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The Labor Productivity Puzzle*

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ABSTRACT

Prior to the mid-1980s, labor productivity growth was a useful barometer of the U.S. economy's performance: it was low when the economy was depressed and high when it was booming. Since then, labor productivity has become significantly less procyclical. In the recent downturn 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 when the economy was depressed and high when it was booming. 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.[1] 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. McGrattan and Prescott (2010) found that once these additional features of reality are introduced into the RBC model, the theoretical predictions are in close conformity to U.S. observations for 1990–2003, a period which includes two depressed periods with labor productivity above trend. Here, we show that these additional features have the potential to generate the same pattern of *measured* labor productivity growth observed in the U.S. 2008–2009 downturn.

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

[1] The model is an extension of models developed earlier, most notably by Kydland and Prescott (1982) and Hansen (1985).

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 downturn, GDP falls but investments 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 labor 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 included. The specific pattern of labor productivity over the business 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).[2] 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 depressed periods. Adding intangible capital generates an apparent labor wedge between the marginal rate of substitution between consumption and leisure and measured labor productivity. When we add 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.

[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' intertemporal 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 Raffo (2012) who conduct a cross-country business cycle accounting exercise.

In our business cycle accounting exercise, we feed into the model sectoral TFPs that 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 this period? We find the results are surprisingly close *given that we have abstracted from any financial market or fiscal distortions associated with the financial crisis.*

We then 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 (e.g., expenditures on R&D and advertising) and to series that move with intangible investments (e.g., 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.

As an additional check on the theory, we provide empirical evidence for negative shocks to TFP, which are the main sources of decline in predicted real activity. The evidence we consider are costs paid by businesses to comply with federal regulations and expenditures and employment of federal regulatory agencies, which have risen dramatically in recent years. We interpret the increase in regulatory costs as a decrease in TFP.

The vast literature that attempts to understand the factors giving rise to aggregate fluctuations 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 between observations and existing theory.[4]

In Section 2, we start with the facts about trends in U.S. labor productivity and discuss 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.[5] Figures 1 and 2 demonstrate this fact for the aggregate economy and the business sector.

Figure 1 shows percent deviations of GDP and labor productivity from trend for the aggregate economy during the period 1960:1–2011:4. 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 Cociuba (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 depressions. The correlation for the second half is only 5 percent and, unlike the first half, there is no

[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 Galí and van Rens (2010), Garin, Pries, and Sims (2011), Mulligan (2011), Schaal (2012), and Berger (2012). monetary policy by Gertler and Kiyotaki (2010), and uncertainty about fiscal policy by McGrattan (forthcoming).

[4] Predictions of new theories are typically compared to those of the earlier vintages of RBC models.

[5] A useful source for studies on productivity trends is the Bureau of Labor Statistics *Monthly Labor Review*. See, for example, Holman, Joyeux, and Kask (2008) and Chernousov, Fleck, and Glaser (2009).

procyclical pattern. During the early 1990s and early 2000s, labor productivity does not decline as much as GDP and recovers faster. By the end of the sample, when the depressed period of 2008–2009 is evident, we see that labor productivity is again above its trend while GDP is below.

Figure 2 shows the same statistics, but here we use data for business value added and business hours over the period 1960:1–2011:3. 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 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

$$y_{bt} = A_t^1 \left(k_{Tt}^1\right)^{\theta} \left(k_{It}\right)^{\phi} \left(h_t^1\right)^{1-\theta-\phi} \tag{3.1}$$

$$x_{It} = A_t^2 \left(k_{Tt}^2\right)^{\theta} \left(k_{It}\right)^{\phi} \left(h_t^2\right)^{1-\theta-\phi}. \tag{3.2}$$

Firms produce business output y_b using their tangible capital k_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^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_{T0}, k_{I0}), the stand-in household maximizes

$$E \sum_{t=0}^{\infty} \beta^t \left[\log c_t + \psi \log\left(1 - h_t\right)\right] N_t \tag{3.3}$$

subject to

$$\begin{aligned}
c_t + x_{Tt} + q_t x_{It} = {} & r_{Tt} k_{Tt} + r_{It} k_{It} + w_t h_t + \zeta_t \\
& - \tau_{ct} c_t - \tau_{ht}\left(w_t h_t - \left(1-\chi\right) q_t x_{It}\right) - \tau_k k_{Tt} \\
& - \tau_p \{ r_{Tt} k_{Tt} + r_{It} k_{It} - \delta_T k_{Tt} - \chi q_t x_{It} - \tau_k k_{Tt} \} \\
& - \tau_d \{ r_{Tt} k_{Tt} + r_{It} k_{It} - x_{Tt} - \chi q_t x_{It} - \tau_k k_{Tt} \\
& \qquad - \tau_p \left(r_{Tt} k_{Tt} + r_{It} k_{It} - \delta_T k_{Tt} - \chi q_t x_{It} - \tau_k k_{Tt} \right) \}
\end{aligned} \tag{3.4}$$

$$k_{T,t+1} = \left[\left(1 - \delta_T\right) k_{Tt} + x_{Tt}\right] / \left(1 + \eta\right) \tag{3.5}$$

$$k_{I,t+1} = \left[\left(1 - \delta_I\right) k_{It} + x_{It}\right] / \left(1 + \eta\right). \tag{3.6}$$

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 β. 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 δ_T and δ_I for tangible and intangible capital, respectively. Other income is denoted by ζ, and the remaining terms in the household budget constraint are tax payments.

Taxes are levied on consumption at rate τ_c, labor income at rate τ_h, tangible capital (that is, property) at rate τ_k, profits at rate τ_p, and capital distributions at rate τ_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 varying tax rates only for consumption and labor. These rates directly impact the wedge between marginal rates of substitution and labor productivity and can be easily measured.[6] 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 ζ 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 wh. We treat hours, investment, and output in the nonbusiness sector exogenously because this sector is not important for the issues being addressed. To

[6] 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.

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 χ 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 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 $c + x_T + \bar{x}_n$. Gross domestic income (GDI) is the sum of all labor income less sweat investment $wh - (1-\chi) q x_I$, business capital income less expensed investment, $r_T k_T + r_I k_I - \chi q x_I$, 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 $q x_I$.

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 $y_t = A_t k_t^\theta h_t^{1-\theta}$, 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^1 not necessarily changing by the same factor as A_t^2), we find that the positive correlation between output and labor productivity is not guaranteed. There are two reasons for this result. 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 the production of final goods and services. Second, true output of the business sector is $y_b + qx_I$, 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 $y_b + y_n + qx_I$ 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 $y_b + qx_I$ 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 $y_b + qx_I$ and true labor productivity $(y_b + qx_I)/(h^1 + h^2)$ both fall in a downturn. What that means for *measured* labor productivity depends on the change in qx_I relative to output y_b. If investment falls by more than output, which is typical in depressed periods, then it is possible that measured labor productivity would rise.

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

$$\psi\left(1+\tau_{ct}\right)\frac{c_t}{1-h_t} = \left(1-\tau_{ht}\right)\left(1-\theta-\phi\right)\frac{y_{bt}+qx_{It}}{h_t^1+h_t^2}, \tag{3.7}$$

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 of (3.7) 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. The same will be true if we compare the marginal rate of substitution to *measured* compensation per hour. In other words, there is an apparent wedge between the marginal rate of substitution and the wage rate of workers.[7]

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

[7] If the wedge were instead between the the wage rate and the marginal product of labor, then we would not have a resolution to the labor productivity puzzle because the time series of U.S. compensation per hour and U.S. GDP per hour are close.

during the 1990s (e.g., 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.[8]

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 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 along many dimensions, including those it was not set up to match.

[8] See McGrattan and Prescott (2010) for details.

4.1. Model Inputs

In Tables 1 and 2, we report the model inputs for our simulations. Overall, with the parameters 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 the appendix. 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 that is consistent with the U.S ratio.[9] 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 the appendix for more details.)

The construction of the tax rates and nonbusiness series shown in Table 2 are also described in detail in the appendix. The TFP parameters are, as noted earlier, chosen to obtain the right patterns of GDP and aggregate labor productivity. Notice that the TFP parameter for the production of final goods and services, A_t^1, falls about 8 percent between 2004 and 2008 and remains low. The TFP parameter for production of new intangible capital, A_t^2, falls about 16 percent over the period 2004–2011, but the pattern is different from A_t^1. 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

[9] 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.

anticipate the Great Recession but assume that the current exogenous inputs will persist.[10]

4.2. Model Predictions

The main results are shown in Figures 3–10, which are comparisons of model predictions with U.S. data. The same detrending procedures are used for the model and the data. Specifically, all time series, with the exception of hours, are in real per capita terms and divided by 1.019^t to account for growth in technology. Hours are per capita.

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 result is somewhat surprising, given that 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

[10] 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).

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. Although we do not have comprehensive measures of total intangible investments, we do have some direct measures of industry R&D and advertising expenditures.[11]

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 the appendix for details on sources for these data.) We do see a significant rise in R&D expenditures before 2008, although a partial explanation for this result is that the trend growth in R&D over the post–World War II 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 percentage is equal to the decline in U.S. tangible investment and thus adds

[11] 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.

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 over the sample—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 downturn? In this section, we show that there is direct evidence in higher annual costs of firms for compliance with federal regulations, rising expenditures of federal regulatory agencies, and rising employment of federal regulatory agencies. We interpret higher regulatory costs to businesses as a key factor for lower TFP.

Crain and Crain (2010) estimate that the total costs of federal regulations have increased since 2005 with the cost for 2008 at roughly \$8,086 per employee. For firms with fewer than 20 employees, they estimate the cost is \$10,585 per employee, which is high when compared to annual wage compensation paid per employee. Crain and Crain estimate costs on those who are regulated and define them to be "resource costs over and above those that show up in the federal budget and agency personnel charts" (p. 12). For example, for pollution control, they include costs of businesses to install abatement equipment but they do not include spending of the Environmental Protection Agency.

Most predictions for future costs are even higher because the current estimates do not include costs related to the Dodd-Frank legislation for financial firms and President Obama's health care initiatives. In their review of "over-regulated America," the *Economist* noted that the Dodd-Frank law, at 848 pages, is 23 times longer than the Glass-Steagall Act. Although high, that estimate does not take into account that many sections call for further detail to be worked out by the regulators. Mathews (2012), in reporting on new health mandates, points out that the number of codes used to classify an illness or injury will rise from 18,000 to 140,000.[12]

Next consider the spending of federal agencies that regulate households and businesses. 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 the appendix 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 we use employment instead of spending. 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 Bureau of Economic Analysis (BEA), and the source of the federal regulatory employment 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

[12] To give an example, in the new system, there are three categories related to drowning and submersion due to falling or jumping from burning water-skis.

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 downturn. Thus far, we have found no macro or microevidence to rule out this theory. In fact, RBC theories look 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 period.

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.[13]

[13] For an interesting discussion of the laundry list of policy interventions over the period 2007–2010, see Taylor (2011).

Appendix A. Data Sources

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. They are adjustments for consumption taxes and fixed asset expenditures.

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.

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.* The data are based on the Current Population Survey (CPS), and we briefly describe them 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 τ_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 National Bureau of Economic Research (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

1	Domestic Business Value Added	.676
2	Consumption of fixed capital	.078
3	Corporate business (NIPA 7.5)	.065
4	Sole proprietorships and partnerships (NIPA 7.5)	.011
5	Other private business (NIPA 7.5)	.002
6	Labor income	.445
7	Compensation of employees	.388
8	Corporate business (NIPA 1.13)	.340
9	Sole proprietorships and partnerships (NIPA 1.13)	.045
10	Other private business (NIPA 1.13)	.003
11	70% proprietors' income with IVA and CCadj (NIPA 1.13)	.058
12	Capital income	.152
13	Corporate profits with IVA and CCadj (NIPA 1.13)	.083
14	30% proprietors' income with IVA and CCadj (NIPA 1.13)	.025
15	Rental income of persons with CCadj (NIPA 1.13)	.004
16	Net interest and miscellaneous payments	.015
17	Corporate business (NIPA 1.13)	.004
18	Sole proprietorships and partnerships (NIPA 1.13)	.008
19	Other private business (NIPA 1.13)	.003
20	Taxes on production and imports[a]	.025
21	Corporate business (NIPA 1.13)	.049
22	Sole proprietorships and partnerships (NIPA 1.13)	.012
23	Other private business (NIPA 1.13)	.001
24	*Less*: Sales tax (NIPA 3.5)	.037

See notes at the end of the table.

Table A. Revised National Accounts (Cont.)

A2. Domestic Nonbusiness Value Added

1	Domestic Nonbusiness Value Added	.326
2	Consumption of fixed capital	.097
3	Households	.073
4	Excluding consumer durables (NIPA 7.5)	.013
5	Consumer durable depreciation (FOF F10)	.060
6	Nonprofits (NIPA 7.5)	.005
7	General government (NIPA 7.5)	.015
8	Government enterprises (NIPA 7.5)	.003
9	Labor income	.147
10	Compensation of employees	.147
11	Households (NIPA 1.13)	.001
12	Nonprofits (NIPA 1.13)	.043
13	General government (NIPA 1.13)	.093
14	Government enterprises (NIPA 1.13)	.010
15	Capital income	.082
16	Current surplus of government enterprises (NIPA 1.13)	.000
17	Rental income of persons with CCadj (NIPA 1.13)	.011
18	Net interest and miscellaneous payments	.031
19	Households (NIPA 1.13)	.030
20	Nonprofits (NIPA 1.13)	.001
21	Taxes on production and imports[a]	.004
22	Households (NIPA 1.13)	.009
23	Nonprofits (NIPA 1.13)	.001
24	*Less*: Sales tax (NIPA 3.5)	.006
25	Imputed additional capital services[b]	.036
26	Household, consumer durables	.013
27	Government capital	.024

See notes at the end of the table.

Table A. Revised National Accounts (Cont.)

A3. Domestic Value Added and Product

1	Total Adjusted Domestic Income	1.000
2	Domestic Business Value Added	.676
3	Domestic Nonbusiness Value Added	.326
4	Statistical Discrepancy	−.002
5	Total Adjusted Domestic Product	1.000
6	Consumption	.781
7	Personal consumption expenditures (NIPA 1.1.5)	.661
8	*Less*: Consumer durables (NIPA 1.1.5)	.086
9	*Less*: Sales tax, nondurables and services (NIPA 3.5)	.038
10	Consumer durable depreciation (FOF F10)	.060
11	Government consumption expenditures (NIPA 3.1)	.148
12	Imputed additional capital services[b]	.036
13	Business tangible investment[c]	.102
14	Corporate gross private domestic investment (FOF F6)	.081
15	Noncorporate gross private domestic investment (FOF F6)	.021
16	Nonbusiness tangible investment	.117
17	Household	.128
18	Excluding consumer durables (FOF F6)	.047
19	Consumer durables (NIPA 1.1.5)	.086
20	*Less:* Sales tax, durables (NIPA 3.5)	.005
21	Nonprofits (FOF F6)	.008
22	Government investment (NIPA 3.1)	.030
23	Net exports of goods and services (NIPA 1.1.5)	−.049

Note: IVA, inventory valuation adjustment; CCadj, capital consumption adjustment.

[a] This category includes business transfers and excludes subsidies.

[b] 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).

[c] 10 percent of farm business is in corporate, with the remainder in noncorporate.

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TABLE 1. Model Parameters

Parameter	Expression	Value
Growth Rates		
Growth in population	η	0.010
Growth in technology	γ	0.019
Preferences		
Discount factor	β	0.979
Utility parameter	ψ	1.186
Depreciation Rates		
Tangible capital	δ_T	0.039
Intangible capital	δ_I	0.039
Capital Tax Rates		
Tax rate on property	τ_k	0.014
Tax rate on profits	τ_p	0.286
Tax rate on distributions	τ_d	0.078
Capital Shares		
Tangible capital	θ	0.212
Intangible capital	α	0.150
Fraction of Intangible financed by workers	χ	0.500

TABLE 2. Time Series for Exogenous Inputs

	Tax Rates		TFP Parameters		Nonbusiness Series		
t	τ_{ct}	τ_{ht}	A_t^1	A_t^2	$\bar{y}_{nt}$	$\bar{x}_{nt}$	$\bar{h}_{nt}$
2004	6.20	35.8	1.67	1.25	0.324	0.116	0.044
2005	6.35	35.1	1.67	1.18	0.316	0.113	0.046
2006	6.36	35.3	1.68	1.20	0.304	0.107	0.046
2007	6.19	35.2	1.66	1.26	0.319	0.101	0.047
2008	6.00	35.2	1.63	1.25	0.323	0.086	0.048
2009	5.77	35.1	1.52	1.12	0.324	0.092	0.047
2010	5.81	35.1	1.53	1.05	0.311	0.084	0.048
2011	5.95	35.1	1.54	1.07	0.301	0.079	0.047

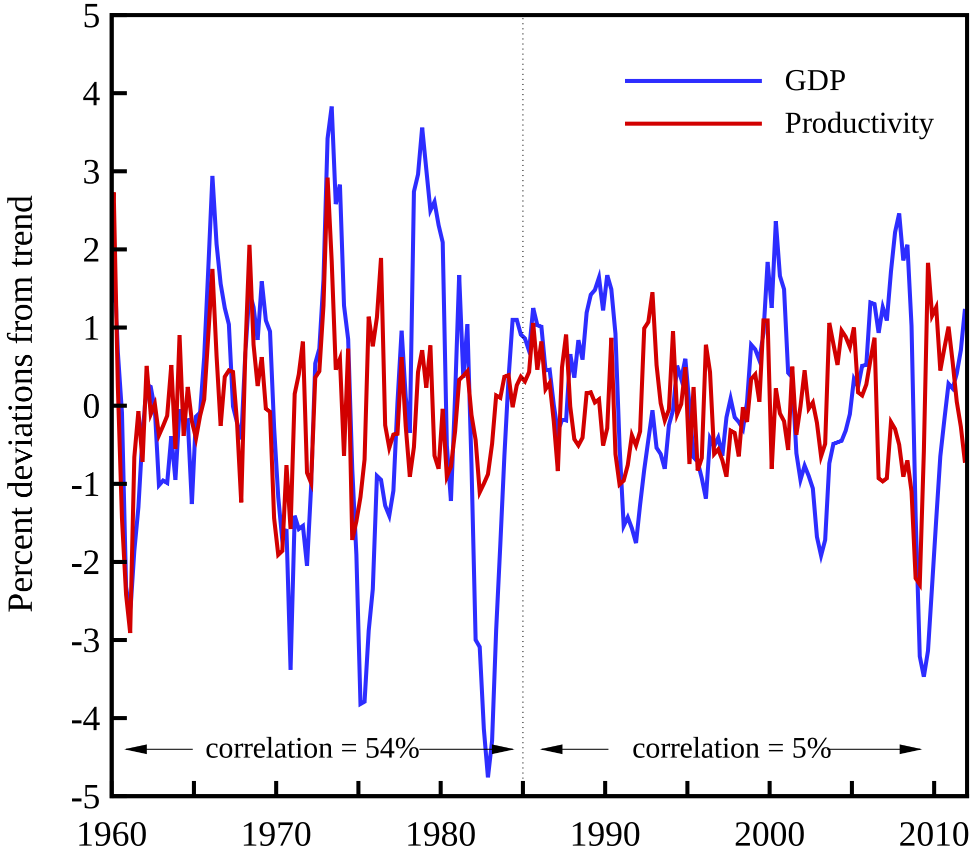

FIGURE 1

GDP and Aggregate Labor Productivity, 1960:1–2011:4,

Percent Deviations from HP-filtered Trend

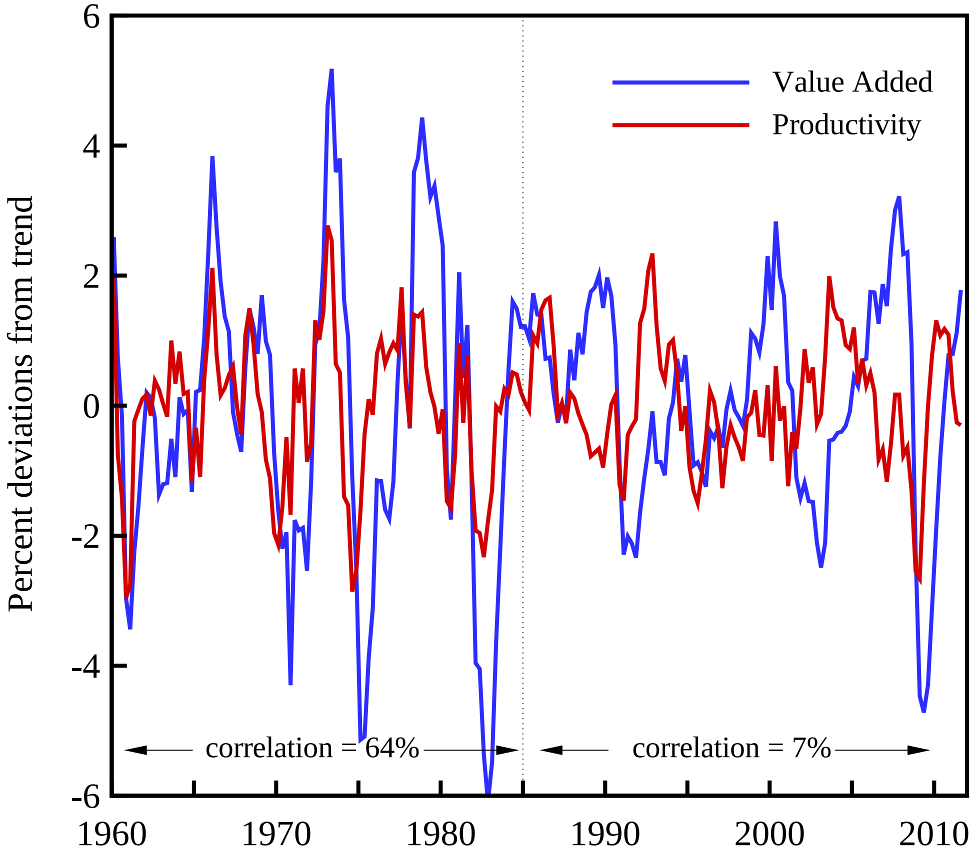

FIGURE 2

Business Value Added and Labor Productivity, 1960:1–2011:3,

Percent Deviations from HP-filtered Trend

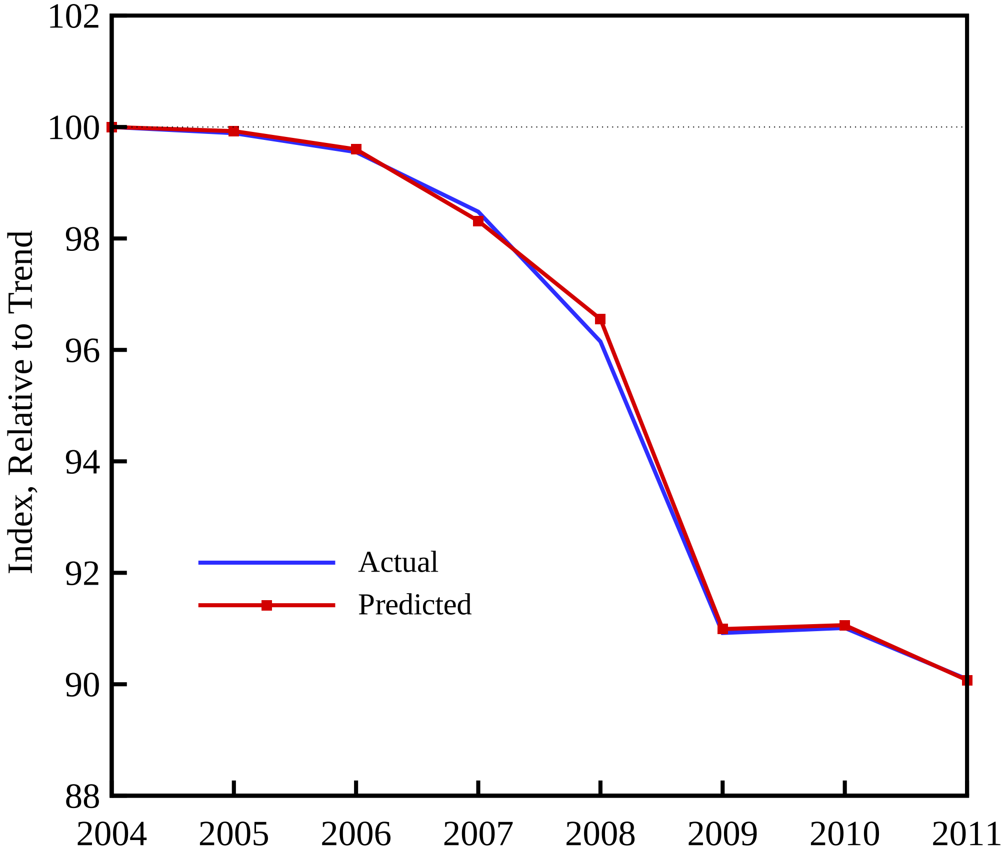

FIGURE 3

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

Relative to a 1.9% Trend

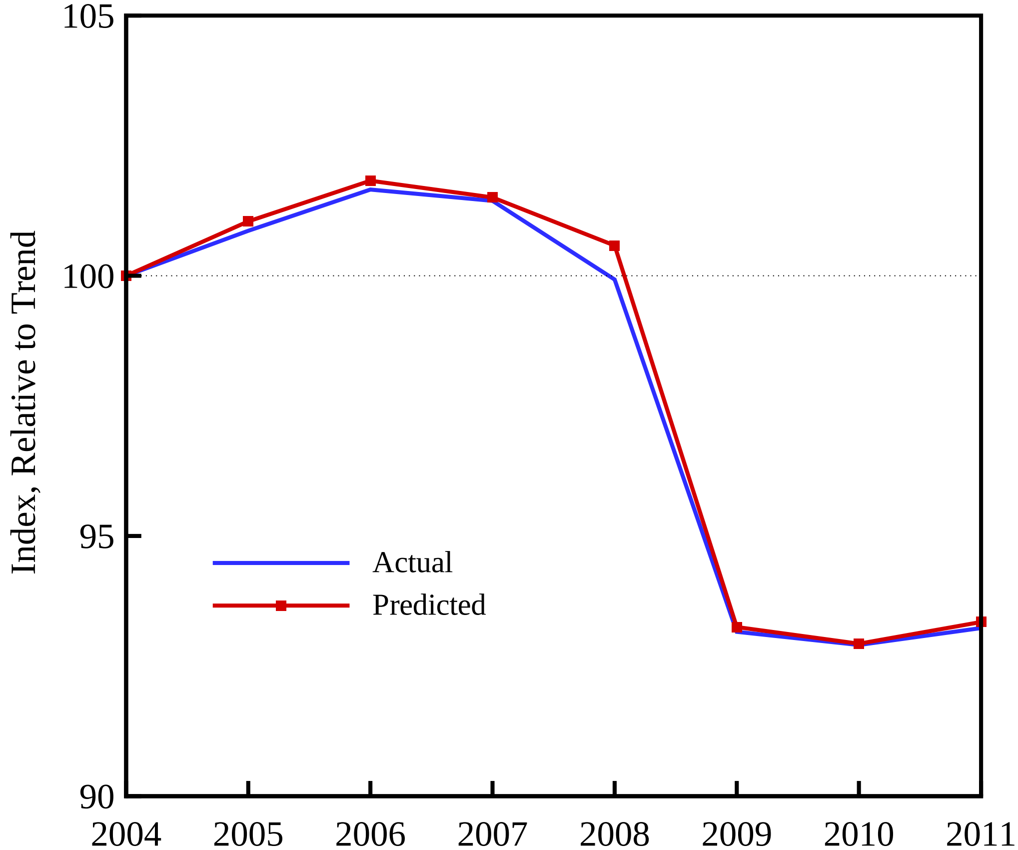

FIGURE 4

Predicted and U.S. Per Capita Hours of Work, 2004–2011

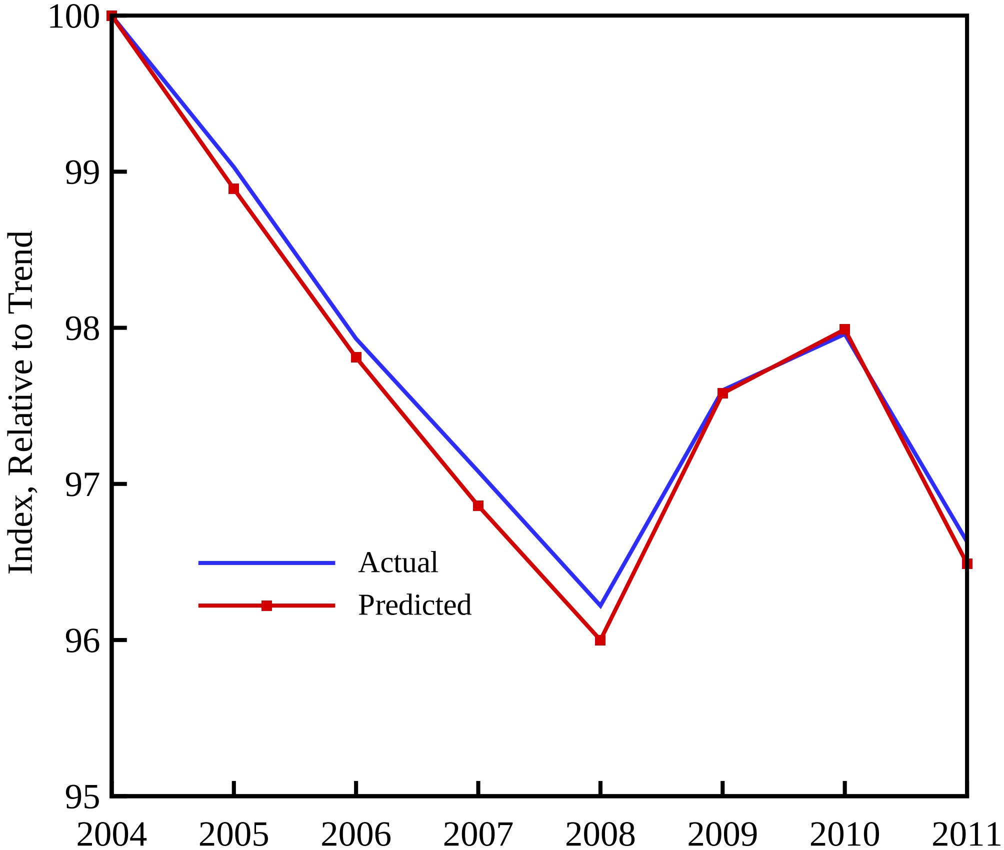

FIGURE 5

Predicted and U.S. Aggregate Labor Productivity, 2004–2011,

Relative to a 1.9% Trend

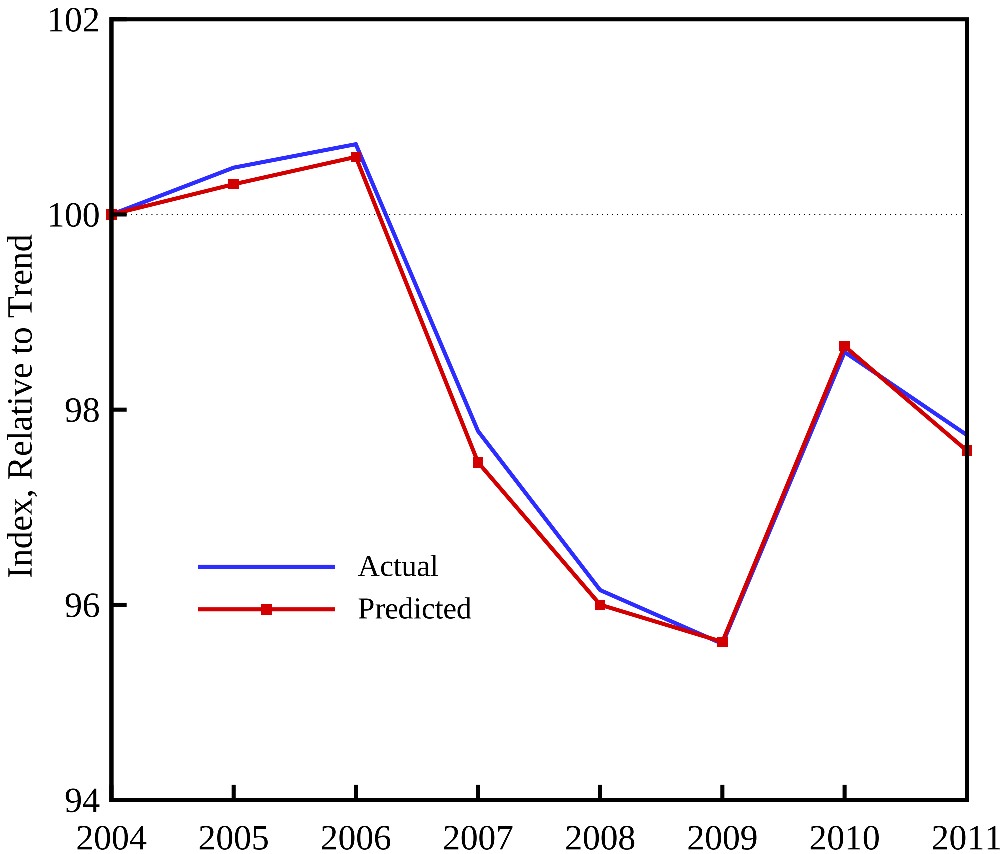

FIGURE 6

Predicted and U.S. Business Sector Labor Productivity, 2004–2011,

Relative to a 1.9% Trend

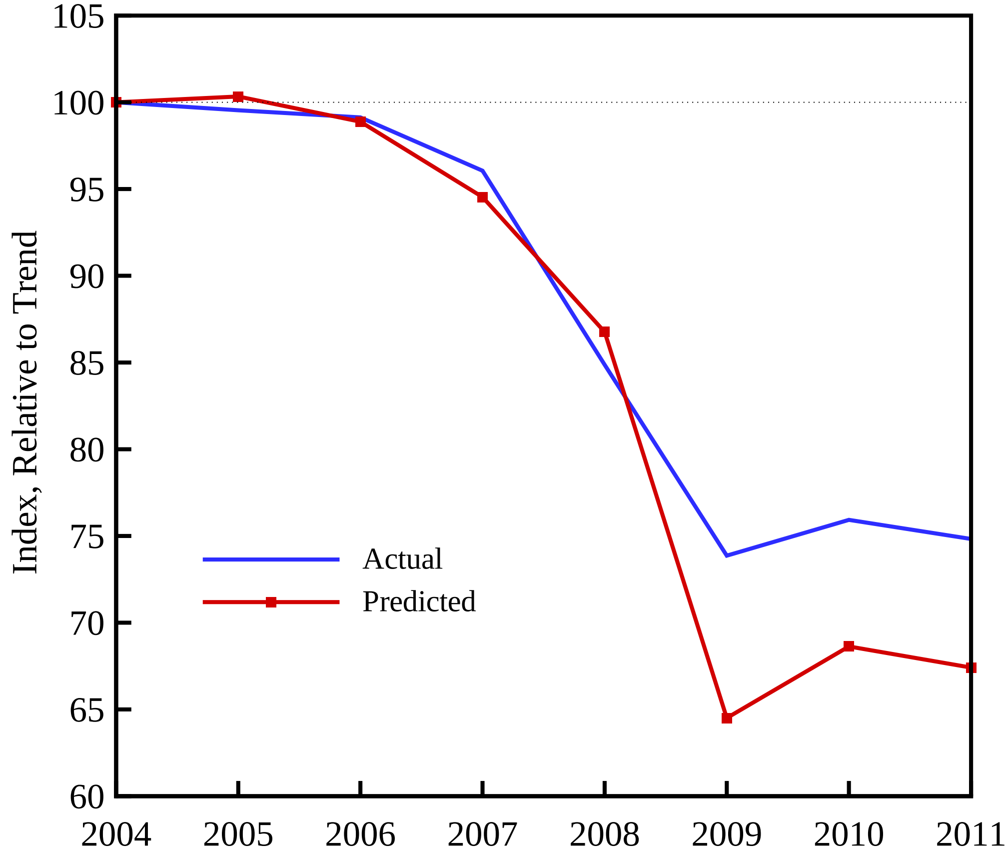

FIGURE 7

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

Relative to a 1.9% Trend

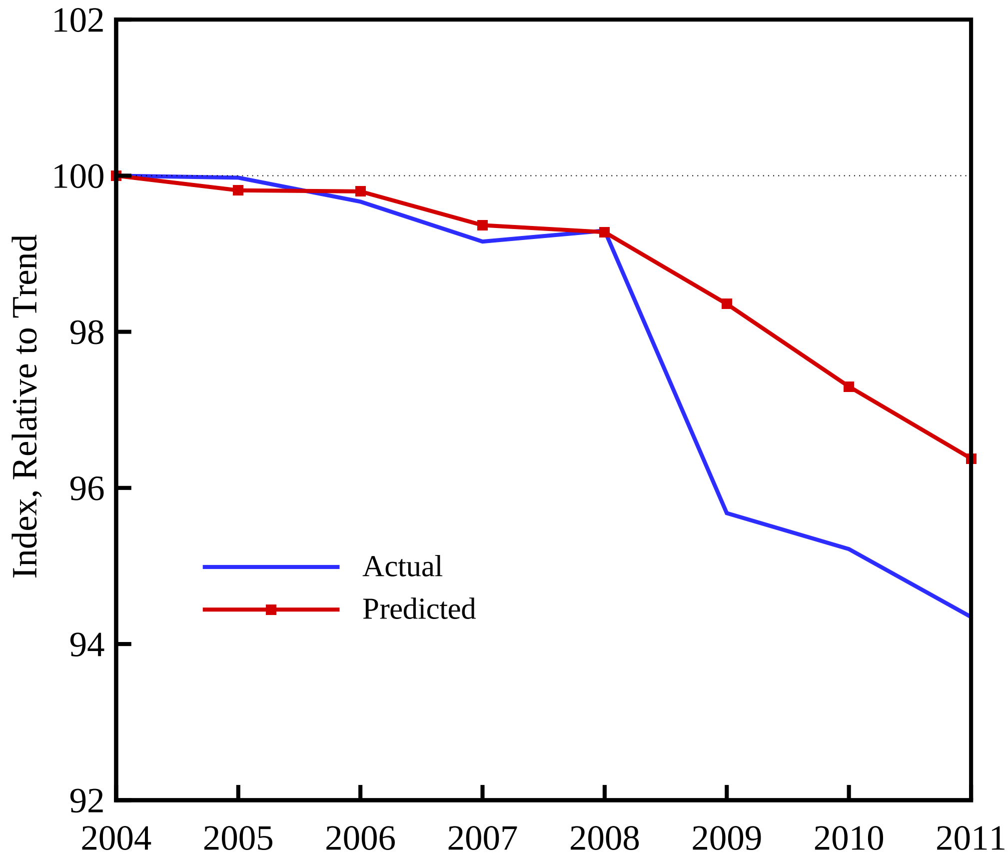

FIGURE 8

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

Relative to a 1.9% Trend

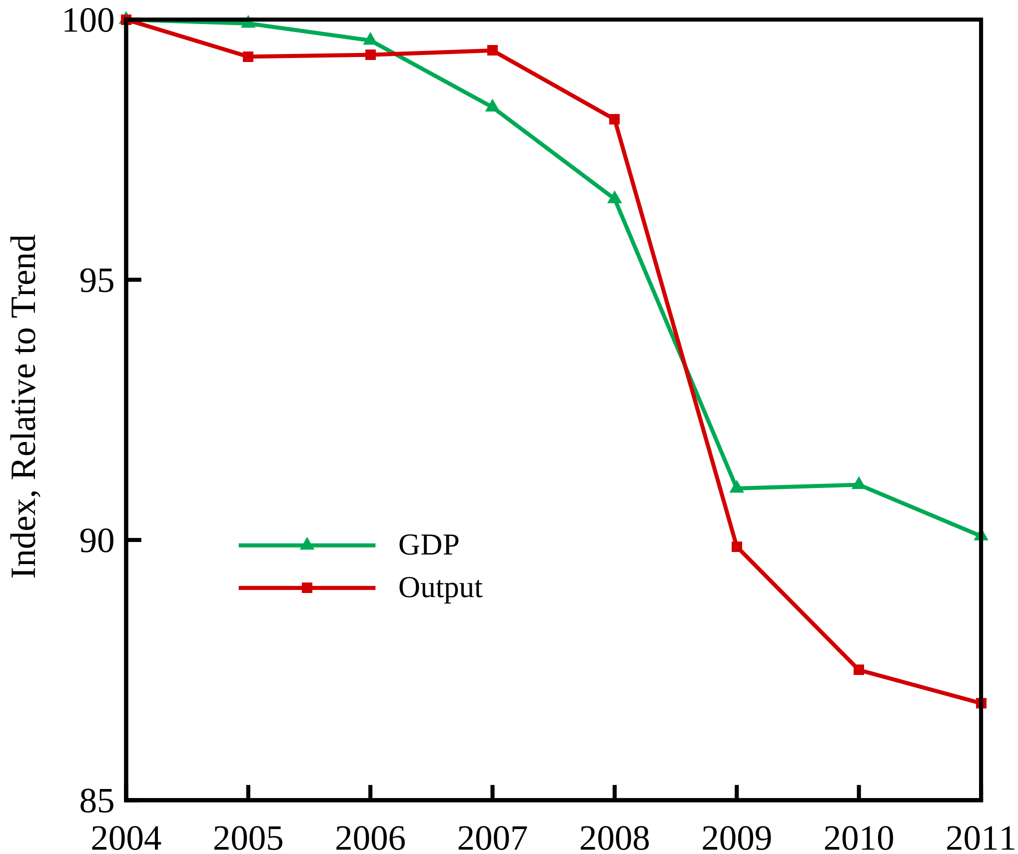

Figure 9

Predicted Real Per Capita GDP and Total Output, 2004–2011,

Relative to a 1.9% Trend

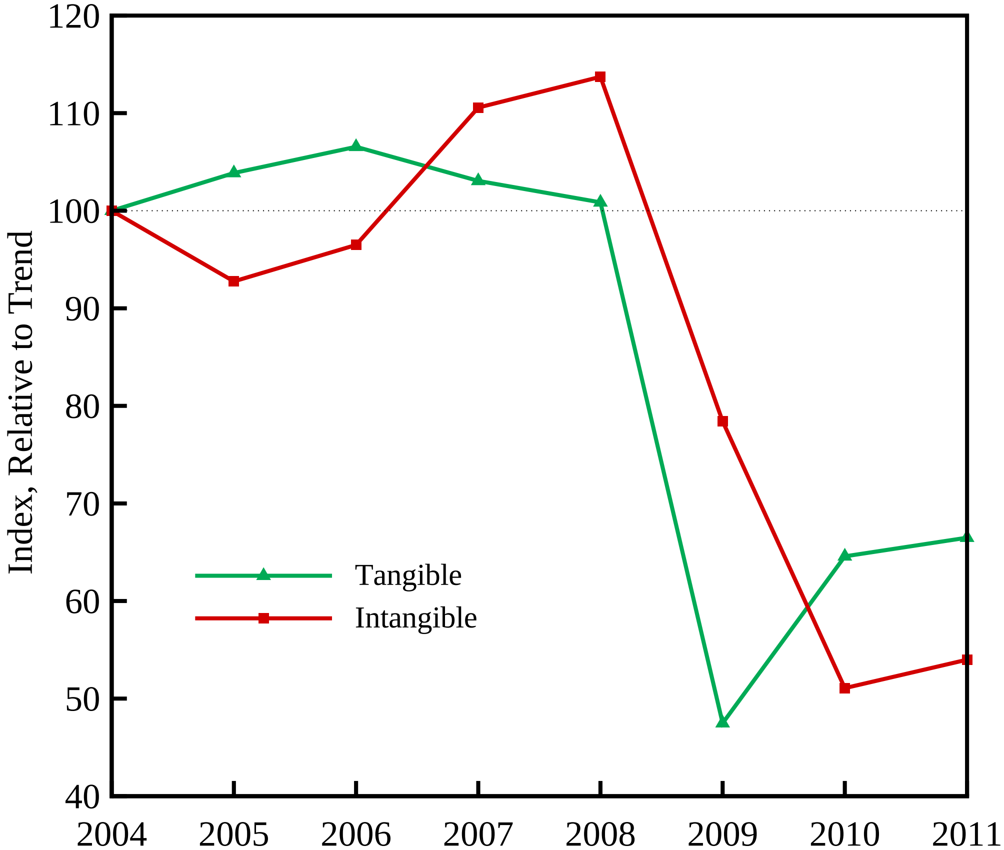

Figure 10

Predicted Real Per Capita Business Investments, 2004–2011,

Relative to a 1.9% Trend

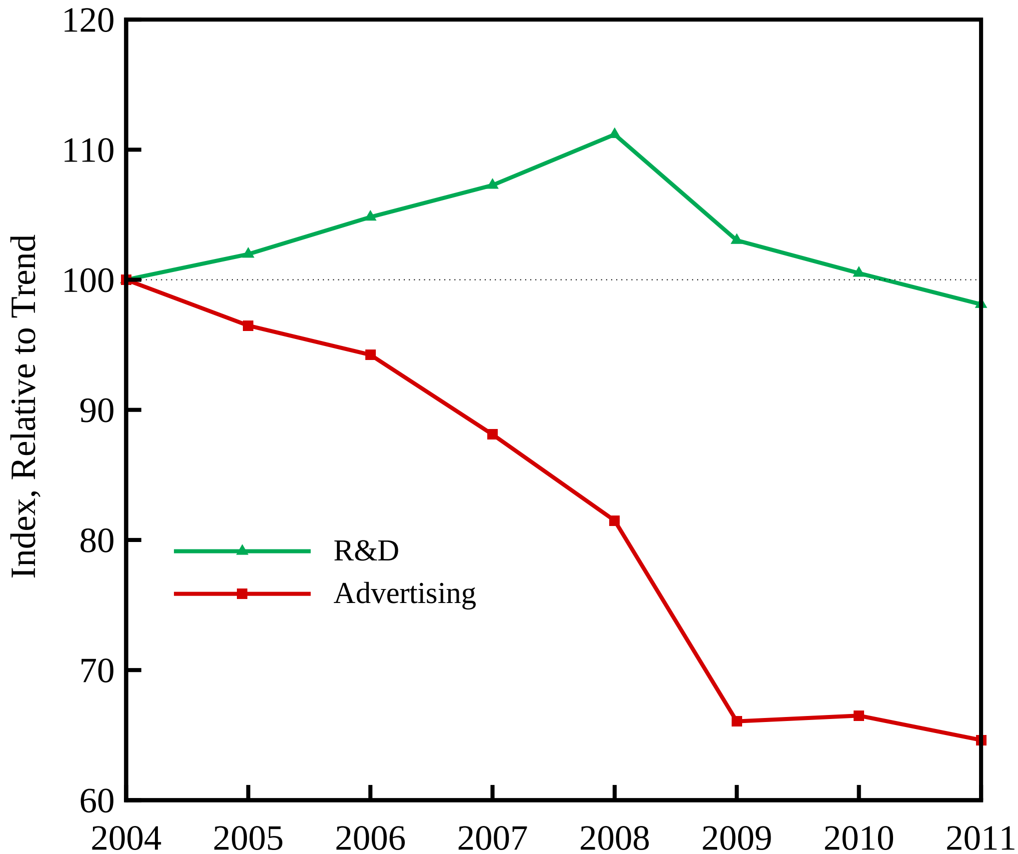

Figure 11

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

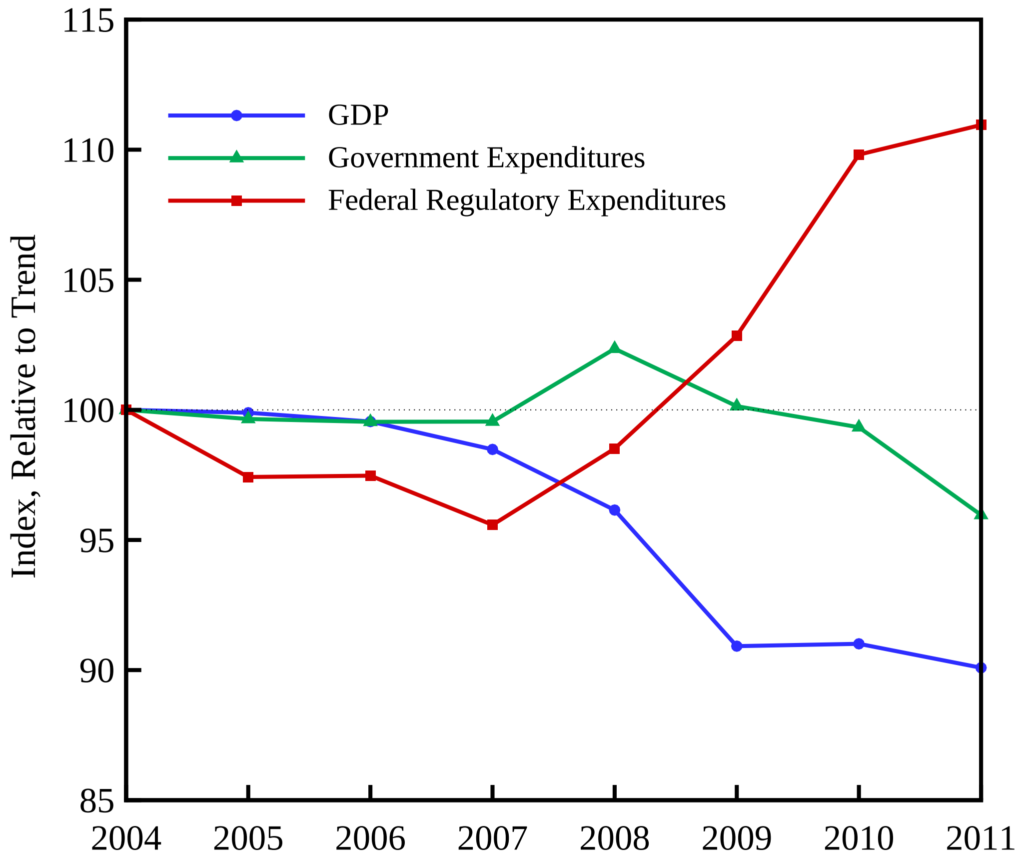

Figure 13

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

Relative to a 1.9% Trend

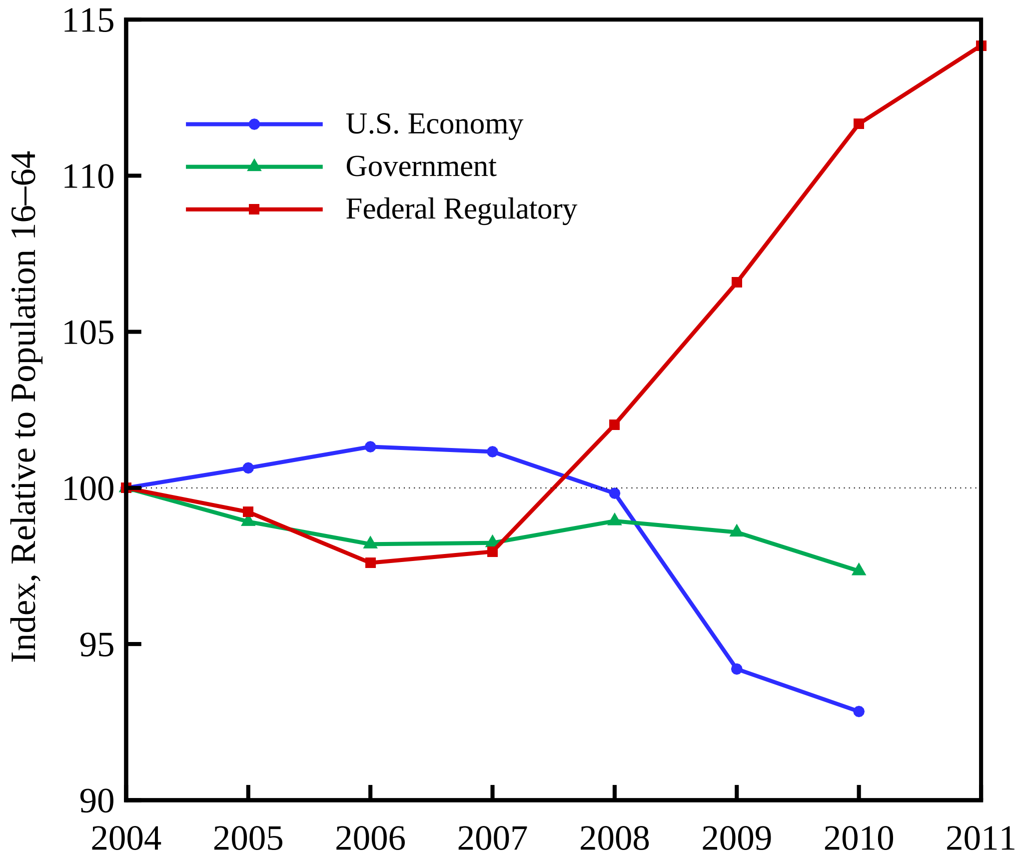

FIGURE 14

Full-Time Equivalent Employment Relative to Population

Ages 16–64, 2004–2011