ABSTRACT

Prior to the mid-1980s, labor productivity growth was a useful barometer of the U.S. economy’s performance: it was low during economic recessions and high during expansions. Since then, labor productivity has become significantly less procyclical. In the recent recession of 2008–2009, labor productivity actually rose as GDP plummeted. These facts have motivated the development of new business cycle theories because the conventional view is that they are inconsistent with existing business cycle theory. In this paper, we analyze recent events with existing theory and find that the labor productivity puzzle is much less of a puzzle than previously thought. In light of these findings, we argue that policy agendas arising from new untested theories should be disregarded.

Keywords: labor productivity, labor wedge, RBC models, intangible capital, nonneutral technology change

JEL classification: E01, E13, E32

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1. Introduction

Prior to the mid-1980s, labor productivity growth was a useful barometer of the U.S. economy’s performance: it was low during economic recessions and high during expansions. The correlation between GDP per hour and GDP was over 50 percent between 1960 and 1985. Since then, the correlation between GDP per hour and GDP—both relative to their long-term trends—has been closer to zero. Researchers have used the large difference in these correlations as evidence that real business cycle (RBC) theories—theories that assume cyclical fluctuations are driven in large part by shocks to total factor productivity (TFP)—are inconsistent with U.S. data because TFP shocks lead simultaneously to high output per hour and high output. In this paper, we reassess this view and find that eulogies for RBC theories are premature.

Specifically, we reassess recent events of the Great Recession of 2008–2009 with the version of a real business cycle model used by McGrattan and Prescott (2010) to study the 1990s technology boom. The main difference between this model and earlier vintages of real business cycle models is the inclusion of intangible capital and nonneutral technology change in the production of final goods and services and new intangible capital. We show that these additional features have the potential to generate high measured labor productivity growth during a recession, something we observe in the recession of 2008–2009.

Intangible capital is accumulated know-how from investing in research and development, brands, and organizations, which is for the most part expensed by companies rather than capitalized. Because it is expensed, it is not included in measures of business value added and thus is not included in GDP. In a typical recession, GDP falls but investments

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1 The model is an extension of models developed earlier, most notably by Kydland and Prescott (1982) and Hansen (1985).
fall by more than GDP in percentage terms. By measuring labor productivity as the ratio
of GDP to total labor input, one underestimates the fall in total output, which is measured
output plus all unmeasured investment, and therefore underestimates the fall in actual la-
bor productivity. In other words, it is possible to observe high measured labor productivity
while output is low if some output is not included in the statistic but all hours of work
are. The specific pattern of labor productivity over the cycle depends in large part on the
nature of the comovement of relative TFPs in production of final goods and services (that
is, GDP) and of new intangible capital.

Using a version of the RBC model with intangible capital and nonneutral technology,
we conduct a business cycle accounting exercise for the Great Recession period in the spirit
of Chari, Kehoe, and McGrattan (2007). First, we show that fluctuations in the sectoral
TFPs have the same impact on the business cycle as time-varying efficiency and labor
wedges—wedges between marginal rates of substitution and transformation that drive
fluctuations in Chari, Kehoe, and McGrattan’s prototype growth model. If the model
had no intangible capital and changes in TFP were neutral, then conventional wisdom
about RBC theory would be right: it predicts that labor productivity is low in recessions.
Adding intangible capital generates an apparent labor wedge between the marginal rate of
substitution between consumption and leisure and measured labor productivity. Adding
nonneutral technology change, it is possible to generate cyclical behavior in this wedge over
the cycle that is consistent with the seemingly puzzling patterns in labor productivity.

In our business cycle accounting exercise, we feed into the model sectoral TFPs that

2 The exercise we conduct here is slightly different from that in McGrattan and Prescott (2010), who
studied the technology boom of the 1990s and assumed changes in policies impacting households’
temporal decisions were inconsequential. In the recent downturn, many argue that the policies
impacting households’ intertemporal decisions are not inconsequential. Later, we contrast the exercise
conducted by McGrattan and Prescott (2010) with what we do in this paper. See also Ohanian and
generate the pattern of GDP and labor productivity that we observed in the United States over the period 2004–2011. In our simulations, we include time-varying taxes on consumption and labor since these taxes also affect the labor wedge. We abstract from time-varying tax rates on capital and other policies that impact the intertemporal decisions of firms and households, and thus we cannot by construction fit all of the time series of interest. But we ask, How close do we come to generating patterns in consumption, aggregate investment, and business investment that we observe in U.S. data over the period? We find the results are surprisingly close given we have abstracted from any financial market or fiscal distortions. We also ask, Does the model predict an implausible drop in intangible investment? We find that the model predicts a fall in business intangible investment of the same magnitude as the fall in business tangible investment. We also compare the predicted path for intangible investment to subcomponents that we can measure such as expenditures on R&D and advertising and to series that move with intangible investments such as the market value of businesses. We find that the patterns and magnitudes of the model predictions are consistent with observations. In essence, we find that the labor productivity puzzle is much less of a puzzle than previously thought.

There is a vast literature that attempts to understand the factors giving rise to aggregate fluctuations that is too great to survey here. We should note, however, that recent events have spurred a renewed interest in the subject.\(^3\) Most of the papers in this burgeoning literature emphasize the need for new theories, but as far as we know, none has demonstrated large deviations with existing theory.

In Section 2, we start with the facts about trends in U.S. labor productivity and discuss

\(^3\) See, for example, the survey by Ohanian (2010) and recent work exploring the impact of stochastic volatility by Bloom (2009), Bloom et al. (2011), financial frictions by Arellano, Bai, and Kehoe (2011) and Campello, Graham, and Harvey (2010), labor market distortions by Gali and van Rens (2010), Mulligan (2011), and Schaal (2012), monetary policy by Gertler and Kiyotaki (2010), and uncertainty about fiscal policy by McGrattan (forthcoming).
the recent comovements of GDP and labor productivity. Section 3 lays out the theory we use. Section 4 assesses the recent events in light of this theory. Section 5 concludes.

2. The Facts

The starting point for our study is U.S. labor productivity. As is well known, labor productivity has become less procyclical in the United States. Figures 1 and 2 demonstrate this for the aggregate economy and the business sector.

Figure 1 shows percent deviations of GDP and labor productivity for the aggregate economy from trend for the period 1960:1–2011:3. Labor productivity in this case is the ratio of GDP to total hours of work for the U.S. economy as constructed by Prescott, Ueberfeldt, and Cocïuva (2005). The formula for trend is based on Hodrick and Prescott (1997). The correlation for the first half of the sample is 54 percent, and it is obvious from the figure that labor productivity was high in booms and low in recessions. The correlation for the second half is only 5 percent and, unlike the first half, there is no procyclical pattern. By the end, when the recession of 2008–2009 is evident, we see that labor productivity is above its trend.

Figure 2 shows the same statistics, but here we use data for business value added and business hours. The business sector includes corporate and noncorporate business. In the first half of the sample, the correlation between value added and labor productivity is 64 percent, which is even higher than it is for the overall economy. In the second half, the correlation is only 7 percent, and again the procyclical pattern is no longer evident.

If we zoom in on the end of the sample in either Figure 1 or Figure 2, we see that

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labor productivity is above trend while outputs, both GDP and business value added, are below trend. This is the puzzle we seek to explore.

We next ask, what does theory tell us about this puzzle?

3. Theory

In this section, we lay out the theory we use to study the comovement of output and productivity. We extend the basic framework of the early real business cycle literature by including intangible capital and sectoral TFPs that are nonneutral. In our earlier work, we found that including these additional features eliminated a large deviation from theory that had existed for studying the 1990s technology boom. Here, we find that including these additional features is needed to generate a comovement in labor productivity and GDP that is consistent with U.S. data.

We start by describing the two technologies available to businesses, which are given by

\[ y_{bt} = A_t^1 \left( k_{T_t}^1 \right)^{\theta} (k_{i,t})^\phi (h_{t}^1)^{1-\theta-\phi} \]  \hspace{1cm} (3.1)

\[ x_{It} = A_t^2 \left( k_{T_t}^2 \right)^{\theta} (k_{i,t})^\phi (h_{t}^2)^{1-\theta-\phi}. \]  \hspace{1cm} (3.2)

Firms produce business output \( y_b \) using their tangible capital \( k_{T_t}^1 \), intangible capital \( k_i \), and labor \( h^1 \). Firms produce intangible capital \( x_i \)—such as new brands, new products R&D, patents, etc.—using tangible capital \( k_{T_t}^2 \), intangible capital \( k_i \), and labor \( h^2 \). The total stock of intangible capital \( k_i \) is an input to both business sectors; it is not split between them as is the case for tangible capital and labor. The idea is that intangibles such as brands and patents are used both to sell final goods and services and by designers and researchers developing new intangible capital.
Given \((k_{T_0}, k_{I_0})\), the stand-in household maximizes

\[
E \sum_{t=0}^{\infty} \beta^t [\log c_t + \psi \log (1 - h_t)] N_t
\]  

subject to

\[
c_t + x_{Tt} + q_t x_{It} = r_{Tt} k_{Tt} + r_{It} k_{It} + w_t h_t + \zeta_t
\]

\[
- \tau_c c_t - \tau_h (w_t h_t - (1 - \chi) q_t x_{It}) - \tau_k k_{Tt}
\]

\[
- \tau_p \{r_{Tt} k_{Tt} + r_{It} k_{It} - \delta_T k_{Tt} - \chi q_t x_{It} - \tau_k k_{Tt}\}
\]

\[
- \tau_d \{r_{Tt} k_{Tt} + r_{It} k_{It} - x_{Tt} - \chi q_t x_{It} - \tau_k k_{Tt}\}
\]

\[
- \tau_p (r_{Tt} k_{Tt} + r_{It} k_{It} - \delta_T k_{Tt} - \chi q_t x_{It} - \tau_k k_{Tt})\}
\]  

\[
k_{T,t+1} = [(1 - \delta_T) k_{Tt} + x_{Tt}] / (1 + \eta)
\]  

\[
k_{I,t+1} = [(1 - \delta_I) k_{It} + x_{It}] / (1 + \eta).
\]

All variables in (3.3)–(3.6) are written in per capita terms, and \(N_t = N_0 (1 + \eta)^t\) is the population in \(t\). Households discount future utility at rate \(\beta\). Consumption \(c\) includes both private and public consumption, and investment \(x_T\) includes both private and public tangible investment. The relative price of intangible investment \(x_I\) and consumption is \(q\). The rental rates for business tangible and intangible capital are denoted by \(r_T\) and \(r_I\), respectively, and the wage rate for labor is denoted by \(w\). Inputs are paid their marginal products. Capital depreciates at rates \(\delta_T\) and \(\delta_I\) for tangible and intangible capital, respectively. Other income is denoted by \(\zeta\), and the remaining terms in the household budget constraint are tax payments.

Taxes are levied on consumption at rate \(\tau_c\), labor income at rate \(\tau_h\), tangible capital (that is, property) at rate \(\tau_k\), profits at rate \(\tau_p\), and capital distributions at rate \(\tau_d\). Note that taxable income for the tax on profits is net of depreciation and property tax, and
taxable income for the tax on distributions is net of property tax and profits tax. Note also that we have assumed that only tax rates on consumption and labor vary. These rates directly impact the wedge between marginal rates of substitution and labor productivity and can be easily measured.\textsuperscript{5} We have abstracted from any variation in capital taxes—or expectations in changes in capital taxes—because we want to see how much of a deviation between theory and data there is if we include only shocks to efficiency and labor wedges.

Other income $\zeta$ is exogenous in the household’s decision problem and includes government transfers and nonbusiness capital income net of taxes and investment. Nonbusiness labor income is included in $w$. We treat hours, investment, and output in the nonbusiness sector exogenously because this sector is not important for the issues being addressed. To be precise, in our simulations of the model, we set the paths of nonbusiness hours $\{\bar{h}_{nt}\}$, investment $\{\bar{x}_{nt}\}$, and output $\{\bar{y}_{nt}\}$ in the model’s nonbusiness sector equal to U.S. paths. Measured output, which corresponds to GDP, is the sum of $y_b$ and $\bar{y}_n$. Measured tangible investment is the sum of business tangible investment $x_T$ and nonbusiness tangible investment $\bar{x}_n$. Measured hours $h$ is the sum of business hours $h^1 + h^2$ and nonbusiness hours $\bar{h}_n$.

The parameter $\chi$ represents the fraction of intangible investment financed by capital owners. The amount $\chi q x_i$ is expensed investment, which is financed by the capital owners who have lower accounting profits the greater this type of investment. The amount $(1 - \chi) q x_i$ is what McGrattan and Prescott (2010) call sweat investment, which is financed by workers who have lower compensation the greater this type of investment. These

\textsuperscript{5} Braun (1994) and McGrattan (1994) extended early real business cycle models that predicted too little variation in hours to include variations in tax rates that have a first-order effect on hours of work.
investments are made with the expectation of future capital gains when the business is
sold or goes public.

Gross domestic product in the economy is the sum of total consumption (public plus
private) and tangible investment (public plus private) for business and nonbusiness; in
per capita terms GDP is \( c + x_T + x_n \). Gross domestic income (GDI) is the sum of all
labor income less sweat investment \( wh - (1 - \chi)qx_i \), business capital income less expensed
investment, \( r_T k_T + r_I k_I - \chi qx_i \), and nonbusiness capital income (which is found residually
as the difference between GDP and the other components of GDI). Summing terms gives
us GDI equal to \( y_b + y_n \). Total output and income—which is not what is measured by
national accountants—includes the value of intangible capital and is therefore equal to
GDP (or GDI) plus \( qx_i \).

3.1. A Possible Resolution of the Puzzle

Next we show that the model has the potential to resolve the labor productivity puzzle. To
gain intuition for why, it helps to first consider the simplest one-sector growth model (\( \phi = 0 \))
that abstracts from any fiscal policies or nonbusiness activity, which is the prototype
model used by Chari, Kehoe, and McGrattan (2007). In that model, the production
technology is given by \( y_t = A_t k^\theta h^{1-\theta}_t \), where \( y \) is total output, \( A \) is aggregate TFP, \( k \) is
total tangible capital, and \( h \) is total hours. On impact, with the capital stock given, a
shock to TFP has a direct effect on output through \( A \) and an indirect effect through hours
\( h \). If the shock is negative, the fall in output has to exceed the fall in hours and therefore
labor productivity \( y/h \) falls.

When we introduce intangible capital and nonneutral TFP (that is, \( A_t^I \) not necessarily
perfectly correlated with \( A_t^I \)), we find that the positive correlation between output and
labor productivity is not guaranteed. There are two reasons for this. First, measured output of the business sector in (3.1) does not depend on total business hours $h^1 + h^2$, only on business hours allocated to production of final goods and services. Second, true output of the business sector is $y_b + qx$, not $y_b$. Therefore, there is a difference between measured labor productivity and true labor productivity.

For the aggregate economy, measured labor productivity is the ratio of GDP $y_b + y_n$ to total hours $h$, while true labor productivity is the ratio of total output $y_b + y_n + qx$ to total hours $h$. For the business sector, measured labor productivity is the ratio of business value added $y_b$ to total business hours $h^1 + h^2$, while true labor productivity is the ratio of total business output $y_b + qx$ to total business hours $h^1 + h^2$ (or, equivalently, the ratio of output of final goods and services in the business sector $y_b$ to total hours allocated to production of final goods and services $h^1$).

What does this imply for the labor productivity puzzle? If shocks to the sectoral TFPs move in opposite directions or change at different rates, the model predicts a shift in hours from one activity to another. Suppose, for example, that true output in the business sector $y_b + qx$ and true labor productivity $(y_b + qx)/(h^1 + h^2)$ both fall in a recession. What that means for measured labor productivity depends on the change in $qx$ relative to output $y_b$. If investment falls by more than output, which is typical in recessions, then it is possible that measured labor productivity would rise.

Variations in $qx$ act like a time-varying labor wedge, as can be seen by households’ intratemporal first-order condition

$$\psi (1 + \tau_{ct}) \frac{ct}{1 - h_t} = (1 - \tau_{ht}) (1 - \theta - \phi) \frac{y_{bt} + qx_{it}}{h_t^1 + h_t^2},$$

which relates the marginal rate of substitution between consumption and leisure to the
after-tax marginal product of labor. Notice that the right-hand side is a function of true labor productivity, not measured labor productivity. If business value added or GDP is used as the output measure when constructing the wedge, it will be a function not only of the tax rates but also of the value of intangible capital.

3.2. Identifying Total Factor Productivities

In McGrattan and Prescott (2010), when deriving estimates of sectoral TFPs, we used the fact that there was little change in policies impacting households’ intertemporal decisions during the 1990s such as policies related to capital taxation or financial markets. That allowed us to use intertemporal first-order conditions of households to derive estimates of sectoral TFPs. We needed to use one of the intertemporal conditions to obtain the relative price of intangible and tangible investment.\(^6\)

For 2008–2009, it is hard to make the case that the changes in financial markets and fiscal policies were inconsequential. Therefore, we do a different kind of exercise here, more in the spirit of business cycle accounting (see Chari, Kehoe, and McGrattan 2007). We choose equilibrium paths for sectoral TFPs that imply model predictions for GDP and labor productivity in line with the U.S. analogues. Above we showed that such an exercise is possible once we add intangible capital and nonneutral technology. Of course, it could be the case that deviations from theory still arise or that intangible investments have to be nonsensical to get the large declines in GDP and hours of work that we observed. In this case, we would agree with the conventional wisdom that says RBC theories are missing something important. If, on the other hand, we find that the deviations from theory are

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small and the implied intangible investments are consistent with available evidence, then
the theory will have passed an important test.

4. Facts in Light of Theory

In this section, we report the results of our accounting exercise. We first describe the
model’s benchmark parameterization and exogenous inputs. Then we simulate the model
and compare the predicted equilibrium paths to U.S. time series. We find that the model
does surprisingly well on many dimensions, including those it was not set up to match.

4.1. Model Inputs

In Tables 1 and 2, we report the model inputs for our simulations. Overall, with the pa-
rameters in Table 1 and the 2004 values of exogenous parameters in Table 2, the model’s
national accounts for 2004 line up with the 2004 U.S. national accounts described in Ap-
pendix A. More specifically, the growth rates shown in Table 1 are consistent with trend
U.S. growth rates. Preference parameters are consistent with U.S. returns to capital and
fraction of time in work. Depreciation rates—which are assumed to be equal for intangible
and tangible investment—generate a tangible investment to capital ratio consistent with
the U.S ratio.\(^7\) Capital tax rates are consistent with taxes on imports and production
and income tax policies. Capital shares and the fraction of intangible capital financed by
workers are consistent with the breakdown of U.S. national incomes. (See Appendix A for
more details.)

The construction of the tax rates and nonbusiness series shown in Table 2 are also

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\(^7\) It is not possible to separately identify the depreciation rate and capital share for intangible capital.
McGrattan and Prescott (2010) show that what matters is not the specific parameter values but
rather the implied intangible capital stock.
described in detail in Appendix A. The TFP parameters are, as noted earlier, chosen to get the right patterns of GDP and aggregate labor productivity. Notice that the TFP parameter for production of final goods and services, \( A_1^t \), falls about 8 percent between 2004 and 2008 and remains low. The TFP parameter for production of new intangible capital, \( A_2^t \), falls about 16 percent over the period 2004–2011, but the pattern is different from \( A_1^t \). It falls initially by 6 percent and then gradually increases before falling again in 2008.

We feed the inputs from Table 2 into the model. In doing so, we assume that households have perfect foresight expectations starting in 2007. Prior to that, they do not anticipate the Great Recession but assume that the current exogenous inputs will persist.\(^8\)

### 4.2. Model Predictions

The main results are shown in Figures 3–10. Figure 3 shows actual and predicted GDP, which by construction line up nicely. Figure 4 shows per capita hours of work in the aggregate economy, which also lines up nicely. Figure 5 shows the ratio and, as we noted earlier, the fact that labor productivity was increasing between 2008 and 2010 while GDP was falling. In Figure 6, we show the labor productivity for the business sector, which rises sharply between 2009 and 2010.

Figures 7 and 8 show predicted and U.S. total (tangible) investment and consumption—two series that were not matched when choosing sectoral TFPs. Interestingly, we overpredict the decline in tangible investment, which is below trend by about 25 percent in 2011 for the United States, whereas the model predicts that it is below by 33 percent. This is

\(^8\) The assumption of perfect foresight expectations is not critical because there are no intertemporal shocks. In the case of the latter, the modeling of uncertainty is critical. See, for example, McGrattan (forthcoming).
somewhat surprising, given we have abstracted from any credit market or financial market problems associated with the financial crisis. The flip side of the overprediction of the fall in investment is of course an underprediction of the fall in consumption since they sum to GDP.

In Figure 9, we compare the path for model GDP—which is nearly the same as the path for U.S. GDP—and the path for model total output. Total output falls by more in the Great Recession because intangible investment falls by more than the value added of final goods and services. In Figure 10, we compare tangible and intangible investments in the business sector. Both investments fall by 50 percent before starting to recover, although the patterns are different. In 2008, intangible investment is roughly 15 percent above trend while tangible investment is on its trend, and the fall in tangible investment is more abrupt than for intangible investment.

4.3. Evidence of Low Intangible Investment

We next ask if there is any evidence for a rise in intangible investment over the period 2004–2008 as we see in the model predictions and if there is any evidence of a decline after 2008. While we do not have comprehensive measures of total intangible investments, we do have some direct measures of industry R&D and advertising expenditures.⁹

In Figure 11, we plot real per capita R&D expenditures financed and performed by industry and real per capita U.S. advertising expenditures. (See Appendix A for details on sources for these data.) We do see a significant rise in R&D expenditures before 2008, although this is partly due to the fact that the trend growth in R&D over the post-WWII

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⁹ There has been some work done, most notably by Corrado, Hulten, and Sichel (2005, 2006) and Hulten (2010), to estimate other components of intangible investments such as organizational capital and marketing capital, but these authors admit that there is still a lot of guesswork involved.
period outpaced GDP growth by about 3 percent per year. In 2008, the trend in R&D is reversed and, relative to its long-run trend, this expenditure series is down close to 20 percent. For advertising, we see a steady decline in expenditures and the magnitude of the decline is the same as for U.S. tangible investments, roughly 25 percent. This is equal to the decline in U.S. tangible investment and thus adds support for the model that predicts tangible and intangible investment should have fallen by roughly the same magnitude.

Other evidence that supports a significant decline in U.S. intangible investments is found in the market value of businesses. In Figure 12, we plot real per capita market value relative to a 1.9 percent trend. In theory, the market value of businesses is the value of their productive capital stocks, both tangible and intangible. The fall in market values is large: roughly 20 to 30 percent during the recession—a magnitude that is far too large to be attributable solely to a decline in the tangible capital stock of U.S. businesses.

4.4. Evidence of Low TFP

The driving forces of the model are shocks to TFP. Is there any evidence of negative shocks during the recent recession? In this section, we show one piece of direct evidence: regulatory expenditures and employment rose dramatically. Many attribute higher regulatory costs on businesses with lower TFP.

In Figure 13, we plot real per capita government expenditures—both total spending and spending on federal regulatory activities—relative to a 1.9 percent growth trend for 2004–2011. The estimates of regulatory spending are taken from Dudley and Warren (2010) and are based on various issues of the Budget of the United States Government. (See Appendix A for more details.) For ease of comparison, we plot these expenditures alongside detrended real U.S. GDP for the same period. What we see is that spending
on regulatory activities grew significantly faster than total spending and GDP. By 2011, regulatory spending is 11 percent above trend, while GDP is 10 percent below trend.

The picture is even more striking if instead of spending we use employment. In Figure 14, we plot full-time equivalent (FTE) employment for the U.S. economy, the total government sector, and federal regulatory activities for the period 2004–2011. The source of employment data for the aggregates is the BEA, and the source of the regulatory activities is Dudley and Warren (2010). Each employment series is divided by the population age 16 to 64. By the end of the sample, the number of FTEs in regulatory activities relative to the population is close to 15 percent above its 2004 level. In contrast, the ratio of FTEs to population in the government sector is below trend, and in the overall economy, the ratio is well below trend.

To summarize, we find that a relatively simple RBC theory does surprisingly well in accounting for the recent recession. Thus far, we have found no macro or microevidence to rule out this theory. In fact, it looks like a good starting point for analyzing the impact of other factors that we abstracted from.

5. Conclusion

In this paper, we analyzed the recent Great Recession of 2008–2009 with an RBC model and found that the labor productivity puzzle is much less of a puzzle than previously thought. The addition of intangible capital and nonneutral technology to the model was crucial in accounting for high productivity and low GDP during the recession.

Although we abstracted from many factors that may have played a role during this period, we did not find large deviations from theory. In our view, deviations from theory
direct the development of science. Researchers should be aware of what they are jettisoning when moving on to new theories of the business cycle, and policymakers should be cautious of doing more harm than good with quick policy fixes based on untested theories.\textsuperscript{10}

\footnotesize\textsuperscript{10} For an interesting discussion of the laundry list of policy interventions over the period 2007–2010, see Taylor (2011).
Appendix A.

Data Appendix

The four main sources for our data are the Bureau of Economic Analysis (BEA), which publishes the national accounts and fixed asset tables; the Federal Reserve Board, which publishes the Flow of Funds tables; the Bureau of Labor Statistics, which publishes data on hours and population; and the National Science Foundation (NSF), which publishes statistics on research and development. We also use several auxiliary sources for data on tax rates and intangible expenditures. In this appendix, we provide details on the specific data we use and the necessary revisions we make to the national accounts so that the data are consistent with growth theory.

A.1. National Accounts and Fixed Assets

A.1.1. Overview and Sources

Table A contains a summary of the revised national accounts along with values for 2004, all relative to an adjusted measure of GDP that is consistent with theory. The table numbers and sources of the raw data are listed in parentheses. The sources are tables from the BEA’s national income and product accounts (NIPA) and fixed asset (FA) tables, and the Federal Reserve’s Flow of Funds accounts (FOF). For example, NIPA 1.1.5 is Table 1.1.5 from the BEA NIPA tables. The values shown in the right-hand column of the table are the shares relative to adjusted GDP for 2004. When we compare model predictions with data, we work with real measures and deflate all nominal U.S. time series by the NIPA GDP implicit price deflator.

We have organized Table A as follows. Tables A1 and A2 are the income side of our revised accounts. In Table A1, we display the components of our measure of domestic business value added. This measure is close to the sum of the value added of corporate business, sole proprietorships and partnerships, and other private business as defined in the NIPA tables. In Table A2, we display the components of our measure of domestic nonbusiness value added. This measure is the sum of value added of the household business sector, nonprofits, general government, and government enterprises. Table A3 provides details of the product side of the accounts along with totals for the income side (for comparison). We have categorized tangible investment into business and nonbusiness as in the case of incomes. That is, investments of corporations and noncorporate business
are included with business investment, and investments of household business, nonprofits, and government are included with nonbusiness investment.

Data on capital stocks are used to impute some services of capital when we revise the accounts. They are also used to set certain model parameters and to initialize stocks when computing model equilibria. We use BEA reproducible stocks (FA Table 1.1 for totals and FA Table 6.1 by owner). To that we add land values based on Federal Reserve market values of real estate from balance sheets of households (FOF B100), nonfarm nonfinancial corporations (FOF B102), and nonfarm noncorporate (FOF B103).

A.1.2. Revisions

We now describe two adjustments to GDP and GDI that ensure the national accounts are consistent with our model.

Consumption Taxes. Unlike the NIPA, our model output does not include consumption taxes as part of consumption and as part of value added. We thus subtract sales and excise taxes from the NIPA data on taxes on production and imports (line 24, Table A1 and line 24, Table A2) and from personal consumption expenditures (line 10, Table A3 and line 22, Table A3), since these taxes primarily affect consumption expenditures. As a result of this adjustment, we use producer prices rather than a mixture of producer and consumer prices.

Fixed Asset Expenditures. We treat expenditures on all fixed assets as investment. Thus, spending on consumer durables is treated as an investment rather than as a consumption expenditure and moved from private consumption (line 8, Table A3) to nonbusiness tangible investment (line 20, Table A3). We introduce a consumer durables services sector in much the same way as the NIPA introduces owner-occupied housing services. Households rent the consumer durables to themselves. Specifically, we add depreciation of consumer durables to consumption of fixed capital of households (line 5, Table A2) and to private consumption (line 11, Table A3). We add imputed additional capital services for consumer durables to capital income (line 26, Table A2) and to private consumption (line 13, Table A3). We assume a rate of return equal to 4.1 percent, which is an estimate of the return on other types of capital. A related adjustment is made for government capital. Specifically, we add imputed additional capital services for government capital to capital income (line 27, Table A3) and to public consumption (line 13, Table A3).

After the above adjustments are made to the nominal U.S. series, we detrend them by dividing by three factors: (1) the NIPA GDP implicit price deflator; (2) the population series (defined below); and (3) the factor $1.019^t$ to account for growth in technology.
A.2. Hours and Population

The primary source of our hours and population data is the U.S. Department of Labor, Bureau of Labor Statistics, Employment and Earnings. They are based on the Current Population Survey (CPS). We briefly describe these data here. Full details are given in Prescott, Ueberfeldt, and Cociuba (2005).

The population covered by our series is the total noninstitutional population, ages 16 to 64, for the United States. Prior to 1982, military hours are estimated and added to civilian hours from the CPS. After 1982, they are included in the CPS estimate of total hours.

For versions of the growth model with business and nonbusiness sectors, we also categorize CPS hours as business and nonbusiness. Using the March supplement (through www.ipums.org), we construct business hours as the sum of hours for the self-employed—both incorporated and unincorporated—and hours for private wage and salary workers less hours for employees in nonprofits. Because private wage and salary workers include employees at nonprofits, we use BEA data on compensation in nonprofits, and assuming an average wage rate equal to the economy-wide average, we can infer hours for nonprofits. Hours in the nonbusiness sector are found by subtracting business hours from the total. We use the hours from the March supplement sample to compute the fractions of hours in business and nonbusiness. For our final series, we multiply these fractions by total hours in the monthly CPS sample.

A.3. Tax Rates

We use data from the U.S. national accounts to construct estimates for the tax rate on consumption in Table 2. The tax rate is found by taking the ratio of sales taxes in NIPA to consumption expenditures in NIPA (which include sales taxes). In our measure of sales taxes, we include federal excise taxes and customs, state and local sales taxes, and other nonproperty licenses and fees. Our measure of NIPA consumption expenditures includes adjustments for consumer durables. Denoting sales tax by $\tau_c c$ and NIPA consumption expenditures by $c + \tau_c c$, the ratio yields $\tau_c / (1 + \tau_c)$. It is easy to determine $\tau_c$ from this ratio.

For the marginal tax rate on labor in Table 2, we use Barro and Redlick (2011) and data from the TAXSIM website at the NBER to extend their series past 2006.

Next, consider the capital tax rates listed in Table 1. The estimate of the tax rate on property is based on NIPA taxes on imports and production. We take property taxes paid
by businesses and divide by the total tangible capital stock of businesses. The tax rate on profits is corporate income tax liabilities divided by before-tax profits. Since Federal Reserve banks pay a 100 percent corporate income tax, we subtract their profits from tax liabilities and profits before constructing the ratio. The tax rate on distributions is the average marginal tax rate on dividend income constructed from individual income tax data. The rate takes into account that pension funds, IRAs, and nonprofits pay a tax rate of zero.

A.4. Intangible Expenditures and Market Values

The source of R&D expenditures shown in Figure 11 is the NSF (2010), with estimates after 2008 based on Battelle Memorial Institute (2009–2012) forecasts. The series we use is R&D that is financed and performed by industry.

The source of advertising expenditures is the U.S. Department of Commerce, Bureau of the Census (2009–2012). Prior to 2008, the estimates are advertising expenditures, and after 2008 they are advertising revenues. For years in which we have both expenditures and revenues, the patterns are the same.

The market value of U.S. business in Figure 12 is the sum of the market value of domestic corporations (FOF L213) and equity in noncorporate business (FOF B100).

To make all series comparable, intangible expenditures and market values are detrended in the same way as the series for the national accounts.

A.5. Federal Regulatory Spending and Employment

Estimates of spending related to federal regulatory activities shown in Figure 13 are constructed by Dudley and Warren (2010), are based on the *Budget of the United States Government*, and are fiscal-year values. The main categories of regulation included in their estimates are consumer safety and health, homeland security, transportation, workplace, environment, energy, finance and banking, industry-specific regulation, and general business regulation. Agencies that primarily perform taxation, entitlement, procurement, subsidy, and credit functions are excluded from the estimates. These agencies include, for example, the Internal Revenue Service, the Social Security Administration, the Commodity Credit Corporation, and the Federal Housing Administration. Dudley and Warren (2010) also report estimates of the full-time equivalent employment required for regulatory activities, which is shown in Figure 14.
### Table A. Revised National Accounts, Relative to Adjusted GDP, 2004

#### A1. Domestic Business Value Added

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<th>Description</th>
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<tr>
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<tr>
<td>2</td>
<td>Consumption of fixed capital</td>
<td>.078</td>
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<tr>
<td>3</td>
<td>Corporate business (NIPA 7.5)</td>
<td>.065</td>
</tr>
<tr>
<td>4</td>
<td>Sole proprietorships and partnerships (NIPA 7.5)</td>
<td>.011</td>
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<tr>
<td>5</td>
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<td>12</td>
<td>Capital income</td>
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<td>13</td>
<td>Corporate profits with IVA and CCadj (NIPA 1.13)</td>
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<td>Rental income of persons with CCadj (NIPA 1.13)</td>
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<tr>
<td>16</td>
<td>Net interest and miscellaneous payments</td>
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*Note:* IVA, inventory valuation adjustment; CCadj, capital consumption adjustment.

<sup>a</sup> This category includes business transfers and excludes subsidies.

<sup>b</sup> Imputed additional capital services are equal to 4.1 percent times the current-cost net stock of government fixed assets and consumer durables goods (FA 1.1).

<sup>c</sup> 10 percent of farm business is in corporate, with the remainder in noncorporate.
References


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### TABLE 2. Time Series for Exogenous Inputs

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Figure 1

GDP and Aggregate Labor Productivity, 1960:1–2011:3,
Percent Deviations from HP-filtered Trend
Figure 2

Business Value Added and Labor Productivity, 1960:1–2011:3,
Percent Deviations from HP-filtered Trend
Figure 3

Predicted and U.S. Real Per Capita GDP, 2004–2011,

Relative to a 1.9% Trend
Figure 4
Predicted and U.S. Per Capita Hours of Work, 2004–2011
Figure 5
Predicted and U.S. Aggregate Labor Productivity, 2004–2011,
Relative to a 1.9% Trend
Figure 6
Predicted and U.S. Business Sector Labor Productivity, 2004–2011,
Relative to a 1.9% Trend
Figure 7

Predicted and U.S. Real Per Capita Investment, 2004–2011,
Relative to a 1.9% Trend
Figure 8
Predicted and U.S. Real Per Capita Consumption, 2004–2011,
Relative to a 1.9% Trend
Figure 9

Predicted Real Per Capita GDP and Total Output, 2004–2011, Relative to a 1.9% Trend
Figure 10
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Relative to a 1.9% Trend
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U.S. Real Per Capita R&D and Advertising Expenditures, 2004–2011, Relative to a 1.9% Trend
Figure 12
U.S. Real Per Capita Market Value of Business, 2004–2011,
Relative to a 1.9% Trend
Figure 13

U.S. Real Per Capita Government Spending and GDP, 2004–2011, Relative to a 1.9% Trend
Figure 14
Full-Time Equivalent Employment Relative to Population
Ages 16–64, 2004–2011