrial Revolution—on the contrary, leisure productivity increased sharply while labor productivity remained stagnant, and that the income effect dominated the substitution effect (Voth 2000). When their full income increased because of more productive leisure, consumers chose to spend more hours laboring.

In the case of entertainment, the income and substitution offsets can be observed so clearly because it was time-intensive at the extreme: consumption involved a fixed, chunky amount of time, few other activities could be done simultaneously, and hardly any goods were used by the consumer. Rising opportunity costs limited the effect of the massive fall in entertainment prices and thus the GDP-share and growth impact of entertainment. The compensation of falling prices by rising opportunity costs is not inconsistent with Becker's (1993: 386) observation that the day's 24-hour limit forever prevents us from reaching a cornucopian Utopia:

> Economic and medical progress have greatly increased length of life, but not the physical flow of time itself, which always restricts everyone to 24 hours per day. So while goods and services have expanded enormously in rich countries, the total time available to consume has not. Thus wants remain unsatisfied in rich countries as well as in poor ones. For while the growing abundance of goods may reduce the value of additional goods, time becomes more valuable as goods become more abundant. The welfare of people cannot be improved in a utopia in which

[38] This is substantially higher than estimates not taking into account opportunity costs / full income. Bakker (2001), for example, finds a long-run GDP-elasticity of demand for entertainment of 2.32 for this period, which is an upper bound to long-run income elasticity, as GDP grew faster than per capita income and the price decrease was ignored. Intertemporal elasticities are different from cross-sectional elasticities, naturally.

everyone's needs are fully satisfied, but the constant flow of time makes such a utopia impossible.

VII. Conclusion[39]

During the early twentieth century, motion picture technology changed entertainment performances from a rivalrous service into a non-rivalrous commodity. This paper aimed to assess impact of motion pictures on US economic growth and welfare during the early twentieth century by developing a robust output measure, and using this to estimate TFP growth, the industry's growth contribution and its welfare impact.

First, we have shown that one can reasonably assume that motion pictures were a close substitute for live entertainment. The use of final year industry/market definition can be misleading when studying the industrialisation of a service. Because of a process of dynamic product differentiation, by the time industrialisation has been completed the surviving traditional service activities are generally highly differentiated from the industrialised part, and that is exactly how the traditional part survived. Final-year cross-price elasticities are very different from initial year cross-price elasticities. One could even speculate that the substitutability forms an inverted U-shape: initially a new product was a very poor substitute for the traditional service. Then with successive step-improvements in the new product, the product became more of a substitute, and then, after the traditional service had differentiated itself, the new product became less of a substitute again.

Using the spectator-hour as the output measure, our first finding is that entertainment output increased a massive 28 fold between 1900 and 1938,

[39] A discussion of how our research and our findings relate to the existing literature can be found in the introduction.

constituting a growth of 9.2 percent per annum, and a per capita increase of 5.8 percent per annum. We found that, at 5.9 percent per annum, TFP-growth was higher than in *any* manufacturing industry, and any other well-measured industry for that matter.

Although this is just one instance of a personal service, as a single case it still falsifies the hypothesis that productivity growth in personal services should be inherently lower than in manufacturing. Further research on other personal services could show whether this kind productivity growth was more widespread.

Second, we find that the contribution of entertainment to aggregate US growth was substantial, though not as big as that of General Purpose Technologies. Entertainment accounted for just under two percent of total GDP-growth and over three percent of aggregate TFP-growth. Only 8 percent of the growth contribution was due to an increase in inputs. As much as 92 percent was driven by extensive growth, with 60 percent due to the productivity effect, 25 percent to the share effect and 7 percent to the input-shift effect. This case suggests that if we include personal services, US economic growth between 1900 and 1940 can be even further reinterpreted as being sustained by growth in services.

Third, to assess motion pictures' welfare impact, we weigh our output measure by the opportunity costs consumers incur when watching the pictures, and add this to the monetary costs to get the full costs. This is *not* a new output measure, but a way to weigh or to value the production concept of output used in the first part of this paper in order to arrive at a welfare concept. We find that as prices fell sharply, opportunity costs increased, leaving the full cost per hour constant. While in 1900 going to a show cost a lot of money and little time, by 1938 it cost a lot of time and little money. The constant full costs leave the question how per capita consumption could increase with 5.8 percent annually. Following Becker (1965) we suggest that this can at least partially be explained by the high income elasticity of time-intensive activities, which is supported by the empirical evidence for this period. If we value the 1938 entertainment output by its full costs, we arrive at 6.2bn, more than eight times the money expenditure.

We hope we have also shown that opportunity costs are a good way to historically proxy the welfare impact of time-using activities, especially since the further back we go, the more difficult it becomes to get data that is detailed an reliable enough to allow the precise estimation of the consumer surplus.

Our findings also suggest that sharp productivity growth may have gone largely unnoticed in some of the most successful industries, because, although the quantity increased enormously, sharp price declines combined with the natural 24-hour day limit to demand, kept the expenditure share low, and the marginal value innocuous. However, a low marginal value can coincide with a large inframarginal value if quantity expands rapidly, a point made by Bresnahan and Gordon (1997), who discuss the classic example of water, and including opportunity costs show that the marginal value of time-intensive services to consumers was far higher than suggested by their market price alone. Further research might identify other industries that also experienced previously unnoticed productivity jumps. It is likely that we are still underestimating a large proportion of the wealth and pleasure that twentieth century economic growth has brought us.

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TABLES

TABLE 1

PRICES, CAPACITY, SALES POTENTIAL, ESTIMATED "PRICE ELASTICITY" AND "CONSUMER SURPLUS" FOR VARIOUS TYPES OF THEATRICAL ENTERTAINMENTS, BOSTON, 1909

	Price	Capacity	Sales	Percentage of		"Price elasticity of demand"			Consumer surplus		CS/Rev.
	($)	(seats)	($)	Capacity	Sales	arc	informal	Log-log	($)	(%)	(%)
Opera	2.00	13,590	27,180	2	10	-2.41	-3.86	-0.30	19,230	17	71
First-class theatres	1.00	111,568	111,568	14	42	-2.41	-1.45	-0.30	55,784	48	50
Popular theatres	1.00	17,811	17,811	2	7	-0.96			8,906	8	50
Stock houses	0.75	21,756	16,317	3	6		-1.08	-1.42	2,720	2	17
Vaudeville houses	0.50	45,744	22,872	6	9	-0.61	-0.82	-1.42	5,718	5	25
Burlesque houses	0.25	80,700	20,175	10	8	-0.48	-0.96	-1.42	10,088	9	50
Vaudeville and moving pictures	0.15	79,362	11,904	10	4	-0.48	-0.99	-1.42	3,968	3	33
Moving-picture theatres	0.10	402,428	40,243	52	15	-1.76	-1.23	-1.42	10,061	9	25
All above entertainments	0.35	772,959	268,070	100	100	-1.07	-0.53	-0.78	116,473	100	43
All live entertainment	0.67	330,850	221,875	43	83	-1.17			104,428	90	47
Motion picture entertainment	0.10	442,109	46,195	57	17	-1.76			12,045	10	26

SOURCE.—Calculated from data from Boston Committee 1909, as mentioned in Garth S. Jowett, 1974.

NOTES.—Capacity = the weekly seating capacity as estimated by the Boston committee (venue capacity times number of performances).
Sales = sales potential, when all seats are sold at the listed prices.
Arc elasticity = between respective price and the next price down.
Informal elasticity = based on best tangents to demand curve at data point, using mixed log-lin, polynomial and power curves at various stretches of the demand curve.
Log-log elasticity = based on constant elasticity log-log model split for two parts of demand curve to get best fit (R2=0.998 and 0.945).
CS = Consumer surplus = area above price line and under hypothetical demand curve for the respective stretch of the curve, estimated using 'price elasticity' (as in this table) following Hausman (1997a). For opera, the intercept at q=0 is set at $4.83, the price that equalizes
"upward and downward" arc elasticity for opera.
Rev. = Revenue.

TABLE 2
CONTRIBUTIONS TO OUTPUT GROWTH IN SPECTATOR ENTERTAINMENT, 1900-1938,
PER CENT PER ANNUM

	TOTAL	DISAGGREGATED	
		Live technology	Film technology
Output	9.19	-1.24	12.86
Contributions			
Capital	1.22	-0.17	
Labor quantity	1.17	-2.58	
Labor quality	0.90	0.90	
All above inputs	3.29	-1.85	5.10
TFP	5.90	0.60	7.76

SOURCE.—Appendices A and B.
NOTE.—The contribution of film technology is an estimate based on the total and live contribution, using expression (3) from the text.

TABLE 3
CONTRIBUTIONS TO LABOR PRODUCTIVITY GROWTH IN ENTERTAINMENT, 1900-1938, PERCENT PER ANNUM

	TOTAL	DISAGGREGATED	
		Live technology	Film technology
Labor productivity	7.52	2.27	9.44
Contributions			
Capital deepening	0.82	0.72	0.95
Labor quality	0.90	0.90	0.90
TFP	5.79	0.66	7.60

SOURCE.—Appendices A and B.
NOTE.—The contribution of film technology is an estimate based on the total and live contribution, using expression (3) from the text.

TABLE 4
KEY PRODUCTION FUNCTION RATIOS FOR THE U.S. ENTERTAINMENT INDUSTRY, 1900 AND 1938

Ratio	Unit	1900	1938	1938 disaggregated	
				Live	Film
Y/L	s-h/hour/yedu	0.20	1.95	0.29	2.23
	$/hour/yedu	0.12	0.20	0.11	0.22
K/Y	$/s-h	0.71	0.15	0.88	0.14
	$/$	1.16	1.51	2.36	1.43
K/L	$/hour/yedu	0.14	0.30	0.26	0.31
TRS	$/hour/yedu	0.41	0.90	0.77	0.92

SOURCE.—Tables 4 and 5; Appendix B.

NOTES.—TRS = The technical rate of substitution; s-h = spectator-hour. yedu = average years of education of the labor force; 6.38 in 1900 and 10.03 in 1938, as in Maddison (1995). Dollars have been deflated to 1938 dollars using the consumer price deflators in Mitchell (1998).

TABLE 5
CONTRIBUTIONS TO REAL PRICE DECLINE IN SPECTATOR ENTERTAINMENT, 1900-1938, PERCENT PER ANNUM

	TOTAL	DISAGGREGATED	
		Live technology	Film technology
Real price	-4.58	-1.27	-5.74
Contributions			
Rental	-0.18	-0.85	
Real wage (quality adjusted)	1.83	1.08	1.93
Dual TFP	6.23	1.50	7.89
Primal TFP	5.90	0.60	7.76
Markup	-0.33	-0.90	-0.13
	1938 VALUES (1900 = 100)		
Real price	17	62	16
Rental	76	27	83
Real wage (quality adjusted)	250	172	263
TFP-level	883	126	1711
Markup	88	71	95

SOURCES.—Appendices A and B; national wages: unskilled: Williamson (2006); all: USDC (1975).
NOTES.— Wages and prices deflated with Mitchell's (1998) consumer price deflators, before real price and wage growth is computed. Wage growth rate is based on average real wage per person-year of education (pyedu).
For comparison: national real unskilled hourly wages grew by 0.87 percent per pyedu per annum, total national hourly wages grew by 0.98 percent per pyedu per annum. The markup is calculated using expression (6) in the text.

TABLE 6

GROWTH CONTRIBUTION OF THE ENTERTAINMENT INDUSTRY, 1900-1938

	Growth (% p.a.)	Fraction (%)	Growth contribution (%-point p.a.)	
Extensive growth contribution				
Growth capital	4.90			
Profits/GDP		0.07		
Total extensive growth contribution				0.003
Intensive growth contribution				
Growth TFP	5.90			
Output/GDP in 1900		0.44		
Pure productivity effect			0.026	
Average additional output/GDP 1900-1938		0.18		
Share effect			0.011	
Growth of inputs	3.29			
Average input share in GDP 1900-1938		0.30		
Input transfer effect			0.003	
Total intensive growth contribution			0.039	0.039
Total growth contribution				0.043
Real GDP growth	2.27			
Caused by entertainment		1.87		0.043
Explained by extensive growth entertainment		0.14		0.003
Explained by intensive growth entertainment		1.73		0.039
Extensive growth/all growth		8		
Pure productivity effect/all growth		60		
Share effect/all growth		25		
Input transfer effect/all growth		7		

SOURCES.—Entertainment data: Appendix A. 1900 and 1938 nominal GDP and real GDP-growth: Williamson (2006).

NOTE.—Profits/GDP and output/GDP: the mid-year value is taken of a geometrical series based on the 1900 and 1938 ratios. The pure effect is the gross output/GDP share (the Domar weight) in 1900 times TFP-growth 1900-1938, the share effect is the same times the average output share 1900-1938 minus the initial share. The input transfer effect is (average value added / GDP) minus (entertainment input / all inputs) for 1900-1938 times the growth rate of inputs. Based on primal TFP-growth. Using dual TFP-growth yields a similar outcome (1.96 percent of GDP-growth explained by entertainment, 1.82 %-point of which intensive.

TABLE 7

CONTRIBUTION OF THE ENTERTAINMENT INDUSTRY TO NATIONAL TFP-GROWTH, 1900-1938

	PRIMAL		DUAL	
	Growth (% p.a.)	Fraction (%)	Growth (% p.a.)	Fraction (%)
National TFP growth	1.14			
TFP-growth entertainment industry	5.90		6.23	
Output/GDP		0.61		
National TFP-growth explained by entertainment		3.19		3.37

SOURCES.—Appendices; Maddison (1995: 255).

NOTE.—National TFP-growth is the weighted average of 1870-1913 and 1913-1950.

TABLE 8

VARIOUS ESTIMATES OF OUTPUT GROWTH FOR SPECTATOR ENTERTAINMENT, AND RECREATION GOODS AND SERVICES, 1900-1938

CATEGORY	OUTPUT VALUED BY	PERIOD	AVERAGE ANNUAL GROWTH OF			SOURCE
			Output	Price	Implied TFP	
Spectator Entertainment	Relative price	1900-1938	4.19	1.40	0.90	This paper; CPI
	Price	1929-1938	-0.47	-1.31	-3.76	NIPA
	Spectator-hours	1929-1938	0.15	-1.31	-3.14	NIPA; this paper.
Recreation Services	Price	1900-1929	5.38	3.13	2.09	Lebergott (1996)
	Price	1900-1938	4.22		0.93	Lebergott (1996)
Recreation Goods	Price	1900-1929	4.65	1.44	1.36	Lebergott (1996)
	Price	1900-1938	3.32		0.03	Lebergott (1996)
Recreation Services and Goods	Price	1900-1929	5.27	2.35	1.98	Lebergott (1996)
	Price	1900-1938	3.81		0.52	Lebergott (1996)
	Price	1901-1938	4.27	0.27	0.98	Owen (1970)
Average		1900-1938	2.96	0.44	-0.33	
Spectator entertainment as measured in this paper	Spectator-hours	1900-1938	9.19	-4.58	5.90	This paper

SOURCES.—Owen (1970); Lebergott (1996); Bureau of Economic Analysis, National Income and Product Accounts of the United States (NIPA).

NOTES.—All rates in percent per annum. Spectator entertainment was on average 57.8 percent of recreation services between 1900 and 1929, when Lebergott data is combined with this paper's data; spectator entertainment shrank from 65 percent to 51 percent of all recreation services expenditure. Spectator entertainment was on average 18.6 percent of all recreation goods and services between 1900 and 1938, when Owen data is combined with this paper's data; its share grew from 15 to 23 percent of all recreation goods and services expenditure. The latter suggest that the expenditure share of recreation goods must have dropped sharply relative to services.

Implied TFP' speculatively assumes that inputs grew at the rate for spectator entertainment reported in table 4 (3.29 percent per annum).

Average: the unweighted average of spectator entertainment growth rates, recreation services growth rates and Owen's estimate of the recreation goods and services growth rate.

TABLE 9
GROWTH OF TOTAL FACTOR PRODUCTIVITY BY INDUSTRY GROUP, UNITED STATES, 1899-1937, IN PERCENT PER ANNUM

RANK	INDUSTRY	38 YEARS	30 YEARS		20 YEARS			10 YEARS			
		1899-1937	1899-1929	1909-1937	1899-1919	1909-1929	1919-1937	1899-1909	1909-1919	1919-1929	1929-1937
1	Spectator entertainment	6.0									
2	Rubber products	5.4	5.8	**6.5**	4.8	**7.5**	**6.0**	2.3	**7.4**	**7.7**	4.0
3	Electric utilities	5.2	5.3	5.2	**6.7**	5.3	3.6	5.2	**8.2**	2.5	5.0
4	Transportation equipment	4.2	5.5	5.3	4.0	**7.7**	4.4	1.1	**7.0**	**8.4**	-0.4
5	Tobacco	4.1	3.5	5.1	3.0	4.6	5.2	1.2	4.9	4.4	**6.3**
6	Residual Transport	3.8	2.5	5.6	0.1	4.4	**8.0**	-1.2	1.5	7.4	**8.8**
7	Oil and Gas mining	3.7	2.5	4.6	1.1	3.2	**6.6**	1.3	0.9	5.5	**8.1**
8	Manufactured gas	3.6	4.1	3.4	4.5	4.1	2.5	4.1	5.0	3.2	1.6
9	Printing, publishing	3.3	3.5	3.1	3.4	3.3	3.2	3.9	3.0	3.7	2.6
10	Paper	2.8	2.5	3.0	1.3	2.5	4.5	2.4	0.3	4.7	4.3
11	Metals mining	2.8	2.4	3.4	1.6	3.0	4.0	1.1	2.2	3.8	4.3
12	Stone, clay, glass	2.7	2.8	2.9	1.4	3.2	4.2	2.2	0.7	5.7	2.3
13	Petroleum, coal products	2.7	2.7	3.4	-0.2	3.7	5.9	0.7	-1.0	8.6	2.7
14	Telephone	2.7	2.8	1.9	3.3	1.7	2.0	4.8	1.9	1.6	2.4
15	Local Transit	2.6	2.6	3.1	1.9	3.4	3.4	1.1	2.7	4.1	2.5
16	Chemicals	2.5	2.4	3.2	0.0	3.3	5.4	0.7	-0.7	**7.4**	3.0
17	Fabricated metals	2.5	2.9	2.6	2.0	3.2	3.0	2.3	1.8	4.6	1.0
18	Apparel	2.5	2.5	3.1	1.7	3.3	3.3	0.7	2.7	4.0	2.5
19	Textiles	2.2	1.6	2.7	1.0	1.9	3.7	1.1	0.9	2.9	4.6
20	Railroads	2.2	2.4	2.4	2.6	2.6	1.8	1.8	3.4	1.9	1.7
21	Nonmetals mining	2.2	2.6	2.4	1.0	3.1	3.6	1.6	0.4	5.9	0.7
22	Miscellaneous mfg.	1.9	1.6	2.2	0.1	2.0	3.8	0.8	-0.6	4.6	2.9
23	Electric machinery	1.8	1.5	2.3	0.4	1.9	3.4	0.6	0.3	3.5	3.2
24	Primary metals	1.7	2.5	1.4	1.1	2.5	2.4	2.7	-0.5	5.5	-1.3
25	Machinery, on-electronic	1.7	1.5	1.9	0.8	1.8	2.6	1.0	0.7	2.9	2.3
26	Leather products	1.7	1.2	2.2	0.3	1.7	3.2	0.1	0.5	2.9	3.6
27	Foods	1.7	1.7	2.1	-0.1	2.4	3.6	0.3	-0.4	5.3	1.5
28	Beverages	1.7	-1.7	1.9	-2.4	-2.9	6.4	0.9	-5.6	-0.2	**15.2**
29	Telegraph	1.6	1.5	1.7	0.1	1.5	3.3	1.5	-1.2	4.3	2.1
30	Bituminous coal mining	1.6	1.8	1.8	1.5	2.1	1.8	1.2	1.8	2.4	1.0

31	Natural gas	1.1	0.4	1.5	0.5	0.6	1.7	0.0	1.1	0.2	3.7
32	Residual sector	1.0	1.0	0.7	1.6	0.7	0.3	1.7	1.5	-0.1	0.8
33	Anthracite coal mining	0.9	0.0	1.4	0.0	0.2	1.9	-0.4	0.5	0.0	4.3
34	Furniture	0.8	0.9	1.4	-0.7	1.8	2.5	-0.8	-0.5	4.2	0.5
35	Farming	0.4	0.2	0.5	-0.3	0.4	1.0	-0.2	-0.3	1.2	0.8
36	Lumber products	0.3	0.3	0.6	-0.8	0.6	1.6	-0.4	-1.2	2.5	0.4
Private domestic economy											
	Total	1.5	1.4	1.6	1.1	1.5	1.8	1.2	1.1	2.0	1.6
Unweighted summary statistics											
	Minimum	0.3	-1.7	0.5	-2.4	-2.9	0.3	-1.2	-5.6	-0.2	-1.3
	Maximum	5.4	5.8	6.5	6.7	7.7	8.0	5.2	8.2	8.6	15.2
	Range	5.1	7.4	6.0	9.1	10.6	7.7	6.4	13.8	8.8	16.5
	Average	2.4	2.2	2.8	1.4	2.6	3.5	1.4	1.4	3.9	3.1
	Standard deviation	1.2	1.5	1.4	1.8	1.9	1.7	1.4	2.7	2.3	3.0
	Coefficient of variation	0.5	0.7	0.5	1.3	0.7	0.5	1.1	1.9	0.6	1.0

SOURCE.—Spectator entertainment: tables 3, 4, 6, above. All else: Kendrick (1961: 136-137).

NOTES.—1899-1937 rates are arrived at by computing 1937 levels using period growth rates and then calculating 1899-1937 as if there had been a constant rate of growth.
Spectator entertainment TFP is average of primal TFP through output calculation, through labor productivity calculation, and the dual TFP.
Values equal to or higher than entertainment TFP-growth have been set in boldface.

TABLE 10

THE GROWTH CONTRIBUTION OF CINEMA TECHNOLOGY VERSUS THAT OF GENERAL PURPOSE TECHNOLOGIES (GPTS) AT VARIOUS INTERVALS, 1830-2000

GPT	COUNTRY	INTERVAL	LAG	GDP-SHARE	GROWTH OF		GROWTH CONTRIBUTION			ACCUMULATED INTENSIVE CONTRIBUTION			NATIONAL GROWTH	
					TFP	K/L	Int.	Ext.	Total	Industry		National	TFP	GDP
			(years)	(%)	(%p.a.)	(%p.a.)	(%)	(%)	(%-point)	(% GDP)	(%Nat)	(% GDP)	(%)	(%)
Film technology	US	1900-1938	25-40	0.6	5.9	3.3	92	8	0.04	1.4	3.8	36.1	1.14	2.27
Railways	US	1840-1890		3.1	2.8	-1.3				1.6	10.9	15.0	0.34	4.76
	UK	1830-1870		2.5	5.5	14.0	52	48	0.27	5.3	38.5	13.7	0.75	2.13
	UK	1870-1910		6.0	3.8	0.2	96	4	0.24	8.5	43.1	19.7	0.56	1.70
Steam	UK	1850-1870	80	1.8	3.5		50	50	0.12	1.2	8.8	13.7	0.75	2.39
		1870-1910	80-120	2.7	1.7		64	36	0.14	1.8	9.1	19.7	0.56	1.70
Steamships	UK	1850-1870		0.7	1.6	9.7	33	67	0.03	0.2	1.6	13.7	0.75	2.39
		1870-1910		3.4	1.6	4.5	50	50	0.10	2.1	10.7	19.7	0.56	1.70
Electricity	US	1929-1948	40		4.6									
ICT	US	1973-1995		3.9			38	62	0.74	5.8	72.6	8.0	0.39	2.84
		1995-2000		6.7			41	59	1.84	3.6	75.4	4.7	1.00	4.10
		2000-2006		5.8			46	54	1.12	3.0	56.0	5.3	0.92	2.36

SOURCES.—-US Railways: Passell and Atack (1994: 450) based on Fogel (1962) and Fishlow (1966). UK Railways: Leunig (2006). Steam and steamships: Crafts (2004). US electricity data is the geometric average of 1919-1929-1941-1948 growth intervals from Kendrick (1961), as reported in Field (2003). ICT: Oliner, Sichel and Stiroh (2007). National TFP growth for US 1900-1938 from Maddison (1995), for the UK from Crafts (2003). US 1973-2006 is the rate for private output as reported in Jorgenson, Ho and Stiroh (2008). National US and UK GDP growth from Williamson (2006).

NOTES.—Lag = estimate of time between innovation and productivity impact. Int. = intensive. Ext. = extensive. %Nat = percentage of accumulated industry growth contribution of accumulated national intensive growth over the time interval. The TFP-growth of UK railways include time-savings, following Leunig (2006), which roughly double the 1830-1870 and triple the 1870-1910 growth contribution. These rates have been calculated from the social savings reported in Leunig (2006) using expression (7) from the text. ICT = information and communication technologies.

TABLE 11

VALUING ENTERTAINMENT OUTPUT GROWTH BY CONSUMERS' FULL COSTS, 1900-1938.

Quantity	Valued by	Unit	Output (million) 1900	1938	Growth rates 1900-1938
Spectator-hours		spectator-hour	249	7,038	9.19
	Relative price	$ of 1938	151	721	4.19
	Opportunity costs	$ of 1938	68	5,479	12.25
	Full costs	$ of 1938	219	6,200	9.19
				MEMORANDUM	
Price per spectator-hour		$ of 1938	0.61	0.10	-4.58
Hourly wage rate		$ of 1938	0.27	0.78	2.80
Full costs per hour		$ of 1938	0.88	0.88	0.00

Notes: relative price = relative to all other prices for consumer goods and services, using the CPI.

Opportunity costs = wage rate times spectator-hours

Full costs = adding output weighed by price to that weighed by opportunity costs

Sources: Appendices A and B.

TABLE 12

TIME AND MONEY SPENT ON CONSUMING SPECTATOR ENTERTAINMENT AND ANNUAL GROWTH RATES, 1900-1938

	1900			1938			1938 disaggregated	
	(hours)	($)	(%)	(hours)	($)	(%)	Film	Live
Consumption per entertainment consumer (spectator-hours)	9.63			81.32			79.53	1.79
Expenditure per entertainment consumer (dollars)		5.86			8.33		7.66	0.67
Share of leisure time used (%)			0.67			3.10	3.03	0.07
Share of wages used (%)			0.73			0.61	0.56	0.05
Share leisure/share wages (%)			91.30			508.57	540.88	139.23
Hourly wage rate (dollars)		0.27			0.78		0.78	0.78
Price of one spectator-hour (dollars)		0.61			0.10		0.10	0.37
Hours of work per spectator-hour	2.23			0.13			0.12	0.48
Full costs to consumer (dollars)		0.88			0.88		0.87	1.15
					0.88		0.87	1.15
Opportunity costs / all costs (%)			30.94			88.37	88.99	67.54
One spectator-hour/all weekly leisure time (%)			3.61			1.98		
Price / all weekly expenditure (%)			3.95			0.39	0.37	1.42

REAL ANNUAL GROWTH RATES, 1900-1938

	All	Live
One spectator-hour/all weekly leisure time	-1.56	
Real hourly wage rate	2.80	
Real price of one spectator-hour	-4.58	-1.27
Real full cost to consumer	0.00	2.12
Hours of work per spectator-hour	-7.18	-3.96

SOURCES.—Wages from Dewhurst, consumer price deflator from Mitchell (1998); entertainment prices and quantities from Appendix B.

NOTES.—All values in constant dollars of 1938. All values are averages for consumers of spectator entertainment. For 1900 this has been set at 1/3 of the population, for 1938 at 2/3. Most findings are insensitive to this assumption
as they concern ratios. All dollar values in current dollars, unless otherwise stated. Opportunity costs / all cost as indicator of time intensity has been taken from Goolsbee and Klenow (2006). Leisure time is total annual hours minus annual working hours from Huberman and Minns (2007) and 365x12 hours for sleep and personal/household care. The findings are not very sensitive to the hours subtracted

FIGURES

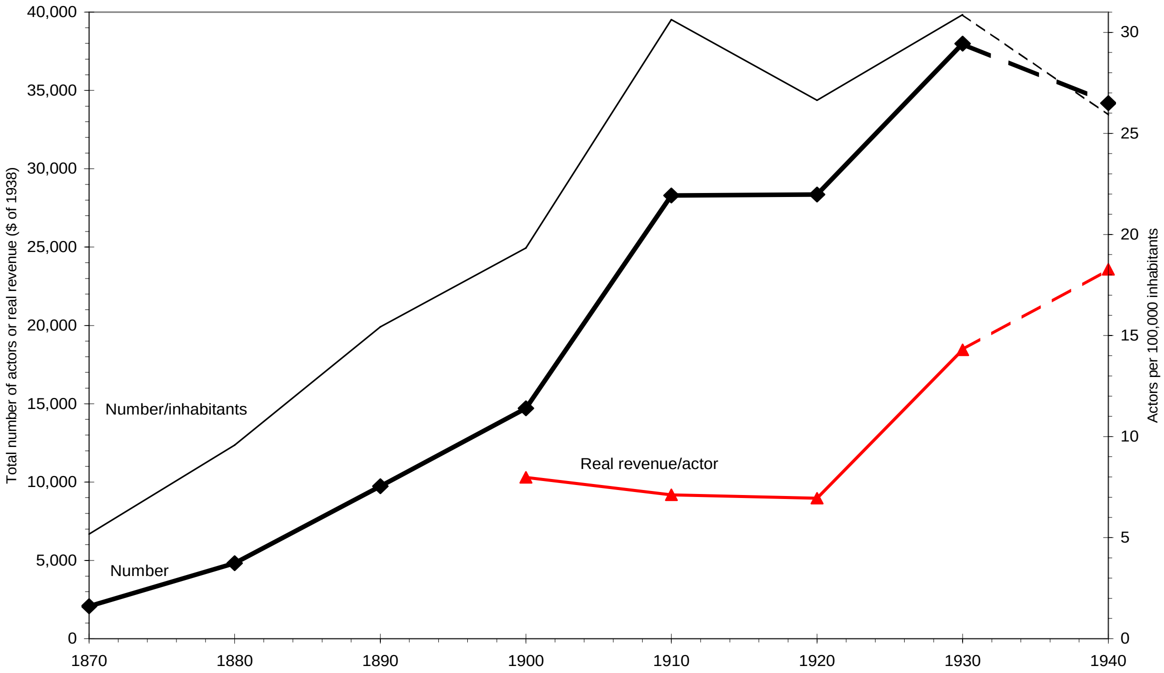

FIG. 1.—Number of actors and actresses and real revenue per actor/actress in the US, 1870-1940.

SOURCE.—US Census, 1870-1940; United States Department of Commerce, Historical Statistics; Appendix B.

NOTE.—the 1940 data is a lower-bound estimate, because 1940 census figures for actors/actresses are not comparable with the 1930 census (Alba M. Edwards, 1943). In 1930 37,993 persons were classified as actor or actress, in 1940 only 19,232. The fact that 1940 census classified persons by the work they were doing during one particular week in March, may have had particularly an effect on the number of actors/actresses. To arrive at a very conservative estimate, it has been assumed that, had the 1930 classification been used, employment would only have decreased by ten percent, yielding a 'comparable' number of 34,194. It is likely that the real comparable number was very much lower.

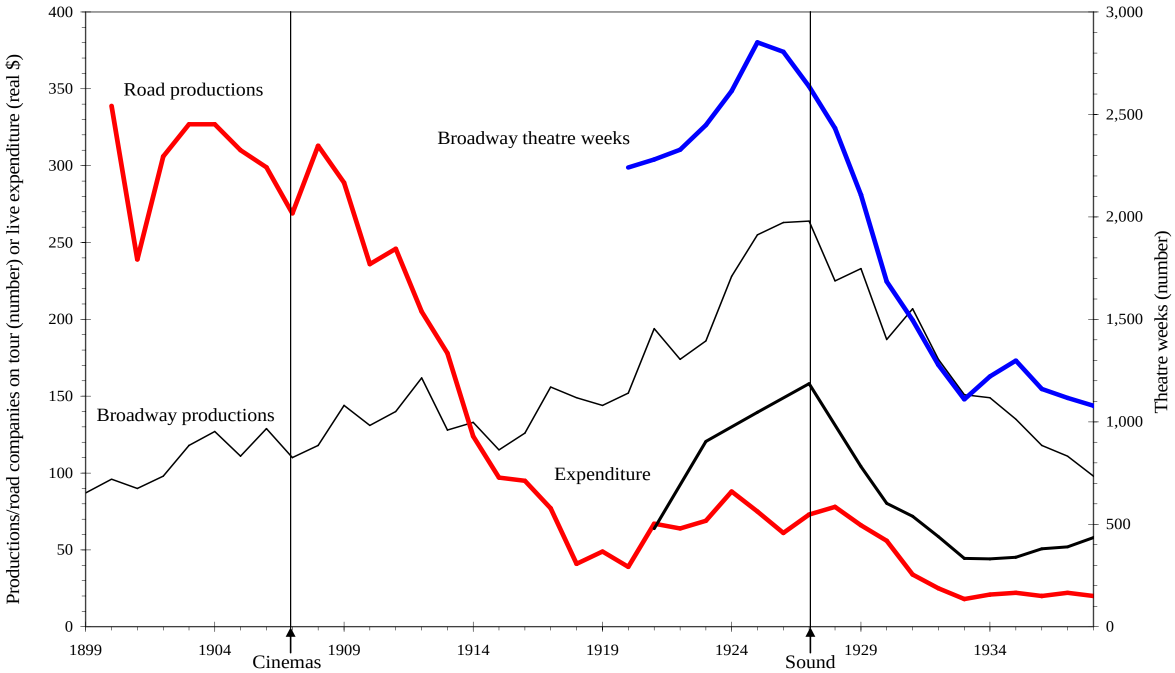

FIG. 2.—Indicators of US live entertainment production (number of road productions on tour, Broadway productions, Broadway theater weeks and real expenditure), 1899-1938.

SOURCES.—Bernheim (1932); McLaughlin (1974: 271-280), US Department of Commerce (1975).

NOTES.— Road productions: this is the average of the total number of companies on tour in April and in December, as listed in Variety. Real expenditure: this it total consumer expenditure in millions of 1938 dollars, deflated by the consumer price index from B. R. Mitchell (1998).

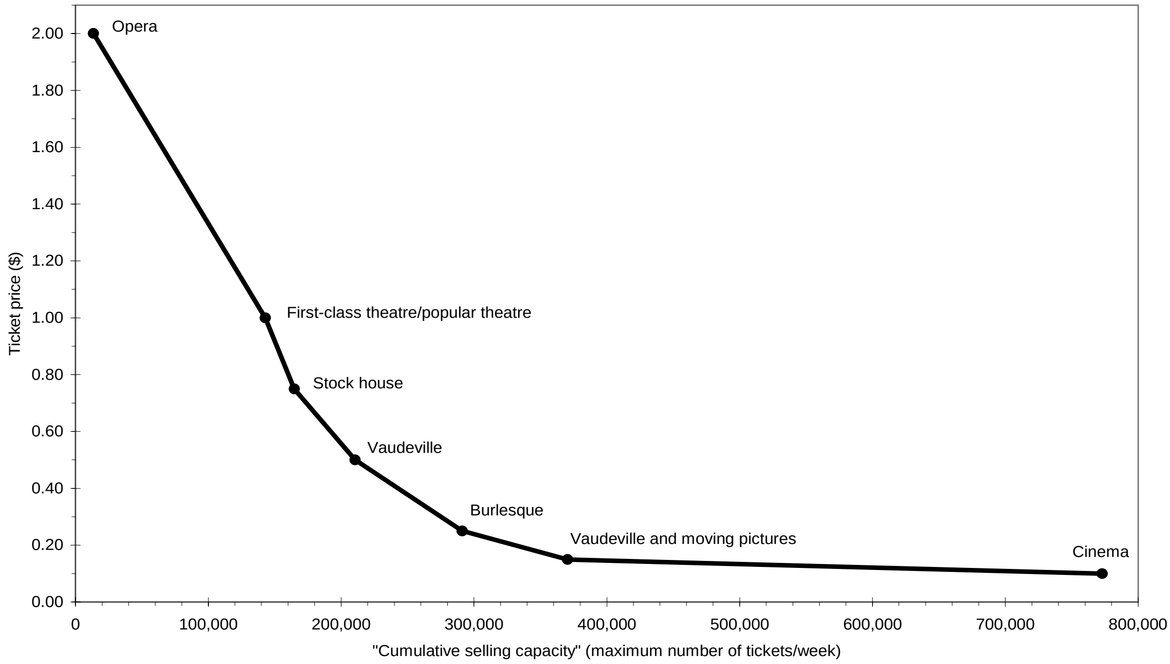

FIG. 3.—Ticket price versus cumulative ticket-selling capacity for theatrical entertainment venues in Boston in 1909 ($ and maximum number of tickets per week)

SOURCES.—Table 1; compiled from Boston Committee (1909), as mentioned in Garth S. Jowett (1974).

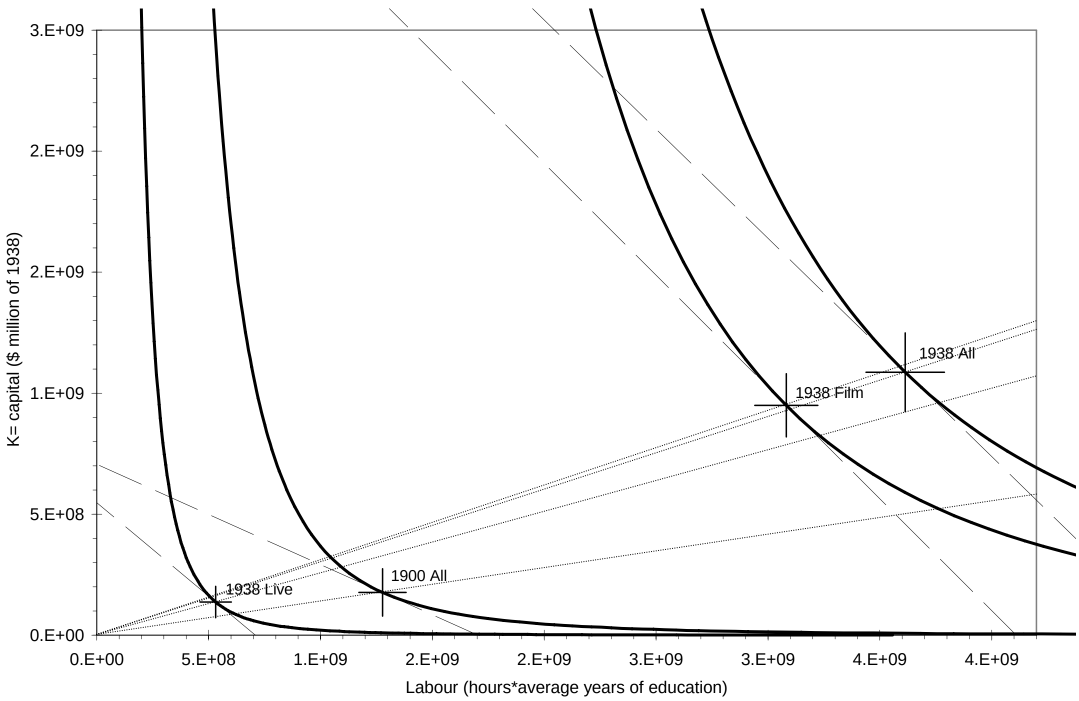

FIG. 4.—Cobb-Douglas production function for US spectator entertainment, 1900 and 1938.

SOURCES.—See Appendix A and B.

NOTES.—The lines tangent on the Cobb-Douglas functions are the technical rate of substitution [(a/(1-a)*K/L]. The lines through the origin and through the four data points are the capital/labor ratios, of course.