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IS PRODUCTIVITY ON VACATION? THE IMPACT OF THE DIGITAL ECONOMY ON THE VALUE OF LEISURE

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Many recent digital innovations (like video games) augment the value of leisure time, which is not captured by Gross Domestic Product. Therefore, the productivity impact of such innovations may be understated. I develop the theoretical foundations for measuring the value of leisure when it is produced using the household's leisure time and recreational durable goods. I apply this framework to estimate the value of US leisure from 1948 to 2016. While the value of leisure is large, it has become less important over time. I find that productivity growth of leisure time has slowed in the digital era. Household stocks of digital goods are small, so have relatively little impact on leisure value. I conclude that mismeasurement due to household digital goods is not a first-order cause of the recent productivity slowdown.

Keywords: Leisure, Consumer Durables, Total Income, Household Production, Productivity

1. INTRODUCTION

Despite the wide adoption of the Internet and digital goods, productivity growth after 2004 has been weak. Syverson (2017) estimates that this slowdown lowered US Gross Domestic Product (GDP) by $2.9 trillion between 2005 and 2015. Some economists argue that GDP has difficulty measuring the impact of the digital economy, and this slow growth of productivity is a measurement problem (Ahmad and Schreyer (2016), Hulten and Nakamura (2017), Diewert and Fox (2017)).

National accounts exclude the value of nonmarket production, largely for practical reasons. A potential channel for the digital economy to be mismeasured is that many recent high-tech innovations, such as smart phones, augment the value of leisure time. They require a great deal of a consumer's time, an aspect sometimes referred to as the "attention economy" (Brynjolfsson and Oh 2012).

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Therefore, the full value of digital innovations may not be captured by the national accounts.[1] Previous work has shown that household production would change output and productivity significantly if it were included in output.[2] Leisure, though it is the largest single category of time use, has not been studied in the same detail.

There is an opposing force to this argument. People may trade off market-produced leisure services for nonmarket leisure. Under this scenario, some GDP growth would reflect the reallocation of nonmarket to market activity (Cruz and Raurich (2018)). Costa (1997) documents a long-run increase in market purchases of leisure goods and services. This marketization has been an important force in household production, another nonmarket use of time (Bridgman et al. (2018)).

Which of these forces dominates is a quantitative question. I examine the value of all uses of time—market, household production, and leisure—using a national accounts framework. Following Eisner (1989), I refer to this extended measure as total income. I use this framework to evaluate the value of recreational innovations for nonmarket uses. I begin by using the Diewert and Schreyer (2014) framework to develop the theoretical foundations of how to measure the value of leisure when it is produced using time and durable recreational goods. I show that the theoretically correct returns needed to impute the value of leisure can be found in the market. I solve a model assuming that leisure is produced by market firms to find the market prices that correspond to the returns to the factors of production. Using these theoretical results, I calculate value of leisure for the USA from 1948 to 2016.

I find that leisure is a large portion of total income. However, total income grows slower than GDP. Both leisure and household production have declined in importance relative to the market. The impact on growth rates is small. Nominal total income per hour grows 4.5% a year from 1948 to 2016, only slightly below the 5.0% for nominal GDP per hour. So while GDP misses a great deal of value, it has a relatively small effect on growth rates.

Leisure labor productivity, the real value of leisure produced per leisure hour, slowed during the digital era. The "missing productivity" scenario requires that the unmeasured productivity effect on leisure time both increased a great deal recently and did not increase much in the past. This is not the case. The expansion of recreational durables predates the personal computer. Between 1955 and 1975, households greatly expanded their stocks of recreational durables. The labor productivity effect of televisions, sporting goods, and recreational vehicles during this period rivals the recent increase in digital goods.

The digital economy is unlikely to be a first-order explanation of changes in leisure value, since the stock of Internet devices owned by households is small relative to the value of leisure. It is negligible relative to the overall economy. Even if the stock of Internet devices were underestimated, the degree of mismeasurement would have to be unrealistically large to have a quantitative effect on productivity.

This paper is part of a literature on the measurement of well-being outside of GDP. There is concern that welfare comparisons based only on GDP may give misleading answers (Stiglitz et al. (2009), Diewert and Schreyer (2014), Jones and Klenow (2016), Corrado et al. (2017), Sichel (2019)). Others have suggested using alternative frameworks to GDP to measure the impact of the digital economy (Hulten and Nakamura (2017), Diewert and Fox (2017), Coyle and Nakamura (2019)). This paper contributes to that literature by deriving the theoretical basis for estimating the aggregate value of leisure.

A number of papers have included leisure production. Ngai and Pissarides (2008), Vandenbroucke (2009), Kopecky (2011), Bridgman (2016b), Aguiar et al. (2017), and Boppart and Ngai (2017) examine changes in hours using models with leisure production. Other papers have considered the value of leisure as a combination of time and goods. Goolsbee and Klenow (2006) use such a framework to examine the value of using the Internet. Kaplow (2010) examines taxation of market goods that are complements to leisure. Gronau and Hamermesh (2006) examine the time and goods intensity of household activities. Gonzalez–Chapela (2007) and (2011) estimate the elasticity of labor supply with respect to recreational goods prices for men and women, respectively. Earlier work in this vein include Owen (1971), Abbott and Ashenfelter (1976), and Barnett (1979). This paper uses a unified aggregate approach to total time use to examine productivity, which is not a focus to these papers.

2. MODEL

This section lays out the methodology for estimating the value of leisure. It follows the strategy Diewert and Schreyer (2014) and Bridgman (2016c) used to value household production. This strategy uses the fact that resources can be used for both market or nonmarket activities. If households allocate these resources to equalize their marginal value across these activities, a common assumption in economic models, we can use observable market quantities to value nonmarket quantities.

This section begins by presenting a standard macroeconomic model augmented with nonmarket leisure and household production. It then shows how the model's equilibrium conditions are used to impute the value of leisure.

2.1. Environment

The household has a unit of time that it can allocate to market, home, or leisure production. The share of time devoted to each activity given by H_t^j for $j \in \{m, h, l\}$:

$$H_t^h + H_t^m + H_t^l \leq 1. \tag{1}$$

Market time earns a wage W_t^m.

The representative household's preferences over market and home consumption goods (C_t^m and C_t^h, respectively), leisure l_t, and market recreational services C_t^l are represented by

$$\sum_t \beta^t [u(C_t^h, C_t^m, C_t^l + l_t) - v^m(H_t^m) - v^h(H_t^h)]. \tag{2}$$

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The u function represents the utility from consumption, and the v^j functions for $j \in \{m, h\}$ represent the disutility to working. Leisure and market recreational services are perfect substitutes. The functions u and v^j for $j \in \{m, h\}$ are differentiable and increasing.

Leisure is produced using leisure production time H_t^l and leisure capital K_t^l in the differentiable, constant returns to scale (CRS) function F^l

$$l_t = F^l(K_t^l, H_t^l). \tag{3}$$

Home consumption is produced using household capital K_t^h and labor. This labor consists of the household's home production hours H_t^h and the hours of hired household workers H_t^s. (The s superscript can be thought of as quantities of "servants.") The hired household worker wage is W_t^s. The technology for producing this consumption is given by the differentiable, CRS function F^h:

$$C_t^h = F^h(K_t^h, H_t^h + H_t^s). \tag{4}$$

The stand-in homeworker household only has preferences over the market good represented by the differentiable utility function $\sum \beta^t u^s(C_t^{m,s})$. These workers may provide $\overline{H}^s$ units of labor time to the home consumption sector and cannot save. Following Diewert and Schreyer (2014), I simplify the analysis by limiting the choices the homeworker household makes. The imputation result would be unchanged if they had the same preferences and were allowed the full set of choices.

The law of motion for the capital stocks K_t^j for $j \in \{l, h, m\}$ is given by

$$K_{t+1}^j = K_t^j(1 - \delta_j) + X_t^j, \tag{5}$$

where X_t^j is the investment and δ_t^j is the depreciation. The rates of return are given by R_t^j.

Market consumption and both types of investment are produced by a market technology

$$C_t^m + C_t^{m,s} + \frac{C_t^l}{A_t^l} + X_t^m + X_t^h + X_t^l = F^m(K_t^m, H_t^m), \tag{6}$$

where A_t^l is the recreational services-specific productivity factor. This factor allows the price of market goods and recreational services to differ.

There are one period bonds B_t. Bonds purchased in period $t-1$ pay the return $1 + R_t^b$ in the next period.

2.2. Equilibrium

Following Diewert and Schreyer (2014) and Bridgman (2016c), I derive the conditions for imputing the value of leisure by comparing the equilibrium when the household produces home consumption and leisure with the case where they are produced by market firms. I solve the model assuming that home consumption and leisure are produced by market firms. With this ownership structure, there are market prices for nonmarket inputs and outputs. This solution generates the expressions for bounds on the equivalent prices for the returns to the factors of production for leisure in terms of observable variables. This equilibrium is equivalent to the case where leisure is produced outside the market. (A proof of this equivalence is reported in the Appendix.)

Under the alternative market structure where all nonmarket quantities are produced in the market, leisure firms hire labor H_t^l at wage W_t^l and rent leisure capital K_t^l at rate R_t^l. The representative firm's problem is

$$\max p_t^l F^l(K_t^l, H_t^l) - W_t^l H_t^l - R_t^l K_t^l, \tag{7}$$

where p_t^l is the leisure price. The price of market firm output is numeraire. The market consumption and investment firms' problem is to maximize

$$F^m(K_t^m, H_t^m) - W_t^m H_t^m - R_t^m K_t^m. \tag{8}$$

Home consumption firms hire labor H_t^h and H_t^s at wages W_t^h and W_t^s, respectively, and rent household capital K_t^h at rate R_t^h. The home consumption firm's problem is

$$\max p_t^h F^h(K_t^h, H_t^h + H_t^s) - W_t^h H_t^h - W_t^s H_t^s - R_t^h K_t^h, \tag{9}$$

where p_t^h is the household consumption price.

The household's budget constraint is

$$\begin{aligned} C_t^m + \sum_{j\in\{m,h,l\}} X_t^j + p_t^l\left(C_t^l + l_t\right) + p_t^h C_t^h + B_{t+1} \\ = \sum_{j\in\{m,h,l\}} \left(W_t^i H_t^j + R_t^j K_t^j\right) + B_t(1 + R_t^b). \end{aligned} \tag{10}$$

It includes the market income from leisure and home production work and capital as well as the market purchases of leisure and home consumption.

The definition of equilibrium is standard.

DEFINITION 1. *An equilibrium for given government policy* $\{B_t, R_t^b\}$ *is sequences of prices* $\{p_t^l, p_t^h, W_t^j, R_t^j\}$ *and quantities* $\{l_t, C_t^j, C_t^{m,s}, K_t^j, X_t^j, H_t^j, H_t^s\}$ *for* $j \in \{m, h, l\}$ *such that, given prices and policy,*

1. *households choose* $\{l_t, C_t^j, K_t^j, X_t^j, H_t^j\}$ *to solve their problem;*
2. *market firms choose* $\{C_t^m, C_t^l, K_t^m, H_t^m\}$ *to solve their problem;*
3. *household production firms choose* $\{C_t^h, K_t^h, H_t^h, H_t^s\}$ *to solve their problem;*
4. *leisure firms choose* $\{l_t, K_t^l, H_t^l\}$ *to solve their problem;*
5. *household worker households choose* $\{C_t^{m,s}, H_t^s\}$ *to solve their problem;*
6. *the resource constraints (equations (3), (4), (5), and (6)) are satisfied.*

2.3. Imputation

The equilibrium conditions provide expressions that allow us to impute the value of leisure. I use the income approach to measure output, where value of leisure is

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imputed by calculating the returns of its inputs:

$$p_t^l F^l(K_t^l, H_t^l) = W_t^l H_t^l + R_t^l K_t^l. \quad \textbf{(11)}$$

This approach estimates the value of production, not welfare as measured by equation (2). We need measures of the leisure wage and return to capital to value leisure. I will show that prices observable in the market can be used to bound the correct prices for imputing the income to the factors of production.

Let $u_j(t)$ be the partial derivative of the utility function with respect to consumption type $j \in \{m, h, l\}$ and $v^{j\prime}(H_t^j)$ for $j \in \{m, h\}$ be the derivative of the disutility of work. Let $F_k^j(t)$ and $F_l^j(t)$ for $j \in \{m, l, h\}$ be the parallel objects for the production functions.

To make the household willing to save both by holding home capital and bonds, the net returns of both assets must be the same: $1 + R_t^l - \delta_l = 1 + R_t^b$. Therefore, the gross return to household capital is bond returns plus the depreciation of leisure capital.

$$R_t^l = R_t^b + \delta_l. \quad \textbf{(12)}$$

For the household to allocate hours to both leisure and household production, the marginal returns to both activities are equalized. Therefore, in equilibrium $W_t^l = W_t^h - v^{h\prime}(H_t^h)/u_m(t)$. Since household and hired homeworker's time are perfect substitutes in home production, their wages are equal. Specifically, the home consumption firm's problem generates $W_t^h = W_t^s$. Therefore, the value of leisure time is $W_t^l = W_t^s - v^{h\prime}(H_t^h)/u_m(t)$, the home worker's wage less the disutility of working in household production.

An advantage of this result is that we do not need to know the market wage of nonparticipants. Most people who do not work in the market do some household production. Therefore, assuming those outside the market equate leisure and household production wages is plausible.

Finally, the model generates a price of leisure. Since market-produced recreational services and home-produced leisure are perfect substitutes, the market price of leisure services is also the price of home-produced leisure. Therefore, the market prices used to impute leisure are correct.

3. VALUE OF LEISURE, 1948–2016

In this section, I use the model to estimate the nominal value of US leisure for the post-World War Two period. Based on the above analysis, we need estimates of the factors of production and their returns for leisure production that is not currently included in GDP. I begin by describing the data sources for the estimates and then report the results of the baseline estimates.

3.1. Leisure Wage

Most of the data required to impute the nominal value of leisure can be recovered directly. The stocks of leisure capital and leisure time are available from the fixed

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asset tables and time use surveys, respectively. The return to leisure capital has a direct market equivalent, as shown in equation (12). The one variable that cannot be recovered directly is the leisure wage. There is a disutility wedge between the observable household worker wage and the leisure wage. To proceed, we need to take a stand on the nature of this wedge.

I begin by examining what the model can tell us about this wedge using the general functional forms. I then examine the implications of particular functional forms.

The model allows us to bound the size of the disutility wedge. Equalizing the wages we can observe, we have

$$W_t^m - W_t^s = \frac{v^{m\prime}(H_t^m) - v^{h\prime}(H_t^h)}{u_m(t)}. \tag{13}$$

The gap between market and home worker wages (the left-hand side of equation (13)) has increased since 1980 in the USA (Bridgman et al. (2012)). This implies that the right-hand side has also increased. Since there are multiple unknowns in a single equation, we cannot pin down what has happened to the gap between leisure and market wages, the household work disutility term $v^{h\prime}(H_t^h)/u_m(t)$. However, these data imply that the relative disutility of market work has been increasing.

We need to take a stand on a functional form to exactly pin down disutility. To get a sense of the quantitative size of disutility wedge, I look at wedge using a version of the preferences suggested in Greenwood et al. (1988)

$$\log\left[(C_t^m)^{\alpha_u}(C_t^h)^{1-\alpha_u} + l(l_t) + C_t^l - \phi^m \frac{(H_t^m)^{1+\theta}}{1+\theta} - \phi^h \frac{(H_t^h)^{1+\theta}}{1+\theta}\right]. \tag{14}$$

Let γ^j be the change in variable j. For example, $C_{t'}^m = \gamma^{C^m} C_t^m$. The change in the disutility wedge from time t to time t' is

$$\frac{v^{h\prime}(H_{t'}^h)}{u_m(t')}\frac{u_m(t)}{v^{h\prime}(H_t^h)} = \left[\frac{\gamma^{C^m}}{\gamma^{C^h}}\right]^{1-\alpha_u}\left(\gamma^{C^h}\right)^{\frac{1}{\theta}}. \tag{15}$$

I feed the data on consumption and hours found in Bridgman (2016b) to find the change in the wedge between 1948 and 2016. I set $\theta = 0.6$, the parameter value used in Greenwood et al. (1988). I use $\alpha_u = 0.75$ based on Bridgman et al. (2012), who find that household production would have been between a third and a fifth of output if it were included in GDP. This exercise generates a disutility wedge that grows 30% between 1948 and 2016, or 0.4% a year.

As a baseline, I set the disutility wedge to zero ($v^h = 0$). The above evidence suggests that the wedge is flat to slightly increasing, so this assumption may not be far off of the reality. To the degree that there is mismeasurement, it will tend to overstate the impact of leisure production. I will examine the robustness of the results when this assumption is weakened. The main result, that leisure value is important but not increasing relative to market production (GDP), is robust to alternative wages.

3.2. Estimates

I need to allocate time to the three uses in the model: market work, home production, and leisure. I use the market and household production hours data in Bridgman (2016a). (See the Appendix for more detail on data sources.) For home production, Bridgman (2016a) extends the estimates in Bridgman et al. (2012) and Bridgman (2016c). Market hours are an extension of those found in Cociuba et al. (2012). I set per capita leisure hours to 5200 less market work and household production hours. I use 5200 since working age people typically have 100 of non-sleep or personal care hours per week in a broad set of countries, including the USA (Bridgman et al. (2018)).

To measure household production, I use estimates from Bridgman (2016c). I use the restrictive definition of home production that excludes recreational capital to avoid double counting.

The capital in leisure production is the net stock of consumer recreational durables, drawn from Bureau of Economic Analysis (BEA) fixed asset tables. The categories of goods that are included are video, audio, photographic, and information processing equipment and media; sporting equipment, supplies, guns, and ammunition; sports and recreational vehicles; recreational books; and musical instruments.

The net rate of return for durables is the rate of return on household financial assets. Specifically, it is personal interest and dividend income drawn from the National Income and Product Accounts (NIPA) divided by household financial assets from the Federal Reserve's Financial Accounts of the United States. To get the gross return, I add the value of depreciation from the fixed asset tables. Finally, I use the wage of home workers from the NIPA industry accounts to value leisure hours.

3.3. Size of Leisure Sector

The estimates allow us to examine the value to total income, the economic value of all uses of time. Total income combines the value of market activity, captured in GDP, with nonmarket time uses, leisure and home production. Figure 1 reports the ratio of US total income to GDP.

The value of nonmarket time is large compared to GDP, about twice as large until the 1980s. This ratio has fallen. This decline is due to falling importance of both household production and leisure production, though declining household production is more important. The ratio of the value of leisure plus GDP to GDP falls from 60% to 40% as large GDP. This fall (20% points) is half the size of household production's 40% points. While excluding the value of leisure leaves out a great deal of value, unmeasured leisure is becoming less important.

Most work, such as Aguiar and Hurst (2007) and Ramey and Francis (2009), looks only at hours. While the number of those hours and their total value are generally correlated, there are some differences. Figure 2 compares leisure's shares

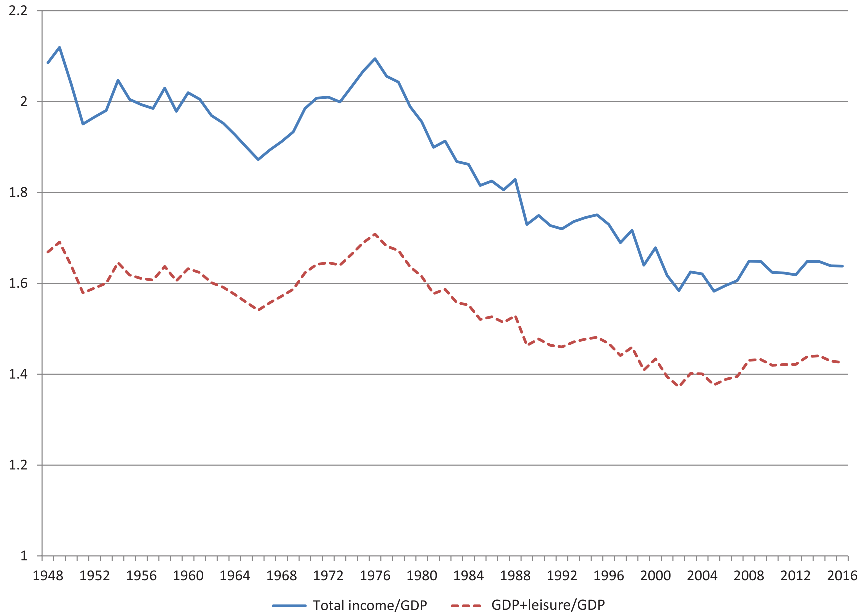

FIGURE 1. Ratio of total income and leisure to GDP, 1948–2016.

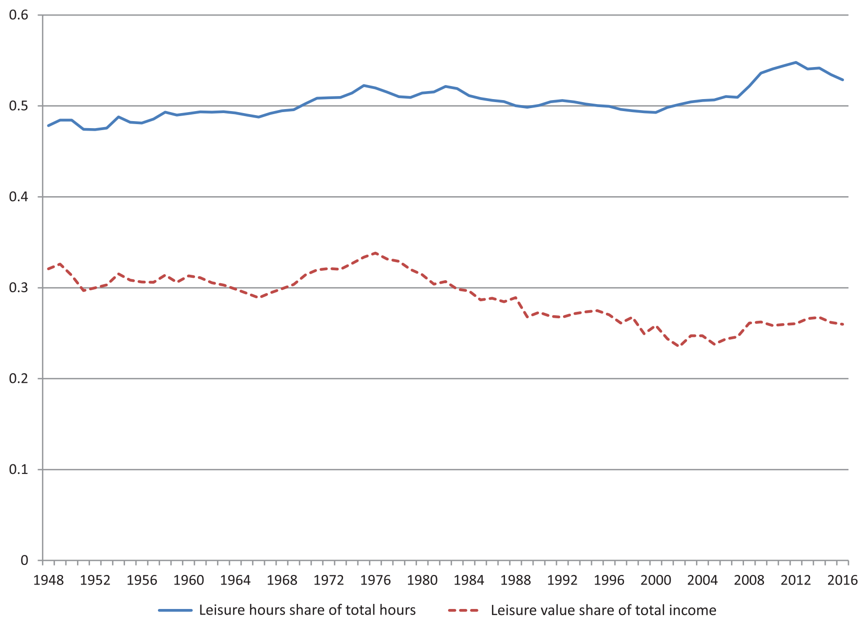

FIGURE 2. Leisure shares of total income and hours, 1948–2016.

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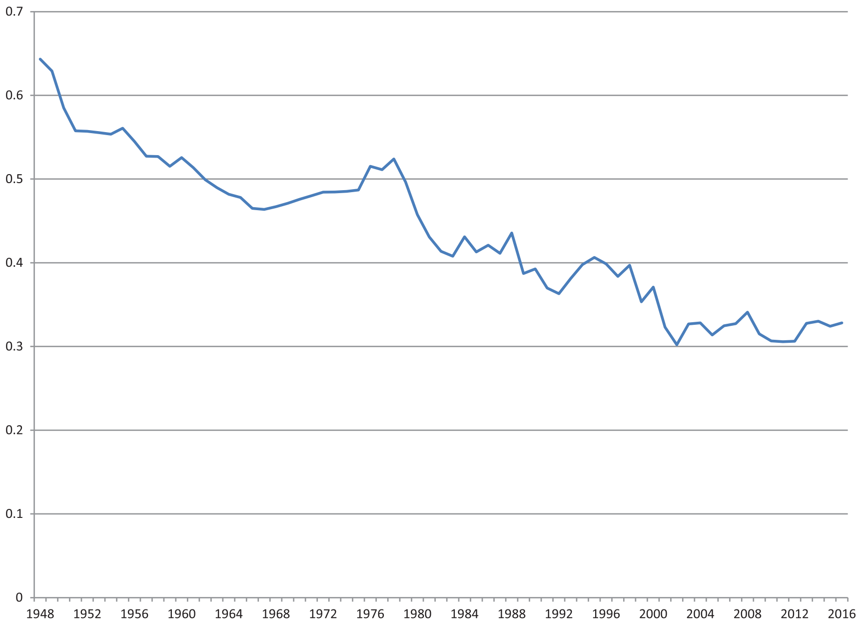

FIGURE 3. Ratio of home worker to total market wages, 1948–2016.

of both total income and hours. There is a slight increase in leisure hours share while the value share is decreasing.

A major reason for the difference between hours and output share is that relative value of a leisure hour has fallen as the gap between market and home worker wages has increased. As shown in Figure 3, home worker wages have fallen from 60% to 30% of market wages.

Leisure production has become more capital intensive. Figure 4 plots the labor share in leisure production. It falls from 97% to 94%. Despite the increasing importance of capital, leisure is still a very labor-intensive activity. In contrast, Bridgman (2016a) finds that household production is more capital intensive, with a labor share that fell from about 80% to 70% over the same period. The "Engines of Liberation" literature, such as Greenwood et al. (2005), has given an important role to consumer durables in the organization of household production. Leisure production has a much narrower channel for these effects.

This labor share may understate total capital since it only includes consumer durables. Houses can be used for recreational purposes. They form the "structures" capital that house the recreational durables "equipment" capital. Figure 4 reports an alternative definition of labor share that includes 25% of housing services to the returns to leisure capital. Including residential capital increases capital share, but leisure remains very labor intensive compared to market and household production.

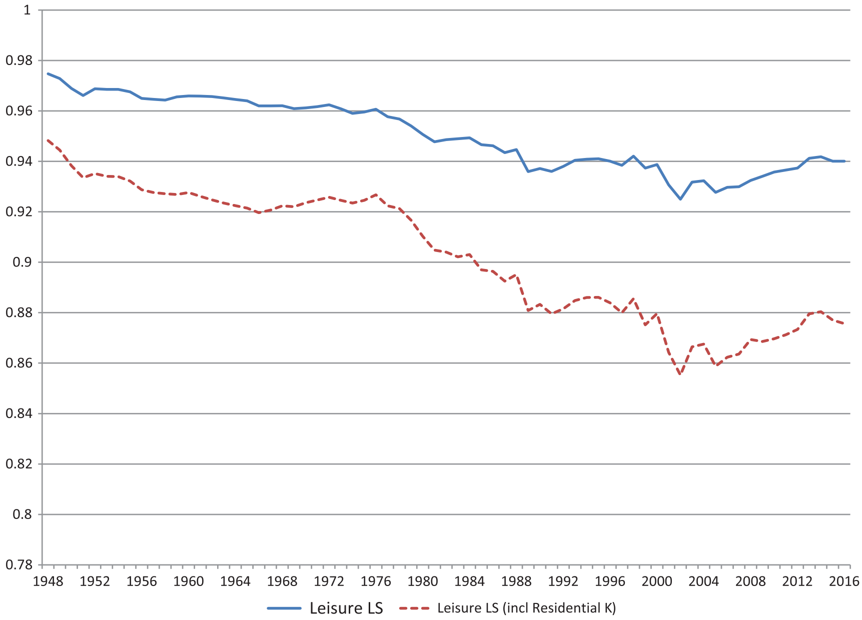

FIGURE 4. Leisure labor share, 1948–2016.

3.4. Can the Nonmarket Digital Economy Explain the Productivity Slowdown?

Productivity growth has been slower recently despite some significant innovations related to computer and communications technology. A literature has suggested that GDP does not fully capture the benefits of these innovations, understating productivity growth. Part of the benefit of these technologies is that they make leisure more enjoyable, which will not be captured by GDP. Now that we have estimates of the value of leisure, we can address the issue of whether changes in this sector can account for recent slow productivity growth.[3]

Syverson (2017) calculates that had labor productivity growth remained on its 1995–2004 trend, nominal GDP would be about \$2.9 trillion higher in 2015. I estimate that the value of leisure grew by \$2.9 trillion between 2004 and 2015.[4] The average growth rate of nominal total income per hour fell from 3.1% during 1995–2004 to 2.6% during 2005–2015. This half percentage point decline is less than the 1% point fall in GDP per hour (from 4% to 3%).

Does this mean that impact of the digital economy on nonmarket production of leisure is a first-order explanation for the productivity slowdown? To the degree that it does, the reasons do not align well with the technological optimists' story. The nonmarket sectors are *less* dynamic than the market sector. The labor productivity growth rate of leisure, measured as nominal leisure output per leisure hour,

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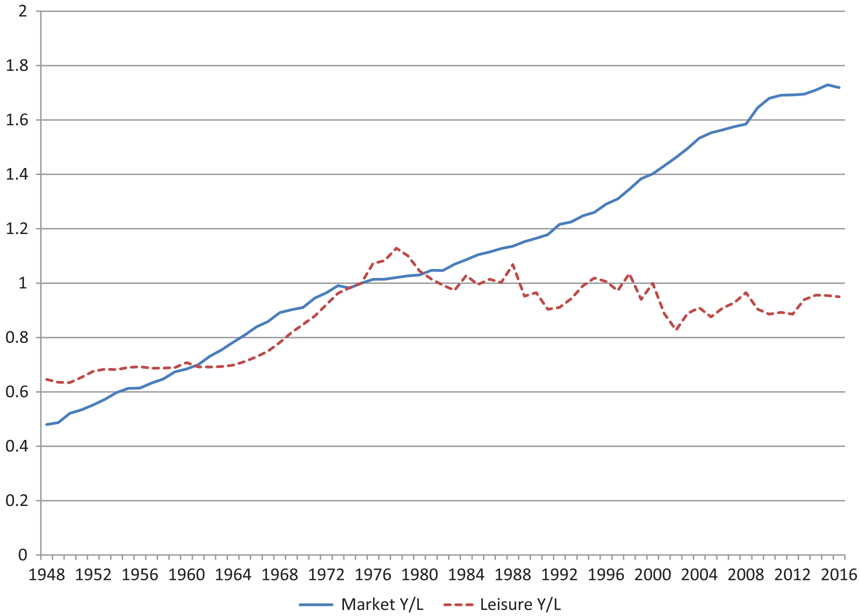

FIGURE 5. Market and leisure labor productivity, 1948–2016.

grew slower than nominal GDP per hour: 4.1% versus 6.2% annually. Nominal leisure labor productivity growth did accelerate in the 2005–2015 period relative to the decade prior, increasing from 1.8% to 2.6%. However, this is much slower than the equivalent GDP per hour growth rates of 5.2% falling to 3.5%. The faster rate of leisure productivity growth in 2005–2015 was still lower than slowdown GDP per hour growth.

This analysis only looks at nominal changes. To measure productivity, we need to deflate the imputed nominal household output to put it in real terms. This exercise would understate real productivity if the price of leisure output were declining relative to the GDP deflator. In that case, real leisure output would be growing faster than market output so leisure productivity would be growing faster.

The theory provides a market analog for nonmarket leisure production. Since nonmarket and market recreational services are perfect substitutes, they have the same price. In the empirical implementation, I use the price of market recreational services to deflate household leisure productivity. Figure 5 shows real labor productivity for the market and leisure sectors. The two grow at a similar rate until the 1980s, when leisure productivity growth flattens out. The 1980s slowdown corresponds to end of post-war capital deepening in leisure production.

For the optimistic scenario to work, unmeasured leisure productivity needs to have both increased a great deal recently and not increased much in the past. The second requirement is not met. The recent digital revolution is not the only time recreational goods have augmented the value of leisure time. The expansion of

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household stocks of recreational durables in the post-war era also led to strong growth. So while the digital economy may be important right now, there were other changes in past that were as important. Therefore, the digital economy does not represent an unprecedented innovation to leisure production.

These trends have little to do with high-tech durable goods. Leisure production is very labor intensive. While there is capital deepening, but much of the change occurs prior to the introduction of computers and other high-tech goods to the household. The share of recreational goods in total household consumer durables increases from 14% in 1955 to 21% in 1975. After this period, recreational goods share is flat to slightly increasing. It was 23% in 2014. While part of this increase is due to television, sporting equipment and recreational vehicles also show major increases. Strong economic growth (after a period of war and depression) and suburbanization are candidates for explaining why recreational goods demand is so strong during this period.

This exercise is limited to the narrow question of whether the exclusion of leisure value from national accounts is why the digital economy has had disappointing productivity impact. It is not meant to account for all of its economic impact. Some of digital value is already included in market output. For example, YouTube's output is already included in GDP. Measuring real output of this sector provides challenges. Much online entertainment is provided without direct cost to the user and is supported by advertising or by creating marketable consumer data. There has been work examining if the digital economy is undervalued due to mismeasurement of this output (Nakamura et al. (2017)). This work has not found a quantitatively large enough role for this type of mismeasurement overturn the productivity slowdown. In any case, it is a separate issue from how much value is created outside the market.

A related issue is that GDP is a measure of the value of production using market prices and does not include consumer surplus. This paper uses a national accounts framework to make it consistent with published productivity statistics. An alternative approach would be to measure welfare, as suggested by Hulten and Nakamura (2017), Diewert and Fox (2017), and Coyle and Nakamura (2019). The digital economy has features that can create a substantial gap between market prices and consumer welfare. Intangible intensive products, such as streaming entertainment, may have low cost to reproduce while being very valuable to consumers. Implementing this approach would require a measure of welfare from market production for comparison. This would involve the difficult task of determining the welfare benefit of both digital leisure innovations and all other innovations included in GDP, such as off-patent medicines and vaccines. I leave it to future work to apply the welfare framework to this question.

4. ROBUSTNESS

This section evaluates how robust these findings are to alternative estimates of leisure value. I will examine quantitative impact of alternative mappings of the data to model quantities and changing various model assumptions. I find that these alternative estimates do not generate a sufficient increase in leisure value to overcome the market decline in productivity growth.

4.1. Capital Stocks

The baseline definition of recreational goods is restrictive. In particular, it excludes telephones since they are included in household production's capital stock. However, including communications equipment has little effect. The average capital share only increases slightly, and the pattern is largely unchanged. The stocks of these goods that are held by the household are relatively small.

Another change would be to further expand the stock of leisure capital to include a portion of residential capital, as done above in the analysis of the labor share. Doing so does not change the pattern much. Further, these services are already in GDP so do not have a productivity effect on total income. In any case, the productivity optimists' argument focusses on new Internet goods, not houses.

It is possible that the stock of Internet devices were underestimated, as it is an industry with rapid change and many new goods. Increasing this stock would increase output since capital income is the stock multiplied by the rate of return. However, Internet devices are already given significant quality adjustment, and the stock owned by households is small relative to the overall economy. The degree of mismeasurement would have to be unrealistically large to have a quantitative effect on productivity. For example, Aizcorbe et al. (2019) do not find the extreme levels of price mismeasurement in smart phones that would be required to overturn the result. The results are consistent with the more pessimistic view in work such as Gordon (2015), Byrne et al. (2016), and Syverson (2017).

4.2. Rate of Return

The baseline model assumes that all market goods are subject to the same production function. In reality, electronic recreational goods have been subject to rapid technological change. The relative price of recreational goods declines significantly over the period of the estimates, suggesting that investment-specific technical change may be important. If so, the rate of return will be underestimated. In this section, I show how this changes the imputation of capital returns. I then show that including this change has a small quantitative impact on the estimates.

To allow for investment-specific technical change, I modify the market technology to be

$$C_t^m + C_t^{m,s} + C_t^l/A_t^l + X_t^m + X_t^h + X_t^l/A_t^x = G(K_t^m, L_t^m), \tag{16}$$

where A_t^x is the rate of transformation for leisure investment. The budget constraint becomes

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$$C_t^m + p_t^h C_t^h + p_t^l(l_t + C_t^l) + X_t^m + X_t^h + q_t^l X_t^l + B_{t+1}$$
$$= \sum_{j\in\{m,h,l\}} (W_t^i H_t^j + R_t^j K_t^j) + B_t(1 + R_t^b), \quad (17)$$

where q_t^l is the price of leisure investment.

The capital imputation equation becomes

$$\left[(q_{t-1}^l/q_t^l)R_t^b + (q_{t-1}^l/q_t^l) - 1\right] q_t^l K_t^l = R_t^l K_t^l - \delta_l q_t^l K_t^l. \quad (18)$$

The bond return, subject to an adjustment for capital gains in leisure capital, is the correct rate of return in this case.[5]

If there is productivity growth in leisure investment, the rate of return for leisure capital will be higher than the bond rate. The productivity growth implies a falling relative price of leisure capital, which implies that owners of that capital are subject to capital losses. Therefore, leisure capital must produce higher returns in the current period to compensate for future capital losses.

To examine how quantitatively important this adjustment is for the estimates, I use the price of recreational durables relative to the Personal Consumption Expenditures deflator as the measure of q_t^l in equation (18). I recalculate the value of leisure production using that rate of return to calculate durables services. All other calculations are the same as the baseline case.

The adjustment is not quantitatively important. Average nominal leisure labor productivity growth rate from 1948 to 2016 increases slightly, from 4.1% to 4.3% per year. The overall pattern is the same, with a slowdown in the 1980s, but with slightly faster growth throughout. This adjustment does not create an increase in productivity in the digital era to counteract the market productivity slowdown.

The recent decline in digital recreational goods prices does not represent a significant change from the rest of the post World War Two era. Non-digital recreational goods prices fell rapidly over most of this period. Again, the digital era has been innovative but does not represent a break with the past.

4.3. Prices

The model assumes that market and nonmarket services are perfect substitutes. This assumption may fail for two reasons. Home-produced leisure may use purchased services. For example, watching television may use consumer durables (a television), purchased services (cable), and time. The cable services will not be perfect substitutes for the other inputs. Also, market producers produce leisure services that cannot be produced in the home, such as overseas vacations.

There is evidence that market leisure expenditures and time are substitutes. I am not aware of empirical work that directly examines the elasticity between leisure services and time. However, Fang et al. (2016) estimate a closely related elasticity, that between market consumption and time devoted to several categories of household time use for the USA between the 1960s and 2014. They allocate household

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consumption expenditures (services, nondurables, and durables together) to various uses and combine that with time devoted to those tasks. They find that market purchases and time are substitutes. This accords with events like the introduction of television, which coincided with a large decline in motion picture admissions.

If the perfect substitutes assumption fails, then market and home leisure services prices are not the same. In that case, there are two prices of leisure: p_m^l and p_l^l for leisure services that are produced in the market and at home, respectively. To examine the quantitative impact of imperfect substitution, I will select functional forms and simulate the differences in leisure services prices. This exercise is not meant to be a definitive measurement. Rather, it is meant to provide a back of the envelope calculation of the importance of the perfect substitution assumption.

To allow for imperfect substitution between market and home leisure services, I modify the preferences to be represented by the modified utility function $\overline{u}(C_t^h, C_t^m, \Phi[C_t^l, l_t])$, where Φ is a Constant Elasticity of Substitution aggregator: $\Phi[C_t^l, l_t] = \left(\kappa(C_t^l)^{\frac{\xi-1}{\xi}} + (1-\kappa)(l_t)^{\frac{\xi-1}{\xi}}\right)^{\frac{\xi}{\xi-1}}$. Further, assume that household leisure production is Cobb–Douglas: $l_t = (K_t^l)^{\alpha}(H_t^l)^{1-\alpha}$. I use this form since Vandenbroucke (2009) estimates that leisure production is approximately Cobb–Douglas. The price ratio is given by

$$\frac{p_{m,t}^l}{p_{l,t}^l} = \frac{\kappa}{1-\kappa}\left[\frac{(K_t^l)^{\alpha}(H_t^l)^{1-\alpha}}{C_t^l}\right]^{\frac{1}{\xi}}. \qquad \textbf{(19)}$$

There is a wedge between the two prices. If this wedge changes over time, then the price deflators of market and nonmarket leisure services will be different. The growth factor γ of each price is given by

$$\frac{\gamma^{p_m^l}}{\gamma^{p_l^l}} = \left[\frac{(\gamma^{K^l})^{\alpha}(\gamma^{H^l})^{1-\alpha}}{\gamma^{C^l}}\right]^{\frac{1}{\xi}}. \qquad \textbf{(20)}$$

The growth of the price gap is given by the ratio of home and market leisure services and the elasticity of substitution ξ. To obtain the ratio, I use the value of 0.08 for α in the USA from Bridgman (2016b), the growth rates of leisure hours calculated above, and the quantity indices of real net recreational durable stocks and real recreational services purchases.[6]

I am not aware of any estimates of the value of ξ, so we cannot pin down the growth of the gap with any certainty. However, we can say something about the direction of the change. From 1950 to 2016, the market leisure services grew about 4 times as fast as home leisure: $(\gamma^{K^l})^{\alpha}(\gamma^{H^l})^{1-\alpha}/\gamma^{C^l} = 0.27$. Recreational durable stock grew faster than purchased leisure services. However, leisure is very labor intensive (the capital share α is very small), and leisure hours grew at a comparatively small rate. This implies that household leisure grew slower than market leisure.

For any positive ξ, this exercise implies that market leisure prices grew slower than household leisure price ($\gamma^{p^l_m} < \gamma^{p^l_l}$). Therefore, assuming perfect substitutes may *overestimate* real home leisure productivity growth. If we use a price index that grows too slowly, then some nominal output growth will be attributed (incorrectly) to real output instead of inflation.

While this exercise is quite speculative, it shows that the lack of significant productivity effects is not purely driven by the assumption of perfect substitution between the market and home. Home leisure productivity growth is slower than that of the market for significant deviations from the baseline assumption.

4.4. Wages

Value of leisure depends on getting wages right since it is a labor-intensive activity. The imputation relies on the assumption that hired household workers wages are good indicators of the value of household production time. This section shows that there is support for this assumption and the results are robust to alternative wages.

Household worker wages could be either too high or too low. They would be too high if household workers were specialists who are more productive than household members. Bridgman et al. (2018) find that there is little dispersion in US household employee wages, suggesting there is little return to skill or experience in this sector. They also find that valuing tasks using specialist wages has little quantitative impact.

Alternatively, household worker wages could be too low since household members are more productive. Of particular concern is that care of children by close family may be more valuable for child development than hired strangers. There is evidence that this concern is not quantitatively important for imputing household production. For example, Bernal and Keane (2011) find no penalty in cognitive development for children in market daycare versus under the mother's care. (See Bridgman et al. (2018) for further discussion.)

To check the robustness to alternative wages, I value leisure at the market wage. Despite the fact that market wages are much higher and grow faster than home workers wages, they do not increase growth much. As seen in Figure 6, leisure still falls relative to market production in the 1980s although the fall is less pronounced compared to the baseline case. The difference is not large enough to account for the missing productivity, even for this exercise which significantly overestimates the leisure wage.

Recall that the baseline case ignored the disutility wedge in household production, so the theory suggests that there is mismeasurement in our measure of wage. However, this mismeasurement likely pushes relative leisure wage, hence output, *down*. I conclude that the result is not driven by mismeasurement of wages.

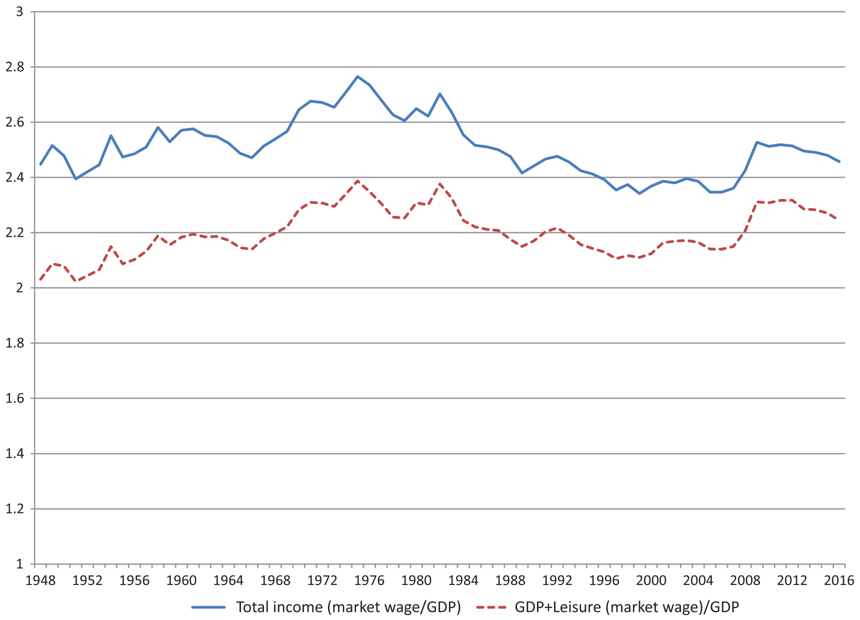

FIGURE 6. Ratio of total income and leisure (market wage valuation) to GDP, 1948–2016.

5. CONCLUSION

National accounts exclude the value of nonmarket production. Many of the recent innovations, such as smart phones, augment the value of leisure time so the full value of such innovations may not be captured by the national accounts. Therefore, the productivity impact of such innovations will be understated. I examine this question examining all uses of time: market, household production, and leisure. I develop the theoretical foundations of how to measure the value of leisure when it is produced using time and recreational durable goods. I then apply this framework to estimate the value of US leisure from 1948 to 2016. While the value of leisure is large, unmeasured leisure has declined in importance. The stock of Internet devices owned by households is small relative to the overall economy. Household digital goods do not have a quantitatively important effect on productivity.

NOTES

1. Another interpretation is that the impact of these innovations is not mismeasured but have not yet had an opportunity to be adopted sufficiently to have a productivity effect (Brynjolfsson et al. 2017).

2. There is a large literature on the measurement of household production, which is impossible to survey here. Estimates of the household sector's magnitude include Eisner (1989) and Landefeld and McCulla (2000) for the USA and Miranda (2014) for cross-country evidence.

3. We cannot isolate the impact of digital leisure due to data constraints. However, it would show up in the aggregate value of leisure if digital leisure had an impact on economy-wide productivity.
4. The value of leisure was $4.9 trillion in 2004 and $7.8 trillion in 2015.
5. Bridgman (2016c) provides a fuller derivation of this imputation.
6. Fixed Asset Table 8.2, line 11 and NIPA Table 2.4.2, line 76.

REFERENCES

Abbott, M. and O. Ashenfelter (1976) Labour supply, commodity demand and the allocation of time. *Review of Economic Studies* 43(3), 389–411.

Aguiar, M. and E. Hurst (2007) Measuring leisure: The allocation of time over five decades. *Quarterly Journal of Economics* 122(3), 969–1006.

Aguiar, M., M. Bils, K. Charles and E. Hurst (2017) Leisure Luxuries and the Labor Supply of Young Men, NBER Working Papers: No. 23552.

Ahmad, N. & P. Schreyer (2016) Are GDP and productivity measures up to the challenges of the digital economy? *International Productivity Monitor* 30, 4–27.

Aizcorbe, A., D. M. Byrne and D. E. Sichel (2019) Getting Smart about Phones: New Price Indexes and the Allocation of Spending Between Devices and Services Plans in Personal Consumption Expenditures. Finance and Economics Discussion Series 2019–012, Federal Reserve Board.

Barnett, W. A. (1979) The joint allocation of leisure and goods expenditure. *Econometrica* 47(3), 539–563.

Bernal, R. and M. P. Keane (2011) Child care choices and children's cognitive achievement: The case of single mothers. *Journal of Labor Economics* 29(3), 459–512.

Boppart, T. & L. R. Ngai (2017) Rising Inequality and Trends in Leisure, CEPR Working Papers: No. 12325.

Bridgman, B. (2016a) Accounting for household production in the national accounts: An update 1965–2014. *Survey of Current Business* 96(2), 1–5.

Bridgman, B. (2016b) Engines of Leisure. Bureau of Economic Analysis, Working Papers: No. 2016–07.

Bridgman, B. (2016c) Home productivity. *Journal of Economic Dynamics and Control* 71(C), 60–76.

Bridgman, B., A. Dugan, M. Lal, M. Osborne and S. Villones (2012) Accounting for household production in the national accounts, 1965–2010. *Survey of Current Business* 92(5), 23–36.

Bridgman, B., G. Duernecker and B. Herrendorf (2018) Structural transformation, marketization, and household production around the world. *Journal of Development Economics* 133, 102–126.

Brynjolfsson, E., D. Rock and C. Syverson (2017) Artificial Intelligence and the Modern Productivity Paradox: A Clash of Expectations and Statistics, NBER Working Papers: No. 24001.

Brynjolfsson, E. and J. Oh (2012) The attention economy: Measuring the value of free digital services on the internet. In: *Proceedings, International Conference on Information Systems, Orlando*.

Byrne, D. M., J. G. Fernald and M. B. Reinsdorf (2016) Does the United States have a productivity slowdown or a measurement problem? In: *Brookings Papers on Economic Activity 2016*, no. 1, pp. 109–182.

Cociuba, S. E., E. C. Prescott and A. Ueberfeldt (2012) U.S. Hours and Productivity Behavior Using CPS Hours Worked Data: 1947-III to 2011-IV, Research memorandum, Federal Reserve Bank of Minneapolis.

Corrado, C., K. Fox, P. Goodridge, J. Haskel, C. Jona-Lasinio, D. Sichel and S. Westlake (2017) Improving GDP: Demolishing, Repointing or Extending?, Indigo Prize Paper, Global Perspectives.

Costa, D. (1997) Less of a Luxury: The Rise of Recreation Since 1888, NBER Working Papers: No. 6054.

Coyle, D. and L. Nakamura (2019) Toward a Framework for Time Use, Welfare, and Household-Centric Economic Measurement, Federal Reserve Bank of Philadelphia Working Papers: No. 19–11.

Cruz, E. and X. Raurich (2018) Leisure Time and the Sectoral Composition of Employment, Working Papers: No. E18/373, Universitat de Barcelona.

Diewert, E. and K. Fox (2017) The Digital Economy, GDP and Consumer Welfare, Mimeo, UNSW Sydney.

Diewert, E. & P. Schreyer (2014) Household production, leisure and living standards. In: D. Jorgenson, J. Landefeld and P. Schreyer (eds.), *Measuring Economic Sustainability and Progress*, pp. 89–114. Chicago: University of Chicago Press.

Eisner, R. (1989) *The Total Incomes System of Accounts*. Chicago: University of Chicago Press.

Fang, L., A. Hannusch and P. Silos (2016) Expenditure vs Time Across Households and Across Decades, Mimeo, Federal Reserve Bank of Atlanta.

Gonzalez-Chapela, J. (2007) On the price of recreation goods as a determinant of male labor supply. *Journal of Labor Economics* 25(4), 795–824.

Gonzalez-Chapela, J. (2011) Recreation, home production, and intertemporal substitution of female labor supply: Evidence on the intensive margin. *Review of Economic Dynamics* 14(3), 532–548.

Goolsbee, A. and P. J. Klenow (2006) Valuing consumer products by the time spent using them: An application to the internet. *American Economic Review Papers and Proceedings* 96(2), 108–113.

Gordon, R. J. (2015) *The Rise and Fall of American Growth: The U.S. Standard of Living since the Civil War*. Princeton, NJ: Princeton University Press.

Greenwood, J., A. Seshadri and M. Yorukoglu (2005) Engines of liberation. *Review of Economic Studies* 72(1), 09–133.

Greenwood, J., Z. Hercowitz and G. W. Huffman (1988) Investment, capacity utilization and the real business cycle. *American Economic Review* 78(3), 402–417.

Gronau, R. and D. S. Hamermesh (2006) Time vs. goods: The value of measuring household production technologies. *Review of Income and Wealth* 52(1), 1–16.

Hulten, C. and L. Nakamura (2017) Accounting for Growth in the Age of the Internet: The Importance of Output-Saving Technical Change, Mimeo, University of Maryland.

Jones, C. I. and P. J. Klenow (2016) Beyond GDP? Welfare across countries and time. *American Economic Review* 106(9), 2426–2457.

Kaplow, L. (2010) Taxing leisure complements. *Economic Inquiry* 48(4), 1065–1071.

Kopecky, K. (2011) The trend in retirement. *International Economic Review* 52(2), 287–316.

Landefeld, J. S. and S. H. McCulla (2000) Accounting for nonmarket household production within a national accounts framework. *Review of Income and Wealth* 46(3), 289–307.

McGrattan, E. R. and E. C. Prescott (2012) The labor productivity puzzle. In: L. Ohanian, J. Taylor & I. Wright (eds.), *Government Policies and the Delayed Economic Recovery*, pp. 115–154. Stanford: Hoover Institution Press.

Miranda, V. (2014) Cooking, Caring and Volunteering: Unpaid Work Around the World, OECD Social, Employment, and Migration Working Papers: No. 116.

Nakamura, L., J. Samuels and R. Soloveichik (2017) Measuring the "Free" Digital Economy within the GDP and Productivity Accounts. Federal Reserve Bank of Philadelphia Working Papers: No. 17–37.

Ngai, L. R. & C. A. Pissarides (2008) Trends in hours and economic growth. *Review of Economic Dynamics* 11, 239–256.

Owen, J. D. (1971) The demand for leisure. *Journal of Political Economy* 79(1), 56–76.

Ramey, V. and N. Francis (2009) A century of work and leisure. *American Economic Journal: Macroeconomics* 1(2), 189–224.

Sichel, D. E. (2019) Productivity Measurement: Racing to Keep Up, NBER Working Papers: No. 25558.

Stiglitz, J. E., A. Sen and J.-P. Fitoussi (2009) Report, Technical report, Commission on the Measurement of Economic Performance and Social Progress.

Syverson, C. (2017) Challenges to mismeasurement explanations for the U.S. productivity slowdown. *Journal of Economic Perspectives* 31(2), 165–183.

Vandenbroucke, G. (2009) Trends in hours: The U.S. from 1900 to 1950. *Journal of Economic Dynamics and Control* 33(1), 237–249.

APPENDIX A: DATA DOCUMENTATION

This appendix describes the data sources.

GDP NIPA Table 1.1.5 (August 28, 2017 Edition)

Recreational Durables NIPA Tables 8.1/8.4 (August 23, 2017 Edition), sum of lines 11 (Recreational durables), 21 (Luggage) and 0.25 of line 2 (Autos).

Hours Bridgman (2016b). Market hours (derived from CPS and Department of Defense data) updated from Cociuba et al. (2012) using McGrattan and Prescott (2012). Household production hours updated from Bridgman (2016a).

Homeworker Wage Compensation and full-time equivalent (FTE) employees of private households, NIPA Tables 6.2 and 6.5 for "private households" (Standard Industrial Code) and "other services ex. Govt" (North American Industry Classification System). Converted to hourly compensation by assuming an FTE works 2080 h annually. FTE employees data for 2000 on come from unpublished estimates obtained from BEA.

Market Wage Labor compensation (NIPA Table 1.10, line 2; August 30, 2017 Edition) divided by market hours.

Rate of Return The rate of return on Household financial assets using data from the Flow of Funds. Specifically, personal income receipts from assets (NIPA Table 2.9 line 5) over total financial assets of the household less equity in noncorporate business (Table B.100 series FL154090005-FL152090205).

APPENDIX B: EQUIVALENCE OF MARKET AND NONMARKET EQUILIBRIA

This section shows that equilibrium with market production of nonmarket sectors (leisure and household production) is the same as that where the household produces it.

If home leisure services and household production are produced by the household, the budget constraint for each period is

$$C_t^m + p_t^l C_t^l + \sum_{j \in \{m,h,l\}} X_t^j + B_{t+1} + W_t^s L_t^s = W_t^m H_t^m + R_t^m K_t^m + B_t(1 + R_t^b). \qquad \textbf{(B1)}$$

The household chooses consumption, investment, labor, and hired household hours to maximize utility (equation (2)) subject to the budget constraint (equation (B1)) and its resource constraints (equations (1), (3), (4), and (5)).

An equilibrium is prices and allocations such that the stand-in household solves its problem, the market firm solves its problem (equation (8)), the household worker household solves its problem, and the resource constraint for market production (equation (6)) is satisfied.

If the first-order conditions are necessary and sufficient, an interior solution to the alternative problem with nonmarket production is given by the resource constraints and the following equations:

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1. $u_m(t-1) = \beta u_m(t)[F_k^m(t) + 1 - \delta_m]$;
2. $u_m(t-1) = \beta u_m(t)[1 - R_t^b]$;
3. $u_m(t)C_t^{s,m} = u_h(t)F_l^h(t)\overline{L}_t^s$;
4. $u_m(t-1) = \beta u_l(t)F_k^l(t) + \beta u_m(t)(1 - \delta_l)$;
5. $u_m(t-1) = \beta u_h(t)F_k^h(t) + \beta u_m(t)(1 - \delta_h)$;
6. $u_m(t)F_l^m(t) - u_h(t)F_l^h(t) = v^{m,\prime}(H_t^m) - v^{h,\prime}(H_t^h)$;
7. $u_m(t)F_l^m(t) - u_l(t)F_l^l(t) = v^{m,\prime}(H_t^m)$.

The solution when home leisure and household production is produced by market firms (set out in the model section) is defined by the resource constraints and the following equations:

1. $u_m(t-1) = \beta u_m(t)[F_k^m(t) + 1 - \delta_m]$;
2. $u_m(t-1) = \beta u_m(t)[1 - R_t^b]$;
3. $u_m(t)C_t^{s,m} = u_h(t)F_l^h(t)\overline{L}_t^s$;
4. $u_l(t-1)/p_{t-1}^l = \beta(u_l(t)/p_t^l)[p_t^l F_k^l(t) + 1 - \delta_l]$;
5. $u_h(t-1)/p_{t-1}^h = \beta(u_h(t)/p_t^h)[p_t^h F_k^h(t) + 1 - \delta_h]$;
6. $u_m(t)[F_l^m(t) - p_t^h F_l^h(t)] = v^{m,\prime}(H_t^m) - v^{h,\prime}(H_t^h)$;
7. $u_m(t)[F_l^m(t) - p_t^l F_l^l(t)] = v^{m,\prime}(H_t^m)$.

The first three equations are the same across ownership structures. Using the fact that $p_t^l = u_l(t)/u_m(t)$ and $p_t^h = u_h(t)/u_m(t)$ makes the final four the same.