Elasticities of Business Investment in the U.S. and their Policy Implications: A Disaggregate Approach to Modeling and Estimation.

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Abstract

Using data from the U. S. Bureau of Economic Analysis for the period 1947-2015, we estimate investment equations for three types of fixed assets and three policy instruments. In particular, we disaggregate investment into structures, equipment and intangibles, and the policy instruments into the rates of replacement, interest and taxes. Additionally, we estimate an equation for total investment. At the aggregate level the long run elasticities of investment with respect to output and the user cost are found to vary narrowly around 0.83; the direct elasticities of investment with respect to the rates of replacement, interest and taxation are 0.91, -0.04 and -0.23, whereas the indirect and inversely additive ones through the user cost are -0.11, -0.05 and -0.27, respectively. To highlight the significance of these findings, we investigate their implications for economic growth by focusing on four policy channels, i.e. aggregate demand, relative prices, and monetary and fiscal policies. We conclude that monetary policy may be weak to stimulate investment, and even fall into the trap of the law of unintended consequences by slowing replacement investment down, since the average age of capital is related negatively to the discount rate. On the contrary fiscal policy is relatively more potent as a 10% reduction in the expected effective tax rate is found to boost investment directly and indirectly by as much as 5%. In general, first best policies would aim at increasing the replacement rate, particularly of intangibles and equipment in the same order.

JEL Classification: E22, E52, E62

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1. Introduction

Over the last 50 years the bulk of research regarding the determinants and the time-structure of investment has drawn on the neoclassical theory of investment behavior, as laid down originally by Jorgenson (1963, 1967) and extended in various directions by Jorgenson, Stephenson (1967a, 1967b, 1967c), Hall, Jorgenson (1967, 1969) and others. Distilled from this literature and enhanced in the light of more recent refinements, this model of investment consists of the building blocks shown below:

$$K^* = \alpha \frac{Q^\rho}{c^\sigma} \quad \text{(a)}$$

$$c = \frac{q}{p}[(\frac{1-uv}{1-u})\delta + (\frac{1-uw}{1-u})r] \quad \text{(b)} \qquad (1)$$

$$I = \dot{K} + \delta K, \quad \text{(c)}$$

where the symbols are defined as follows: Q stands for the quantity of output; K^*, K are the quantities of optimal capital stock and that in place; I is the quantity of gross investment; c is the user cost of capital; δ, r, u represent the rates of depreciation, interest and taxes; q, p are the prices of investment goods and output; σ is the elasticity of substitution of capital for labor and coincides inversely with the elasticity of the user cost of capital; ρ is the elasticity of output and more technically the distribution parameter of the production function, which is assumed to be of the Constant-Elasticity-of-Substitution (CES) type; v, w are the proportions of current replacement and interest cost allowable for tax purposes; α is a shift parameter; a dot over a variable indicates its time derivative; and capital gains are ignored. However, the empirical results obtained thus far are of limited usefulness for policy analysis and implementation. The lengthy working paper by Kose et al. (2017), which was just released by the World Bank and refers to the deceleration of investment in emerging countries since 2010, provides a timely example. Its authors think of a relationship derived from (1) in which investment is determined in the long-run by a set of variables, including among others the interest rate, the tax rate, and the rate of replacement. But even though it is these variables that constitute the instruments of fiscal and monetary policies, most of what we know about their influence on investment is indirect, because in much of the relevant empirical literature they are presumed to influence investment through the user cost of capital. By implication, improving policy effectiveness in this important area warrants a reorientation of research efforts.

Underscoring this need are at least three reasons. The first is that the identification and estimation of a stable relation between investment and the user cost has defied all improvements in modeling, data resourcefulness and estimating techniques. To ascertain this assessment, consider the elasticity of substitution of capital for labor σ. In the log-run it holds that $\dot{K} = 0$ and $K^* = K$.[1] Substituting into 1(a) and the resulting expression into 1(c) yields:

$$I = \alpha \frac{Q^{\rho}}{c^{\sigma}} \delta, \ \alpha, \delta, \rho, \sigma > 0 . \tag{2}$$

Note that since c is in the denominator of this equation the additive inverse of σ coincides with the elasticity of investment with respect to the user cost.[2] From the survey by Chirinko (2008) not long ago, but also from more recent studies like the one by Dwenger (2014), it turns out that its estimates vary widely from above 1 to close to 0, with most of them falling in the range between 0.4 and 0.7. These are very imprecise to be suitable for policy purposes. The second reason is methodological and derives from the observation that the user cost formula 1(b) is an aggregating function which glosses over the complex interactions of the variables (δ, r, u) and the implications are not hard to see. To unscramble the effects of a change, for example, in the tax rate, u, Hall, Jorgenson (1967, 1969) ignored these interactions.[3] On the contrary, working with a large sample of firm data, Chirinko, Fazzari, Meyer (1999, 73) could not do the same, because they had to take account of the firm's capital structure. So they specified the user cost as a multiplicative function of the relative capital and output prices, the tax rate, and the sum of the interest and depreciation rates. Lastly, the third reason springs from the expectation that by focusing on its determinants rather than the user cost itself, the estimations may yield sharper results since, even if these three rates change in compensating ways within each observation period, keeping them apart would be expected to preserve their variability and thus render their estimated influence on investment more succinct.

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[1] We assume that in the long run the economy enters into a stationary state. In that state the capital stock is by definition stationary, and hence, gross investment equals retirements. By implication, all deviations from equation (2) reflect the short term adjustments that take place in the form of changes in net and replacement investment. As it will become apparent shortly, this conceptualization fits most appropriately with the error-correction approach that we adopt in the estimations.

[2] Even though at pertinent places below we shall issue reminders of this important detail, it should be kept in mind throughout because it will facilitate the understanding of the interpretation of our results.

[3] For example, in Hall, Jorgenson (1967, 404) they state the following:

> "The effects of a change in tax policy are: (1) an initial burst of net investment which brings the capital stock up to the new desired capital stock, (2) a permanent increase in gross investment resulting from replacement of a larger capital stock, and (3) a proportionate increase in net and gross investment caused by changes in other determinants of desired capital stock. To calculate the magnitudes of these effects for various alternative policies, we have assumed that tax policy has no effect on the before-tax rate of return or on the price of capital goods."(Emphasis added)

The objectives in this paper are fourfold. The first is to estimate the long-run investment equation (2) along with its short-term dynamics by disaggregating the user cost into its constituent determinants. The second objective is to take advantage of the data on investment that are published by the U.S Bureau of Economic Analysis (henceforth BEA) for the period 1947-1015. These data are disaggregated into structures, equipment, and intellectual property products (henceforth intangibles). Our expectation being that, by estimating the model separately for the three types of investment goods as well as for total investment, we may get some glimpse into the implications of the aggregation for the estimated parameters. The third objective is to compute the long-run elasticities of investment with respect to its key determinants so as to shed some light on sensitivity of the three types of investments, as well as of total investment, to changes in the policy instruments involved. Lastly, the fourth objective is to highlight the policy implications of our findings to the current debate about the causes of secular stagnation in the U.S. For, if our hunch that fiscal and monetary policies have influenced adversely the developments in the front of capital and investment is confirmed, reversing the trends may require serious overhauling of these policies.

Next section is devoted to the specification of the model. Section 3 focuses on the data, the definition and the measurement of the variables that enter into the model in the estimation stage. Section 4 discusses certain issues that have to do with the chosen estimating technique and provides the tables with the results. Section 4 presents and comments on the elasticities computed from the estimates of the model. Section 5 relates the findings from the empirical analysis to the issue of secular stagnation; and, finally, the paper closes in Section 6 with a summary of the main findings and conclusions.

2. Specification of the model

If business firms use Constant-Elasticity-of-substitution (CES) production functions and maximize their net worth in the presence of taxes and competitive product and input markets, in the long run the behavior of investment in the economy is described by (2). Ignoring capital gains, the user cost term in the latter equation is given by 1(b). To disaggregate the user cost term into its determinants in a tractable manner, we propose to set the latter equation as per (3) below:

$$c = \frac{q}{p}[(\frac{1-uv}{1-u})\delta + (\frac{1-uw}{1-u})r] \cong \frac{q}{p}\delta^{\alpha_1} r^{\alpha_2} u^{\alpha_3}, \quad \alpha_1 \neq 0, \ \alpha_2, \alpha_3 \geq 0. \tag{3}$$

In this specification we allow the exponent of δ to take any non-zero value on the conceptualization that for certain fixed assets the utilization and maintenance policies that business firms apply relate the rate of replacement inversely to the user cost.[4]

Substituting (3) into (2) and expressing the resulting equation in logarithms yields:

$$\begin{gathered} i = \beta_0 + \beta_1 o + \beta_2 \delta' + \beta_3 r' + \beta_4 u' + \beta_5 (q' - p'), \\ i = \ln I,\ o = \ln Q,\ \delta' = \ln \delta,\ r' = \ln r,\ u' = \ln u,\ q' = \ln q,\ p' = \ln p, \\ \beta_0 = \ln \alpha,\ \beta_1 = \rho,\ \beta_2 = 1 - \sigma\alpha_1,\ \beta_3 = -\sigma\alpha_2,\ \beta_4 = -\sigma\alpha_3,\ \beta_5 = -\sigma, \\ \beta_0 \geq 0,\ \beta_1 > 0,\ \beta_2 \neq 1,\ \beta_3, \beta_4 \geq 0,\ \beta_5 < 0. \end{gathered} \tag{4}$$

This is the equation which according to the neoclassical theory of investment purports to explain the investment behavior of the representative firm in the long-run. The elasticities in this time frame are certainly significant because they highlight the cumulative responses of investment to policy changes. But of not less significance are also the short-term elasticities which measure the distribution of the effects from the policy changes over time. These characterize the short-run dynamics of investment and their time-structure is based considerably on the particular econometric method adopted for the estimation of the model. To this issue we will return in due course.

3. Data, definitions and measurement of the variables

All variables relate to the business sector of the United States and the data for their compilation come from: the archives of the U.S Bureau of Economic Analysis (BEA); the database of the Federal Reserve Bank of St' Louis; the data base of the federal reserve board of Governors; and the database of the National Bureau of Economic Research. Which variable comes from which data source is reported in the notes section of Table A-1 in the Appendix. As depicted in this table, the time length of the series covers the period 1947-2015.

Colum 1 in Table 1 displays the symbols of the variables, the logarithms of which enter in the estimations of equation (4). Column 2 gives the numbers of columns of the series from

Table 1 about here

Table A-1 in the Appendix that were employed in the derivation of the corresponding varia-

[4] According to Bitros, Flytzanis (2009) this happens whenever the said policies are *upgrading* for the particular fixed assets under consideration.

bles, and column 3 reports the definitions of the variables. Observe that for the rates of replacement, interest and taxes there are more than one definition and measurement. As these are alternative policy instruments, in the estimations we shall experiment with them in search of the best policy instrumentation. Also, it should be noted that all non-price variables refer to the private nonresidential U.S economy.

Before turning to the estimation procedures and the results, a comment is in order regarding a general conceptual problem with the data in hand. No doubt they are the best available, since they have been compiled by a reliable source using state-of-the-art methods. But they are aggregate and as such they are subject to the limitations of the aggregation problem dis cussed, say, in Zarembka (1975) and Brown, Chang (1976). Bitros (2008b) attempted to highlight the difficulties involved and their implications and by so doing warn about the pitfalls associated with the use of aggregate data, particularly in the area of investment and capital. Hopefully, in this research, by focusing in addition to aggregate investment to its three major constituent components, we convey our awareness of the problem and the need for testing our inferences and policy prescriptions at all possible levels.

4. Issues of estimation and results

Equation (4) is like any other demand equation in economics. It relates the demand for investment to output and several price variables, including the key policy variables of the interest rate, the tax rate and the capital replacement rate. Thus, as is commonly the case, the main issue that arises is how to estimate the long-run (LR) and short-run (SR) elasticities, together with their standard errors in a way that will permit us to draw valid inferences regarding the possible effectiveness of fiscal and monetary policy policies that are effected by means of the corresponding instruments.

If we were to fit (4) in the log-level form in which it stands presently by Ordinary Least Squares (OLS), the estimates could be subject to the "spurious regression phenomenon" first described in Granger and Newbold (1974). This phenomenon refers to the possibility that the OLS parameter estimates do not converge to constants and hence the usual *t*- and *F*-ratio test statistics do not have even the limiting distributions. For, if used, they would generate spurious inferences. The problem arises fundamentally because the variables in levels are most commonly nonstationary and this explains why many researchers apply OLS in the first-difference form of the variables.

However, in more recent years the practice of taking the first differences in order to attain stationarity in the levels of the variables has come under severe criticism. The reason is that, if the levels of the nonstationary variables are cointegrated, as discussed in Engle and Granger (1987), then such regressions should not be estimated in first difference form, because regressions in the levels of cointegrated variables can be consistently estimated by OLS without being subject to the spurious regression phenomenon. In the light of the above considerations, before a decision was made as to the proper method of estimation, all variables were tested for stationarity. Table 2 displays the results from this test. The p-values of the Phillips-Perron

Table 2 about here

test in the lower part of this table indicate that all variables are stationary in the first differences. Therefore, potentially, in the absence of cointegration in the variables entering into equation (4), the estimation might be effected by applying OLS. Relevant to resolving these issues are the results in Table 3. As recommended by the Engle-Granger approach, we estimated all four equations by OLS, extracted from them the residuals, and finally we run on

Table 3 about here

the latter Phillips-Perron tests to determine the presence or not of cointegration. The first step in upper part of the table shows the estimates of the equations from which the tested residuals resulted, whereas the second step in the lower part displays the p-values of the statistics. From them we confirmed the presence of cointegration in all four equations and on this ground we determined that the proper way to estimate the four equations was to adopt the Error Correction Method (ECM).

The error-correction investment demand model consists of two parts. The first part is the long-run equilibrium investment demand function represented by (5) as rewritten and augmented below with the addition of the long-run random disturbance term e:

$$\begin{gathered} i = \beta_0 + \beta_1 o + \beta_2 \delta' + \beta_3 r' + \beta_4 u' + \beta_5 (q' - p') + e, \\ \beta_0 \geq 0,\ \beta_1 > 0,\ \beta_2 \neq 0,\ \beta_3, \beta_4 \geq 0,\ \beta_5 < 0. \end{gathered} \tag{5}$$

Equation (5) says that the demand for investment by firms, say structures, *stru*, depends on output as measured by the gross value added, *gva*, three policy variables represented by its own replacement rate, $\delta stru_h$, for $h = 1,2$, some instruments standing for the rates of interest and taxes, $r' = r_j$, for $j = 1,2,3,4$ and $u' = u_k$, for k=1,2, and the difference in the unit price of structures minus the unit price of output, *dstru-dgva*. The set of parameters $(\beta_1, \beta_2, \beta_3, \beta_4, \beta_5)$ give respectively the .long-run elasticities of the investment demand for structures with respect to output, the policy variables, and the relative prices.

Regarding next the second part of the model, this is a dynamic error-correction equation of the following form:

$$Di = \gamma_0 + \sum_{s=1}^{n1} \gamma_{1s} Di_{t-s} + \sum_{s=0}^{n2} \gamma_{2s} Do_{t-s} + \sum_{s=0}^{n3} \gamma_{3s} D\delta'_{t-s} + \\ + \sum_{s=0}^{n4} \gamma_{4s} Dr'_{t-s} + \sum_{s=0}^{n5} \gamma_{5s} Du'_{t-s} + \sum_{s=0}^{n6} \gamma_{6s} D(q'-p')_{t-s} + \lambda e_{t-1} + v_t. \qquad (6)$$

In this equation all variables are as defined above; v_t is the short-run random disturbance term; D stands for the difference operator; n_i, for $i = 1, 2, \ldots 6$, represents the number of lags in each of the six variables; and e_{t-1} is the lagged value of the long-run random disturbance. Equation (6) gives the short-run determinants of investment demand. We see that they include past changes in the dependent variable, current and past values of output, and so on. The parameter λ that multiplies the term e_{t-1} is the error correction coefficient. The meaning of this term is that investment in, say, structures, *stru*, because of unforeseen lags in the planning and construction stages does not match always the levels judged as optimal by firms on the basis of their long term factors specified in equation (1). By implication, in the short-run, the firms adjust the levels of their structures to correct any disequilibrium from their long-run desired levels. The parameter λ in equation (5) measures the impact of such disequilibria in explaining the short-run movements in the level of structures in place.

In the above discussion it is important to note that the precision with which the parameter λ is estimated depends crucially on the stationarity or not of the long run disturbance error term e_{t-1}; For, if these errors are serially correlated, the size of this parameter will be smaller the higher the coefficient of serial correlation. This explains why before adopting the ECM approach to estimation it is imperative to establish that the series of long-run errors is stationary. In our case the test statistics shown in the lower part of Table 3 provide enough assurance that the errors in all four equations are stationary, and that therefore the ECM is the proper method of estimation.

Solving equation (5) for the lagged error term e_{t-1} and substituting into equation (6) together with the notation from equation (4) we obtain equation (7) below:

$$Di_t = d_0 + \sum_{s=1}^{n1} \gamma_{1s} Di_{t-s} + \sum_{s=0}^{n2} \gamma_{2s} Do_{t-s} + \sum_{s=0}^{n3} \gamma_{3s} D\delta'_{t-s} + \sum_{s=0}^{n4} \gamma_{4s} Dr'_{t-s} + \sum_{s=0}^{n5} \gamma_{5s} Du'_{t-s} + \sum_{s=0}^{n6} \gamma_{6s} D(q'-p')_{t-s} + d_1 i_{t-1} + d_2 o_{t-1} + d_3 \delta'_{t-1} + d_4 r'_{t-1} + d_5 u'_{t-1} + d_6 (q'-p')_{t-1} + v_t. \tag{7}$$

$$d_0 = \gamma_0 - \lambda\beta_0,\ d_1 = \lambda,\ d_2 = -\lambda\beta_1,\ d_3 = -\lambda\beta_2,\ d_4 = -\lambda\beta_3,\ d_5 = -\lambda\beta_4,\ d_6 = -\lambda\beta_5.$$

This is the error-correction-model we estimate by OLS using the data for structures, equipment, intangibles, and total investment. In this model the parameter λ measures how deviations from the long term equilibrium relationship impact the short-run movements in the demand for investment.

Table 4 displays the results. On inspection it turns out that from an econometric point view they are closed to those that we might have expected. With a few exceptions, the variables in

Table 4 about here

the long- and in the short-run part of the model enter with statistically significant coefficients; the values of the alternative test statistics D-W and Breusch-Godfrey assure us that the size of the coefficients and their t-ratios are free from biases due to serial correlation in the data; the signs of the coefficients are consistent with our prior expectations from theory; and the explanatory power of the equations is very high. Moreover, a particularly important finding is the presence of policy instruments across equations and segments of the model. To capture the influence of fiscal policy, aside from having experimented with two tax rate instruments, we run the estimations with one and two time lags and leads in the corresponding series. Invariably leading the series performed better, thus implying that it is not so much the tax rate that influences investment, but its anticipations. Also, from among the two tax rate instruments, we found that the one measured without inventory valuation and capital consumption adjustment gave consistently better results. With regard to monetary policy, we tried four instruments. The one that performed admissibly was the Fed's discount rate for primary credits. But even so, certain qualifications are in order. First, notice that the coefficients of r_{2t} in the equations for structure and equipment lie at the borderline of statistical significance. This may render the effectiveness of monetary policy at that level quite uncertain. Second, across all equations the coefficients of the discount rate are less than one sixth the sizes of those pertaining to the tax rate u_{1t+1}. No doubt this difference will show up in the form of far smaller elasticities of investment with respect to the interest rate than the tax rate. Yet it is useful to have in mind where this disparity comes from. Thirdly, in view of these limitations, one might think that monetary policy may exercise its predominant effects indirectly through the user cost and in particular the parameter α_2. We shall see shortly that this is not the case, because the estimated elasticity of the user cost with respect to the interest rate is also much lower than that of the tax rate α_3.

The above assessments should not be interpreted to imply that we experienced no disappointments at the estimation stage. For one, notice the absence of monetary and fiscal policy instruments from the equation of intangibles. Despite the time and effort we devoted to the estimation of this equation, investment in intellectual property products appears to be driven by two forces: predominantly by output or gross-value-added, and secondarily by the replacement rate. In our view both findings can be rationalized by an appeal to the nature of these products and the high rate by which they become obsolete over time. But such a discussion would take us far afield. For this reason we shall turn now to the elasticities which are implied by the estimated investment equations.

Relevant to them are the results exhibited in Table 5. The figures in the first row give the elasticity of substitution of capital for labor, i.e. σ. The additive inverse of this coincides with

Table 5 about here

the elasticity of investment with respect to the user cost and as we pointed out in the introduction its precise value has escaped research efforts. Depending on the level of aggregation, we observe that it varies from a low of 0.46 for equipment to as high as 3.33 for intangibles, with its value for overall investment estimated at 0.84, i.e. about 15% above the upper bound of the range most frequently reported in the literature. Here then we have some possible explanation for its elusiveness. If the composition of investment changes over time, the value of this elasticity would be expected to shift upwards or downwards, depending on which of the included fixed assets loose or gain share in overall investment. In the U.S. business sector since the 1960s total investment has tilted against structures and in favor of intangibles, which we found to have almost five times the capital-labor substitution relative to structures. Hence, no wonder that Eisner, Nadiri (1968) found the value of σ to lie in the vicinity of 0.2 and researchers in more recent studies have reported it to be close to 0.7.

The second row of the table gives the elasticity of investment with respect to output. Again we observe considerable variation along the scale of disaggregation, with the lowest value of

ρ computed for structures and the highest for equipment, with that of total investment in between. From the data on the average ages of the three types of fixed assets under consideration we know that structures has the highest economic longevity, followed by equipment and lastly by intangibles. On the other hand, from the computed values of ρ it turns out that the output elasticity of structures is lowest, followed by intangibles and equipment, which have roughly the same output elasticity. So it is tempting to surmise that perhaps the output elasticities are inversely related to the longevity of investments. For, if this is actually the case, this evidence would go a long way in explaining the substantial shift in recent decades in the composition of business investment in the U.S away from structures and towards equipment, and particularly intangibles like computer software. Moreover, the finding that the standard errors of these elasticities are exceedingly small across all types of fixed investments should be reassuring about their robustness and stability.

Of singular interest are also the elasticities that relate to the rates of replacement, interest and taxes. Looking across the rows labeled by an initial δ, notice that all such elasticities are significant at high levels of confidence. But the innovation is not in these findings. We knew and expected them from earlier studies, like for example by Bitros, Kelejian (1974), which established that retirements relate affirmatively to gross investment. Rather the innovation lies in two other aspects. The first of them is that that the replacement rate enters into the investment equations directly and indirectly through the user cost. To highlight the implications, consider the equation of total investment and contemplate a one-time increase in the replacement rate by 10%. From the elasticity of δinv_{t-1} in the extreme right column in Table 5, we see that overall investment would increase by 9.08%. But the replacement rate enters also through the user cost and channels its influence via the parameter α_1. In the column for total investment we see that this parameter takes the value 0.111. Therefore, since the user cost is in the denominator of equation (2), the presumed change in the replacement rate would increase overall investment by 7.97%. As for the second aspect, this relates to the finding that the sum of the direct and indirect elasticities of the replacement rate varies with the type of producer's goods under consideration, being lowest for equipment and highest for intangibles. We do not wish to read too much into these differences. But if one were to suggest that they may spring from the differences in the uncertainty that accompanies the rates of technological progress embodied in the corresponding classes of producer's goods, we would be agreeable on the basis of the analytical results obtained, say, by Bitros (2008a).

Moving downwards in Table 5 we come across the row r_{2t-1}.The figures in this row are the elasticities of investment with respect to the Fed's discount rate. From the standard errors of the ones in the equations for structures and equipment it follows that they are weakly statistically significant. Even worse, as we already pointed out above, in the equation for intangibles this coefficient is missing altogether, which implies that it was not found to be different from zero. By implication, we can say nothing with certainty about the effectiveness of monetary policy at this level of disaggregation. But regarding total investment monetary policy may be effective, albeit timidly. For, if the discount rate is reduced by 10%, total investment would be expected to increase directly and indirectly through the user cost by only 0.95 %. On the contrary, fiscal policy enacted through changes in the business tax rate may be effective at all levels of aggregation and to a large extent. To ascertain this it suffices to look across the row labeled u_{1t+1}. We see that the elasticities are statistically significant with high levels of confidence and that their sizes are many times those pertaining to the interest rate. In this case, for example, a 10% reduction in the business tax rate would increase overall investment, again directly and indirectly through the user cost, by 4.96%. Hence, on account of policy certainty and effectiveness, the evidence favors fiscal over monetary initiatives.

In conclusion, the results are quite encouraging both on technical and substantive grounds. Econometrically they meet all standard criteria of acceptability and the elasticities to which they lead shed considerable light to outstanding issues in the investment literature. More specifically, the disaggregation into structures, equipment and intangibles has proved advantageous in resolving the long standing issue that surrounds the nature of the replacement rate; the disaggregation of the user cost to its constituent components has unlocked the potential to get a glimpse through its veil to the indirect influence they exert on investment; and the adopted method of estimation has enable on the one hand the identification and the estimation of all parameters involved, and on the other, the discrimination between the long term and short term effects of the main determinants of investment. On the substantive plane, the evidence has shown that the first best channel to increase investment are policies to raise the rate of replacement by business firms, whereas reducing the business tax rate is second best and reducing the discount rate is by far the third best choice. With these findings in hand, we are ready now to look into their implications.

5. Business investment and economic growth

Observe from Table 4 that the variable of gross value added is present everywhere with statistically significant and consistently-signed coefficients. It follows that the demand for output does matter to business firms and that this evidence strengthens the case of all those who argue that the deceleration of economic growth in recent decades is due partly to the deceleration of investment because of insufficient aggregate demand. But given that aggregate demand links to economic growth mainly through net investment, which commands a relatively small share in total investment, it would take considerable strengthening of the aggregate demand in the short run in order to achieve a moderate stimulus of overall business investment in the long run. Moreover, while considering policies for boosting economic growth through this channel, effectiveness may be enhanced by raising output demand through those of the three producer's goods whose demand is relatively more elastic, and also by striving to avoid adverse changes in the relative prices, because they are related negatively to investment in all three types of producer's goods.

Paying attention to changes in relative prices is advisable because of the evidence from Table 4 that they affect the composition of the capital stock, which in turn influences the productivity of capital and thereby economic growth. Relevant to this point is Figure 1 below which displays the changes in relative prices and quantities of producer's goods in the U.S. business sector since 1929. From Figure 1(a) it turns out that sine the 1960s structures became continuously more expensive relative to equipment and intangibles. According to Table 5 the

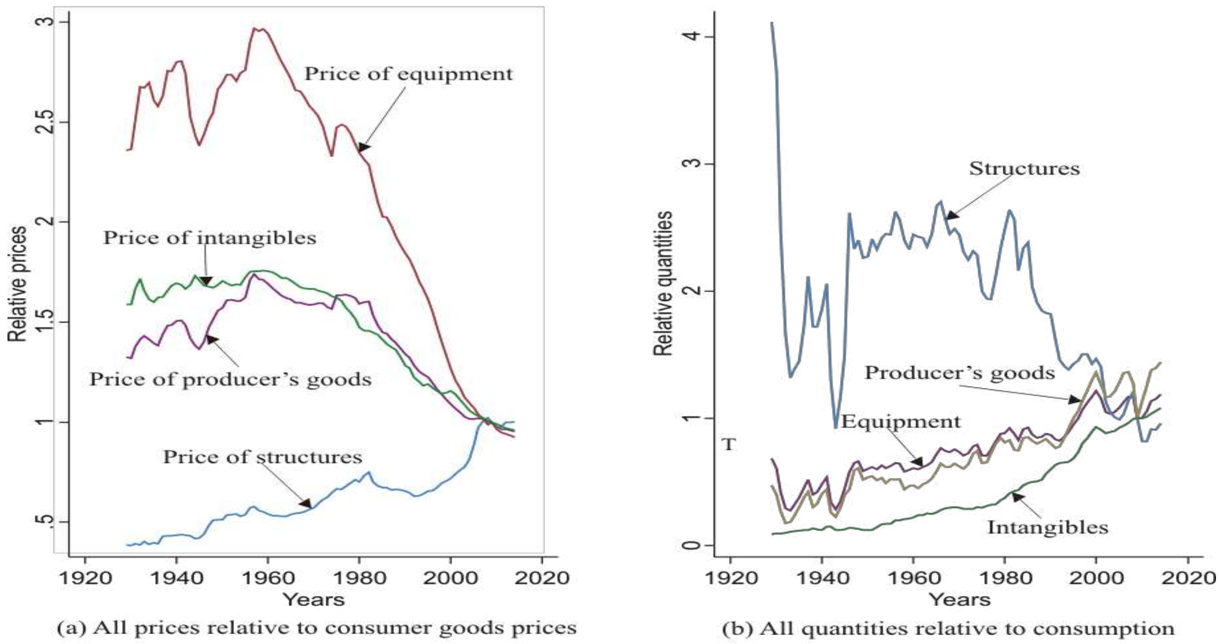

Figure 1: Relative prices and quantities of producer's goods in the US business sector since 1929

elasticities of investment with respect to the relative prices coincide with the additive inverse of the elasticities of substitution of capital for labor displayed in the first row. For example, for structures we see that given a 10% increase in their relative prices, investment in this fixed asset would decline by 6%, whereas an equiproportional decline in the relative prices of equipment, intangibles and overall fixed assets would increase investment by 4.6, 33.3, and 8.35 percent, respectively. Thus, as the quantity of structures declined and those of equipment and intangibles increased according to Figure 1(b), the composition of the capital stock tilted against the former and in favor of latter, particularly from the early 1980s when with the advent of globalization it became increasingly beneficial for business firms to outsource the construction of machinery and intangibles from third countries. We believe that these developments rendered the composition of capital stock increasingly unbalanced, thus leading to a deceleration of overall investment and a slowdown in the productivity of capital. That a serious break in this process took place in 1980 we suspect from the significance of the dummy variable in the equation for equipment in Table 4.

Turning next to fiscal policy, this channel is activated by initiatives in two fronts. Namely by changing the statutory business tax rate and/or by reforming the regime that pertains to depreciation allowances for tax purposes. Regarding the changes in the statutory tax rate, according to our results, the effects would be transmitted to investment directly through the presence of the effective tax rate in the investment equations and indirectly through the user cost. The estimated impact of such changes on total investment is sizable, since a 10% change in the expected effective tax rate would lead to a $\cong 5\%$ percent change in total investment in the opposite direction.[5] By contrast, reforming the provisions of depreciation allowances affects investment through the replacement rate, the impact of which is more powerful relatively to that of the tax rate, since a 10% change in the replacement rate would change total investment by $\cong 8\%$ in the same direction. To understand the implications of these findings, one does not need to look further than the debates that took place in the U.S. following the presentation by the Joint Committee on Taxation (2014) of their tax reform plan, which provided for repealing partially the Modified Accelerated Cost Recovery System (MACRS) in exchange for a 5-percentage point reduction in the statutory corporate tax rate. For, soon after the initial deliberations, and under the weight of the submitted scientific evidence, it became clear that the 5-percentage point reduction in the corporate tax rate was insufficient to counterbalance the negative effects on investment from abolishing even partially the provisions under the MACRS framework and the tax reform plan has remained ever since in limbo.

Thus, from this incident and our results it follows that the first best policy for fiscal authorities is to ease the conditions of depreciation allowances. By doing so, ceteris paribus, business firms

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[5] Notice that the variable u_t enters in the investment equations with a one period forward lag. By implication, its coefficients should reflect the expectations by business firms of how government actions at $t-1$ may influence the effective tax rate at t and $t+1$.

would be given an extra incentive to increase replacement investment and by modernizing the productive capacity of their plant and equipment raise productivity and hence economic growth. Compared to this policy, the reduction of the statutory tax rate is inferior because: (a) the linkage of the statutory to the effective tax rate is uncertain, and (b) the predicted stimulus of investment from the reduction of the effective tax rate is about 60% the size of that which would be expected from an equivalent change in the replacement rate. Lastly, the policy of trying to fine-tune the trade-off that exists between changes in the statutory business tax rate and changes in the provisions of depreciation allowances is third best because it posits a problem exceedingly difficult to solve as it mixes the technical issues of the recovery of capital under condition of technological uncertainty with the politics that surround all the time the public budget.

Now let us switch to monetary policy. Recall from the equation in the extreme right column of Table 4 that the federal discount rate enters with a negative and statistically significant coefficient. Also, recall from Table 5 that the elasticities of investment with respect to the discount rate are of the right sign but relatively low. Hence, we may surmise that, while monetary policy may have influenced the trends that dominated business investment in the post war period, the extent of this influence should be interpreted to imply that it has taken protracted and sizeable changes in the discount rate in order to bring about moderate changes in business investment in the opposite direction. Still, this finding leaves open the question of the possible channels through which monetary policy changes link to the process of economic growth, and this makes it imperative to look into the question of how they filter through replacement and net investment, which are the main avenues through which new technology enters into the economy and boosts productivity and economic growth. Figure 2 exhibits the five year mov-

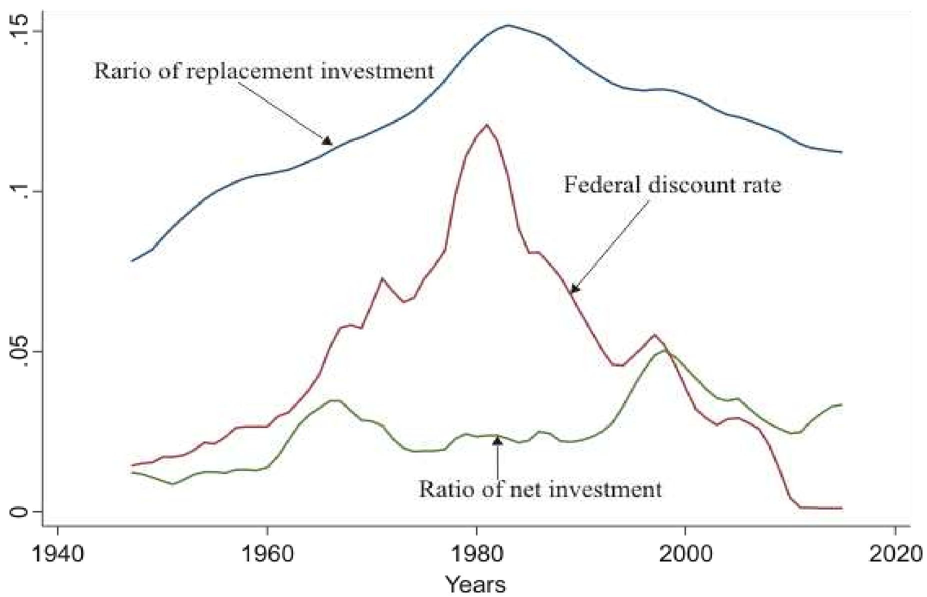

Figure 2: Five year moving average series of the federal discount rate and the ratios of net and replacement investment

ing average series of the federal discount rate and the ratios of replacement and net investment to the capital stock in the business sector of the U.S economy. The five year moving average series of the corporate bond yield has the same general shape as the curve of the discount rate, so it is reasonable to assume that expectations about the discount rate drive the changes in the corporate bond yield and the whole term structure of interest rates on which investment decisions are taken. Looking at this figure, one cannot fail to notice that in the period before the 1980 the federal discount rate rose almost in tandem with replacement investment, whereas since then the two series have been declining in a roughly similar fashion. From Table 6 it turns out that their correlation is 0.757, which is very high to be spurious. Consequently, the inverse relationship we found earlier between the discount rate and total investment should spring from an inverse relationship between the discount rate and net investment. But why does replacement investment move consistently and beyond any doubt in direct relation to the discount rate is not profound and it needs some explanation. We believe that, as monetary authorities raise (reduce) the cost of credit, the user cost of capital increases (decreases) and business firms accelerate (slow down) the replacement of their productive facilities just for rational user cost minimizing purposes. Doing so though reduces (increases) the average age of capital and its productivity increases (declines), because the capital stock incorporates at a faster (slower) rate the most recent technological advances. If this explanation is correct, we would expect the correlation of the productivity of capital curve to coincide roughly with the curve of the replacement investment in Figure 2, because total investment is dominated by the share of replacement investment.

Figure 3 displays the five year moving average series of certain key variables to get a glimpse into the possible effects of monetary policy on economic growth. Recall that Total

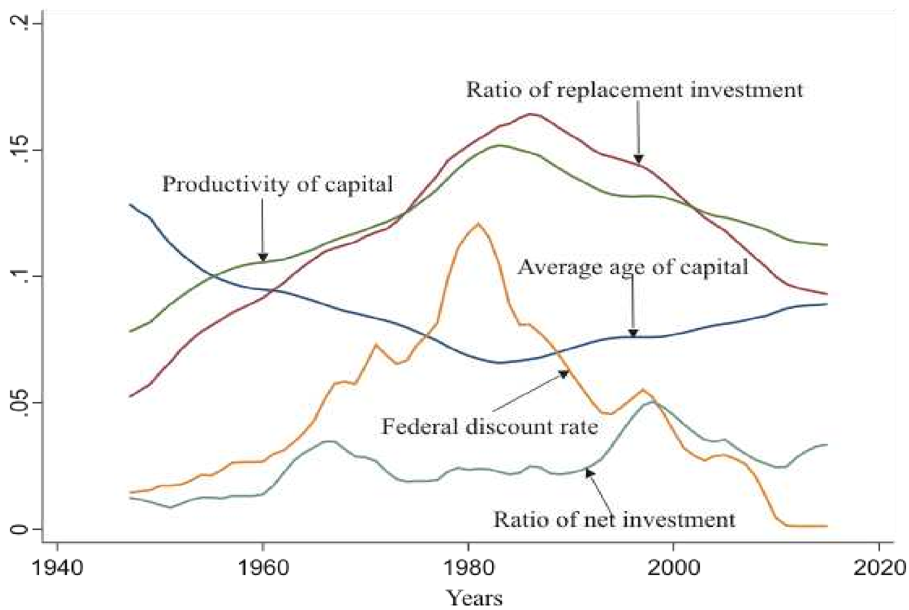

Figure 3: Productivity of capital and monetary policy

Factor Productivity (TFP) is defined as a weighted average of the ratio of output to labor input and the ratio of output to capital input. Here we focus on the latter driver of economic growth. In Figure 3 the ratio of output to capital input is represented by the green colored line and it has been derived by dividing the gross value added by capital years. Given that capital has two dimensions, i.e. quantity and useful life, we believe that by reckoning capital in terms of capital years, we obtain a more accurate index of capital input. Now looking at the curves labeled "productivity of capital' and 'ratio of replacement investment', we observe that they are correlated positively to such extent that their correlation from Table 6 stands at 0.9817. Hence, with a comfortable degree of confidence, we may conclude that the contribution of capital to economic growth is driven mainly by the rate of replacement investment. As replacement accelerates and

Table 6 about here

the average age of capital declines, new technological advances are adopted at a faster rate, and hence, the rising productivity of capital boosts economic growth. When the opposite trends take hold, as in the years since 1980, replacement investment decelerates the average useful life of capital increases, and the productivity of capital declines.

In Figure 3 we show also the curve of the five year moving average series of the federal discount rate. Comparing its shape to the other two curves we observe that all three curves are highly correlated. From Table 6 we see that their correlation is a little over 0.75. Consequently, even though monetary policy may exert some limited influence on economic growth by linking inversely the discount rate to net investment, the bulk of its influence is channeled by linking directly the discount rate to replacement investment, most likely in the particular manner that we explained above.

Provided that we are right and the discount rate links directly to economic growth through the replacement policies of business firms, monetary policies in advanced economies should be reviewed and revised in this light. For, it is quite possible that the reduction in the discount rate since the 1980s may have contributed negatively to economic growth by inducing business firms to slow down replacement, retarding the incorporation of new technological advances in the capital stock and driving productivity to long term decline. The main point we are making by putting forward this view is that net investment in advanced countries is only a small share of total investment and that the bulk of productivity enhancing technological change enters into the economy via the process of replacement. By suggesting this explanation for the investment related slowdown of productivity in recent decades, we are aware that we take a different path from that of world renowned researchers like Gordon (2015a, 2015b)) who stress the importance of net investment. We believe that by bringing into purview the possible effects of policies through the user cost of capital to replacement investment, we expand our understanding of the reasons for the persistent decline of productivity and the trend towards secular stagnation in advanced economies.

6. Summary of findings and conclusions

The focus in this research has been on the elasticities of investment in the U.S. business sector and their policy implications. Using the rich set of data that have been compiled by the U. S. Bureau of Economic Analysis for the period 1947-2015, we estimated investment equations for three types of fixed assets and three policy instruments. In particular, we disaggregated investment into structures, equipment and intellectual property products, and the policy instruments into the rate of replacement, the interest rate and the tax rate. Additionally, we estimated an equation for total investment.

All estimations were performed by means of the error-correction-estimating technique, which enables in one stroke the estimation of the long and the short-run elasticities, and we obtained results at both the aggregate and disaggregate levels that pass the standard statistical criteria with comfortable margins of confidence. In the long run we found that the policy instruments influence investment in structures, equipment and intangibles differently, both directly and indirectly through the user cost. On this ground we concluded that, if the policy instruments had been subsumed under the user cost, as done traditionally, their joint impact most likely would have been miscalculated. Furthermore, our results show that in all three types of fixed assets considered the overall effects on investment from changes in the rate of replacement are generally stronger than those from equiproportional changes in the tax rate and the discount rate.

In their vast majority the elasticities turned out to be statistically significant and generally of the right sign. At the level of total investment, we found the following elasticities:

- Elasticity of substitution of capital for labor, coinciding with the additive inverse of the elasticity of with respect to the user cost, as well as the relative prices: 0.835.
- Elasticity of output or gross-value added: 0.826.
- Direct elasticities with respect to the rates of replacement, interest and taxation: 0.908, -0.043, -0.226.
- Indirect elasticities with respect to the rates of replacement, interest and taxation: 0.111, 0.052, 0.270.

- Overall elasticities with respect to the rates of replacement, interest and taxation: 0.797, -0.095, -0.496.[6]

Drawing on the marked differences among the overall elasticities, we ranked policies aimed at the replacement rate as first best, the policies aimed at the tax rate as second best and the policies aimed at the interest rate as third best.

To highlight the significance of our results, we investigated their implications for economic growth by focusing on four policy channels, i.e. aggregate demand, relative prices, and fiscal and monetary policies. With reference to the first channel, we found some evidence in support of the claims that the deceleration of economic growth in recent decades may be due to lack of adequate aggregate demand. Having established that investment is directly and strongly related to gross value added, we suggested that policies aimed at boosting aggregate demand should target investment in those producer's goods that are more output elastic and in any case watch out for adverse developments in the front of relative prices. The reason being that we found relative prices to be negatively related to investment and to affect the composition of the capital stock, which is linked to the productivity of capital, and hence to economic growth. Finally, and to our view most importantly, looking through the veil of the user cost, we discovered that fiscal and monetary policies, as instrumented by the effective tax rate and the depreciation allowances, the former, and the discount rate, the latter, link to investment directly and indirectly. By reference to the size of the respective elasticities, fiscal policies channeled through the replacement rate are first best, whereas fiscal policies channeled through the statutory tax rate are second best. We have ranked monetary policies as third best on two grounds. First, because of the weak effects of the discount rate, and secondly because of the way it appears to link to net and replacement investment. The identification and estimation of the latter linkage highlights the possibility that monetary policy may be not only ineffective in stimulating investment, and hence economic growth, but even fall into the trap of the law of unintended consequences by slowing replacement investment down, since the useful life of capital is negatively related to the discount rate. Clearly, if this finding is confirmed by further studies, it will go a long way towards explaining why, contrary to expectations, replacement investment has not reversed its downward trend since 1980, despite the race of monetary policy to the zero bound of the discount rate.

[6] Given that the expression of the user cost is in the denominator of equation (2), these elasticities were obtained by adding the values of direct elasticities with the additive inverse values of the indirect elasticities.

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8. Tables

Table 1: Symbols and definitions of the variables

(1)	(2)	(3)	(1)	(2)	(3)
gva_t	1/6	Gross value added	$\delta stru_{2t}$	15	Replacement rate of investment[2]
$stru_t$	2/7	Investment in structures	δeq_{2t}	16	Replacement rate of investment[2]
eq_t	3/8	Investment in equipment	δint_{2t}	17	Replacement rate of investment[2]
int_t	4/9	Investment in intangibles	δinv_{2t}	18	Replacement rate of investment[2]
inv_t	5/10	Total investment	r_{1t}	19	Effective federal funds rate
$pgva_t$	6	Deflator of *gva*	r_{2t}	20	Discount rate
$dstru_t$	7	Deflator of *stru*	r_{3t}	21	10-year government bond yield
deq_t	8	Deflator of *eq*	r_{4t}	22	Moody's Baa corporate bond yield
$dint_t$	9	Deflator of *int*	u_{1t}	23	Rate of corporate taxes[3]
$dinv_t$	10	Deflator of *inv*	u_{2t}	24	Rate of corporate taxes[4]
$\delta stru_{1t}$	11	Replacement rate of structures[1]			
δeq_{1t}	12	Replacement rate of equipment[1]			
δint_{1t}	13	Replacement rate of intangibles[1]			
δinv_{1t}	14	Replacement rate of investment[1]			

Notes

1. The calculation of these replacement rates are based on the current-cost average ages of the corresponding types of investment.
2. The calculation of these replacement rates are based on the historical-cost average ages of the corresponding types of investment.
3. Without inventory valuation and capital consumption adjustment.
4. With inventory valuation and capital consumption adjustment.

Table 2: Phillips-Perron tests on the levels and first differences of the variables[1,2]

Levels					
Series	PP t-Statistic	P-Value	Series	PP t-Statistic	P-Value
gva_t	-1.760	0.4006	r_{1t}	-1.969	0.3002
$stru_t$	-2.366	0.1516	r_{2t}	-0.835	0.8085
eq_t	0.038	0.9616	r_{3t}	-1.013	0.7485
int_t	-1.540	0.5135	r_{4t}	-1.723	0.4195
inv	-0.804	0.8180	u_{1t}	-1.858	0.3522
$\delta stru_{1t}$	-2.361	0.1531	u_{2t}	-1.313	0.6230
δeq_{1t}	-2.735	0.0682	$dstru_t$-$dgva_t$	0.445	0.9831
δint_{1t}	-1.412	0.5766	deq_t-$dgva_t$	1.995	0.9987
δinv_{1t}	-3.331	0.0135	$dint_t$-$dgva_t$	1.578	0.9978
$\delta stru_{2t}$[2]	-3.503	0.0079	$dinv_t$-$dgva_t$	1.005	0.9943
δeq_{2t}	-1.734	0.4136			
δint_{2t}	-1.593	0.4873			
δinv_{2t}	-4.047	0.0012			
First differences					
$Dgva_t$	-7.609	0.0000	Dr_{1t}	-6.949	0.0000
$Dstru_t$	-5.875	0.0000	Dr_{2t}	-6.562	0.0000
Deq_t	-7.020	0.0000	Dr_{3t}	-7.755	0.0000
$Dint_t$	-6.495	0.0000	Dr_{4t}	-5.796	0.0000
$Dinv_t$	-6.264	0.0000	Du_{1t}	-7.496	0.0000
$D\delta stru_{1t}$[3]	-2.737	0.0678	Du_{2t}	-6.182	0.0000
$D\delta eq_{1t}$	-6.203	0.0000	$D(dstru_t$-$dgva_t)$	-4.632	0.0001
$D\delta int_{1t}$	-5.689	0.0000	$D(deq_t$- $dgva_t)$	--3.767	0.0033
$D\delta inv_{1t}$	-4.101	0.0010	$D(dint_t$-$dgva_t)$	-5.248	0.0000
$D\delta stru_{2t}$[3]	-2.583	0.0967	$D(dinv_t$-$dgva_t)$	-4.206	0.0006
$D\delta eq_{2t}$	-6.238	0.0000			
$D\delta int_{2t}$	-5.797	0.0000			
$D\delta inv_{2t}$	-3.921	0.0019			

Notes:

1. If instead of the Phillips-Perron test we had used the Augmented Dicky-Fuller test, the conclusions would not have changed.
2. In all cases the default lags computed endogenously by the test were 3.
3. Observe that in this case the differencing of the variable worsens the value of the PP t-statistic.
4. In these two cases, when the test was run with a trend, the values of the statistic were (-5.046, 0.0002) and (-3.185, 0.0874).

Table 3: Test results for cointegration[1]

Step A (OLS residuals from the four equations				
Variables	Dependent Variables			
	$stru_t$	*eq_t*	*int_t*	*inv_t*
Constant	-0.517 (-1.38)	-1.391 (-4.28)	-4.924 (-14.8)	-0.667 (-1.43)
gva_t	0.656 (9.08)	1.107 (28.4)	1.972 (29.5)	0.954 (14.5)
$\delta stru_{2t}$	0.304 (1.74)	….	….	….
δeq_{2t}	….	0.701 3.99)	….	….
δint_{2t}	….	….	1.154 (3.78)	….
δinv_{2t}	….	….	….	-0.337 (-2.21)
r_{2t}	….	0.034 (2.70)	….	0.038 (2.89)
r_{4t}	0.217 (3.18)	….	-0.280 (-3.56)	
u_{2t}	0.236 (2.39)	….	-0.199 (-1.85)	….
$(dstru_t\text{-}dgva_t)$	-0.153 (-1.13)	….	….	….
$(deq_t\text{-}dgva_t)$	….	-1.003 (-10.4)		….
$(dint_t\text{-}dgva_t)$	….	….	0.728 (2.02)	….
$(dinv_t\text{-}dgva_t)$	….	….	….	-1.134 (-4.07)
$Dummy_t$	-0.166 (-3.74)	….	0.077(1.46)	-0.140 (-5.38)
Adjusted R^2	0.971	0.996	0.997	0.996
Root MSE	0.0710	0.0651	0.0787	0.0475
Step B (Unit root tests on residuals)				
Phillips-Perron t-statistic	*$stru_t$*	*eq_t*	*int_t*	*inv_t*
z(t)	-4.547	-3.971	-3.461	-4.042
p-value	0.0002	0.0016	0.0090	0.0012

Notes:
1. If instead of the Phillips-Perron test we had used the Augmented Dicky-Fuller test, the conclusions would not have changed.

<u>Table 4</u>: OLS estimates of equation (7)

Variables	Dependent Variables[1]			
	$Dstru_t$	Deq_t	$Dint_t$	$Dinv_t$
Constant	….	-0.967 (-4.64)	….	….
$stru_{t-1}$	-0.452 (-5.05)	….	….	….
eq_{t-1}	….	-0.415 ((-4.34)	…	….
int_{t-1}	….	….	-0.052 (-2.09)	….
inv_{t-1}	….	….		-0.368 (-5.01)
gva_{t-1}	0.286 (4.94)	0.584 (4.90)	0.068 (2.37)	0.305 (5.14)
$\delta stru_{2t-1}$	0.533 (6.14)	….		….
δeq_{2t-1}	….	0.358 (2.65)		….
δint_{2t-1}	….	…	0.114 (1.82)	….
δinv_{2t-1}	….	…	…	0.334 (6.07)
r_{2t-1}	-0.019 (-1.82)	-0.011 (-1.65)	…	-0.016 (-3.04)
u_{1t+1}	-0.118 (-2.41)	-0.084 (-2.49)	…	-0.083 (-2.30)
$(dstru\text{-}dgva)_{t-1}$	-0.273 (-3.39)	….	…	….
$(deq\text{-}dgva)_{t-1}$	….	-0.191 (-2.03)	…	….
$(dint\text{-}dgva)_{t-1}$	….	….	-0.137 (-1.30)	….
$(dinv\text{-}dgva)_{t-1}$	….	….	….	-0.308 (-3.23)
$Dstru_{t-1}$	0.179 (1.84)	….		….
Deq_{t-1}	….	0.206 (4.20)		….
$Dinv_{t-1}$	….	….	….	0.364 (5.11)
$Dgva_t$	1.176 (5.30)	2.086 (14.2)	0.655 (4.23)	1,285 (8.92)
$D\delta stru_{2t}$	3.127 (5.77)	….	….	….
$D\delta eq_{2t-1}$	….	0.619 (2.41)		….
$D\delta int_{1t}$	….	….	1.298 (5.35)	….
$D\delta inv_{2t}$	….	….	….	1.456 (5.12)
Dr_{2t}	…	0.059 (6.25)		
Dr_{2t-1}	0.056 (3.40)	….	….	….
Du_{1t-1}	….	0.112 (2.38)	….	….
Dummy	….	-0037 (-2.06)		
R^2	0.783	0.923	0.823	0.858
R^2-adjusted	0.744	0.907	0.806	0.835
D-W	2.093	1.779	1.941	2.020
Breusch-Godfrey	0.404	0.309	0.929	0.873
Root MSE	0.039	0.026	0.035	0.028

<u>Notes</u> :
1. The numbers within the parentheses give the values of the t-statistic.

Table 5 : Elasticities implied by the long-run estimates of the model

	Investment[1]			
	$stru_{t\text{-}1}$	$eq_{t\text{-}1}$	$int_{t\text{-}1}$	$inv_{t\text{-}1}$
$\sigma^{2,3}$	0.603 0.603 (0.177)	0.461 0.461 (0.144)	2.621 3.327 (1.044)	0.835 0.835 (0.157)
ρ	0.634 0.634 (0.070)	1.409 1.409 (0.071)	1.300 1.129 (0.179)	0.827 0.827 (0.046)
$\delta stru_{2t\text{-}1}$	1.181 1.181 (0.123)	….	….	….
$\delta eq_{2t\text{-}1}$	….	0.863 0.863 (0.071)	….	….
$\delta int_{2t\text{-}1}$	….	….	2.193 1.964 (0.388)	….
$\delta inv_{2t\text{-}1}$	….	….	….	0.908 0.908 (0.064)
$r_{2t\text{-}1}$	-0.043 -0.043 (0.028)	-0.026 -0.026 (0.018)	….	-0.043 -0.043 (0.017)
u_{1t+1}	-0.261 -0.261 (0.113)	-0.204 -0.204 (0.095)	….	-0.226 -0.226 (0.093)
	User cost			
$\alpha_1 \Leftrightarrow \delta_{2t-1}$	-0.300	0.297	-0.455	0.111
$\alpha_2 \Leftrightarrow r_{2t-1}$	0.071	0.056	….	0.052
$\alpha_3 \Leftrightarrow u_{1t-1}$	0.433	0.442	….	0.270

Notes:

1. The numbers within the parenthesis are standard errors. These were computed by estimating the equations in Table 4 nonlinearly so as to factor out the parameter λ in equation (7).
2. The estimates of the elasticities at the top of the rows were computed from the OLS estimates shown in Table (4). Observe that in the equations for structures, equipment and total investment the linear and nonlinear estimates of the elasticities coincide, whereas in the equation for intangibles they differ considerably.
3. Recall that the parameter σ is in the denominator of equation (2) and that therefore an increase in the user cost leads to a decline in investment.

Table 6: Correlation coefficients

	Variables[1]				
	sminv	smnetinv	smrepinv	smprod	smdisrate
sminv[2]	1.0000				
smnetinv[2]	0.7383	1.0000			
smrepinv[2]	0.9298	0.4381	1.0000		
smprod[3]	0.9251	0.4604	0.9817	1.0000	
smdisrate[2]	0.5938	0.0622	0.7574	0.7698	1.0000

Notes:

1. The symbol sm in front of the variables denotes their five year moving average.
2. These series are ratios to the capital stock and they are defined as follows: inv=total investment, netinv=net investment, repinv=replacement investment, prod=productivity, disrate=federal discount rate.
3. This series is gross value added divided by capital years.

Appendix A

Table A-1: Raw data used in the estimations

Years	Initial variables[1,2]													
	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1947	1.300	0.081	0.015	0.002	0.026	0.158	0.064	0.331	0.224	0.197	29.2	7.6	5.3	20.1
1948	1.366	0.095	0.017	0.002	0.029	0.168	0.072	0.355	0.235	0.213	28.7	7.1	5.4	19.5
1949	1.349	0.092	0.016	0.002	0.027	0.167	0.071	0.369	0.236	0.218	28.5	7.0	5.5	19.3
1950	1.486	0.100	0.018	0.002	0.030	0.168	0.072	0.378	0.241	0.222	27.9	6.9	5.6	19
1951	1.586	0.120	0.020	0.002	0.034	0.180	0.081	0.410	0.256	0.243	27.4	6.8	5.6	18.7
1952	1.628	0.122	0.020	0.003	0.035	0.183	0.083	0.418	0.259	0.248	27.1	6.8	5.6	18.6
1953	1.709	0.136	0.022	0.004	0.039	0.185	0.084	0.419	0.264	0.251	26.9	6.8	5.4	18.3
1954	1.686	0.139	0.021	0.004	0.039	0.186	0.083	0.429	0.266	0.253	26.6	6.8	5.4	18.2
1955	1.830	0.152	0.024	0.004	0.043	0.188	0.085	0.434	0.272	0.257	26.1	6.9	5.3	18
1956	1.862	0.182	0.026	0.005	0.050	0.194	0.092	0.466	0.283	0.276	25.7	6.9	5.1	17.7
1957	1.890	0.190	0.029	0.006	0.053	0.201	0.096	0.492	0.292	0.289	25.5	6.9	5.1	17.4
1958	1.856	0.176	0.025	0.006	0.049	0.204	0.095	0.502	0.299	0.291	25.4	7.1	5.0	17.3
1959	2.005	0.181	0.028	0.007	0.053	0.206	0.095	0.511	0.304	0.295	25.1	7.2	5.0	17.1
1960	2.043	0.196	0.030	0.007	0.056	0.209	0.095	0.515	0.308	0.297	25.0	7.2	5.0	16.9
1961	2.086	0.197	0.029	0.008	0.057	0.210	0.095	0.512	0.310	0.296	25.0	7.3	5.0	16.9
1962	2.221	0.208	0.032	0.008	0.061	0.212	0.095	0.510	0.312	0.296	24.9	7.3	5.0	16.7
1963	2.323	0.212	0.034	0.009	0.065	0.214	0.096	0.507	0.312	0.296	24.5	7.3	5.0	16.5
1964	2.468	0.237	0.039	0.010	0.072	0.216	0.097	0.507	0.317	0.298	24.2	7.2	5.0	16.3
1965	2.645	0.283	0.046	0.011	0.085	0.219	0.100	0.508	0.319	0.302	23.9	7.0	5.0	15.9
1966	2.826	0.313	0.053	0.013	0.097	0.225	0.104	0.509	0.324	0.306	23.8	6.7	4.9	15.4
1967	2.884	0.315	0.054	0.014	0.099	0.231	0.107	0.521	0.329	0.314	23.7	6.6	4.8	15.1
1968	3.030	0.336	0.059	0.016	0.108	0.240	0.113	0.535	0.340	0.325	23.5	6.5	4.8	14.9
1969	3.122	0.377	0.065	0.017	0.120	0.251	0.120	0.550	0.355	0.339	23.3	6.5	4.8	14.7
1970	3.122	0.403	0.066	0.018	0.125	0.262	0.128	0.571	0.372	0.355	23.1	6.5	4.8	14.6
1971	3.239	0.427	0.069	0.019	0.130	0.273	0.138	0.589	0.386	0.371	23.0	6.6	4.9	14.7
1972	3.450	0.472	0.079	0.021	0.147	0.282	0.148	0.597	0.397	0.384	22.8	6.6	4.9	14.6
1973	3.689	0.550	0.095	0.023	0.173	0.297	0.159	0.607	0.417	0.400	22.6	6.5	4.9	14.6
1974	3.634	0.612	0.104	0.026	0.191	0.326	0.181	0.652	0.456	0.438	22.6	6.5	4.9	14.7
1975	3.597	0.614	0.108	0.028	0.197	0.357	0.202	0.752	0.493	0.496	22.8	6.7	4.9	14.6
1976	3.839	0.659	0.121	0.032	0.219	0.376	0.212	0.798	0.514	0.523	22.9	6.7	4.9	14.7
1977	4.058	0.746	0.149	0.036	0.259	0.399	0.231	0.847	0.537	0.558	22.8	6.8	4.8	14.5
1978	4.316	0.936	0.181	0.040	0.315	0.426	0.253	0.894	0.565	0.595	22.6	6.7	4.8	14.4
1979	4.465	1.177	0.208	0.048	0.374	0.462	0.283	0.952	0.602	0.643	22.6	6.6	4.7	14.2
1980	4.422	1.362	0.216	0.054	0.407	0.504	0.309	1.036	0.649	0.700	22.6	6.7	4.6	14.1
1981	4.550	1.673	0.241	0.065	0.473	0.550	0.351	1.111	0.697	0.767	22.4	6.7	4.5	13.9
1982	4.419	1.776	0.235	0.073	0.485	0.582	0.379	1.157	0.737	0.810	22.7	6.8	4.4	13.9
1983	4.662	1.543	0.247	0.081	0.482	0.601	0.369	1.161	0.765	0.809	22.8	7.0	4.4	14.1
1984	5.071	1.774	0.292	0.095	0.564	0.619	0.373	1.151	0.786	0.812	22.8	7.0	4.3	14.1
1985	5.306	1.945	0.308	0.105	0.608	0.636	0.381	1.151	0.799	0.820	22.7	7.0	4.2	13.9
1986	5.499	1.765	0.318	0.114	0.608	0.645	0.389	1.174	0.805	0.834	22.7	7.1	4.2	13.8
1987	5.701	1.742	0.321	0.120	0.615	0.657	0.395	1.182	0.820	0.844	22.7	7.1	4.2	13.9
1988	5.945	1.828	0.347	0.133	0.662	0.678	0.412	1.198	0.845	0.865	22.7	7.2	4.2	13.9
1989	6.174	1.937	0.372	0.150	0.716	0.702	0.428	1.221	0.856	0.885	22.8	7.3	4.2	14
1990	6.273	2.029	0.372	0.164	0.739	0.726	0.442	1.246	0.865	0.904	22.8	7.3	4.2	13.9
1991	6.238	1.836	0.361	0.179	0.724	0.746	0.450	1.267	0.885	0.921	23.1	7.5	4.2	14
1992	6.501	1.726	0.382	0.188	0.742	0.758	0.450	1.265	0.875	0.918	23.4	7.5	4.2	14.2
1993	6.687	1.772	0.425	0.197	0.799	0.776	0.463	1.250	0.881	0.920	23.6	7.5	4.2	14.4
1994	7.013	1.868	0.476	0.206	0.869	0.789	0.479	1.248	0.884	0.927	23.8	7.4	4.3	14.5
1995	7.230	2.073	0.528	0.227	0.962	0.803	0.500	1.235	0.909	0.936	23.9	7.4	4.3	14.5
1996	7.568	2.246	0.565	0.253	1.043	0.816	0.513	1.207	0.912	0.930	23.9	7.3	4.3	14.5
1997	7.970	2.503	0.611	0.288	1.149	0.828	0.532	1.173	0.917	0.925	23.9	7.1	4.2	14.4
1998	8.378	2.751	0.660	0.318	1.253	0.832	0.557	1.121	0.913	0.910	23.9	7.0	4.1	14.4
1999	8.856	2.839	0.714	0.364	1.362	0.837	0.574	1.077	0.931	0.902	23.9	6.8	4.0	14.2

2000	9.253	3.181	0.766	0.410	1.494	0.853	0.596	1.054	0.961	0.907	23.8	6.7	4.0	14.1
2001	9.313	3.297	0.712	0.413	1.454	0.868	0.628	1.023	0.964	0.904	23.9	6.7	4.0	14.2
2002	9.480	2.829	0.660	0.406	1.349	0.874	0.654	1.003	0.954	0.900	23.9	6.8	4.1	14.4
2003	9.783	2.818	0.669	0.421	1.372	0.886	0.678	0.985	0.952	0.899	24.0	6.9	4.1	14.6
2004	10.225	3.018	0.719	0.442	1.463	0.907	0.729	0.984	0.951	0.911	23.9	7.0	4.2	14.9
2005	10.612	3.456	0.791	0.475	1.612	0.935	0.821	0.986	0.960	0.938	23.9	7.0	4.2	15.1
2006	10.948	4.156	0.856	0.505	1.776	0.960	0.921	0.983	0.975	0.966	23.9	7.0	4.2	15.2
2007	11.177	4.969	0.886	0.538	1.921	0.983	0.976	0.986	0.992	0.986	23.9	6.9	4.2	15.2
2008	11.051	5.524	0.825	0.563	1.941	0.997	1.023	0.987	1.008	1.003	24.1	7.1	4.2	15.3
2009	10.598	4.382	0.644	0.551	1.633	1.000	1.000	1.000	1.000	1.000	24.6	7.3	4.3	15.5
2010	10.933	3.620	0.732	0.564	1.658	1.012	0.988	0.980	1.005	0.991	25.1	7.5	4.4	15.7
2011	11.164	3.816	0.838	0.592	1.812	1.033	1.019	0.989	1.019	1.005	25.5	7.5	4.4	15.9
2012	11.487	4.480	0.938	0.622	2.008	1.053	1.059	0.999	1.030	1.022	25.9	7.4	4.4	16
2013	11.744	4.636	0.983	0.648	2.094	1.069	1.081	1.001	1.038	1.030	26.3	7.3	4.5	16
2014	12.091	5.307	1.041	0.680	2.251	1.086	1.122	1.005	1.048	1.044	26.7	7.3	4.5	16.1
2015	12.465	5.073	1.086	0.718	2.311	1.093	1.122	1.013	1.056	1.051	27.0	7.2	4.5	16.1

Notes

1. Unless specifically noted, all data in this table have been extracted from the National Income and Product Accounts (NIPA) published by the U.S. Bureau of Economic Analysis (BEA).
2. Explanation of definitions and particular sources of variables by number of column:

1. Gross value added in trillions of current dollars, Table 1.3.5, line 2.
2. Gross investment in private nonresidential structures in billions of current dollars, Table 5.3.5, line3.
3. Gross investment in private nonresidential equipment in billions of current dollars, Table 5.3.5, line 9.
4. Gross investment in private intellectual property products in billions of current dollars, Table 5.3.5, line 16.
5. Gross private nonresidential investment in billions of current dollars, Table 5.3.5, line 2.
6. Price index for gross value added in the business sector, 2009=1, Table 1.3.4, line 2.
7. Price index for nonresidential private fixed structures, 2009=1, Table 5.3.4, line 3.
8. Price index for nonresidential private equipment, 2009=1, Table 5.3.4, line 9.
9. Price index for private intellectual property products, 2009=1, Table 5.3.4, line 16.
10. Price index for nonresidential private investment, 2009=1, Table 5.3.4, line 2.
11. Current-cost average age of private nonresidential structures, Table 2.9, line 36.
12. Current-cost average age of private nonresidential equipment, Table 2.9, line 3.
13. Current-cost average age of private nonresidential intellectual property products, Table 2.9, line 77.
14. Current-cost average age of private nonresidential investment, Table 4.9, line 1.

Table A-1: Continued from above

Years	Variables[1,2]									
	15	16	17	18	19	20	21	22	23	24
1947	19.7	6.1	4.6	14.0	0.010	0.010	0.022	0.032	0.467	0.346
1948	18.7	5.5	4.6	13.0	0.015	0.012	0.024	0.035	0.395	0.340
1949	18.1	5.3	4.7	12.5	0.015	0.011	0.023	0.034	0.351	0.339
1950	17.4	5.2	4.7	11.9	0.018	0.013	0.023	0.032	0.497	0.409
1951	16.6	5.1	4.8	11.4	0.018	0.017	0.026	0.034	0.549	0.498
1952	16.0	5.1	4.7	11.0	0.018	0.018	0.027	0.035	0.489	0.470
1953	15.4	5.1	4.5	10.6	0.020	0.019	0.029	0.037	0.504	0.470
1954	15.0	5.2	4.4	10.4	0.015	0.013	0.025	0.035	0.447	0.431
1955	14.5	5.2	4.4	10.2	0.018	0.024	0.028	0.035	0.439	0.428
1956	14.0	5.2	4.3	9.9	0.027	0.034	0.032	0.039	0.443	0.418
1957	13.5	5.2	4.2	9.6	0.031	0.034	0.037	0.047	0.436	0.418
1958	13.3	5.3	4.2	9.6	0.016	0.028	0.033	0.047	0.433	0.421
1959	13.1	5.4	4.2	9.5	0.033	0.045	0.043	0.051	0.426	0.421
1960	13.0	5.5	4.2	9.5	0.032	0.029	0.041	0.052	0.416	0.421
1961	12.9	5.6	4.2	9.5	0.020	0.029	0.039	0.051	0.408	0.423
1962	12.8	5.7	4.2	9.4	0.027	0.030	0.040	0.050	0.375	0.405
1963	12.7	5.7	4.2	9.4	0.032	0.036	0.040	0.049	0.372	0.407
1964	12.6	5.7	4.2	9.3	0.035	0.040	0.042	0.048	0.361	0.392
1965	12.4	5.5	4.2	9.1	0.041	0.046	0.043	0.049	0.347	0.372
1966	12.2	5.4	4.1	8.9	0.051	0.045	0.049	0.057	0.351	0.373
1967	12.1	5.3	4.0	8.8	0.042	0.045	0.051	0.062	0.349	0.373
1968	12.0	5.3	4.0	8.7	0.057	0.054	0.057	0.069	0.388	0.402
1969	11.9	5.2	3.9	8.5	0.082	0.060	0.067	0.078	0.404	0.411
1970	11.7	5.3	4.0	8.5	0.072	0.055	0.074	0.091	0.400	0.399
1971	11.6	5.3	4.0	8.4	0.047	0.045	0.062	0.086	0.376	0.380
1972	11.5	5.3	4.0	8.4	0.044	0.045	0.062	0.082	0.359	0.362
1973	11.3	5.2	4.0	8.2	0.087	0.075	0.068	0.082	0.372	0.337
1974	11.1	5.1	4.0	8.0	0.105	0.078	0.076	0.095	0.415	0.321
1975	11.0	5.1	3.9	7.9	0.058	0.060	0.080	0.106	0.368	0.329
1976	10.9	5.0	3.8	7.8	0.051	0.053	0.076	0.098	0.370	0.327
1977	10.8	4.9	3.8	7.6	0.055	0.060	0.074	0.090	0.357	0.319
1978	10.5	4.7	3.7	7.4	0.079	0.095	0.084	0.095	0.352	0.309
1979	10.1	4.5	3.6	7.1	0.112	0.120	0.094	0.107	0.356	0.292
1980	9.7	4.5	3.5	6.9	0.134	0.130	0.115	0.137	0.383	0.300
1981	9.2	4.5	3.4	6.6	0.164	0.120	0.139	0.160	0.332	0.293
1982	8.9	4.6	3.3	6.6	0.123	0.085	0.130	0.161	0.279	0.272
1983	8.9	4.7	3.3	6.6	0.091	0.085	0.111	0.136	0.279	0.293
1984	8.9	4.7	3.2	6.6	0.102	0.080	0.124	0.142	0.281	0.315
1985	8.8	4.8	3.2	6.5	0.081	0.075	0.106	0.127	0.274	0.333
1986	8.9	4.9	3.2	6.6	0.068	0.055	0.077	0.104	0.332	0.400
1987	9.0	5.0	3.3	6.8	0.067	0.060	0.084	0.106	0.351	0.384
1988	9.2	5.0	3.3	6.9	0.076	0.065	0.089	0.108	0.334	0.353
1989	9.3	5.1	3.3	6.9	0.092	0.070	0.085	0.102	0.345	0.363
1990	9.4	5.2	3.4	7.0	0.081	0.065	0.086	0.104	0.341	0.348
1991	9.7	5.3	3.4	7.2	0.057	0.035	0.079	0.098	0.299	0.311
1992	10.0	5.4	3.4	7.4	0.035	0.030	0.070	0.090	0.305	0.309
1993	10.3	5.4	3.5	7.5	0.030	0.030	0.059	0.079	0.320	0.327
1994	10.6	5.4	3.6	7.6	0.042	0.048	0.071	0.086	0.303	0.310
1995	10.8	5.3	3.6	7.6	0.058	0.053	0.066	0.082	0.303	0.308
1996	10.9	5.3	3.6	7.6	0.053	0.050	0.064	0.081	0.287	0.303
1997	11.0	5.3	3.6	7.6	0.055	0.050	0.064	0.079	0.277	0.298

1998	11.1	5.2	3.5	7.6	0.054	0.045	0.053	0.072	0.301	0.329	
1999	11.1	5.2	3.5	7.6	0.050	0.050	0.056	0.079	0.303	0.325	
2000	11.2	5.2	3.4	7.5	0.062	0.060	0.060	0.084	0.330	0.341	
2001	11.2	5.3	3.5	7.6	0.039	0.013	0.050	0.080	0.260	0.280	
2002	11.4	5.4	3.6	7.8	0.017	0.008	0.046	0.078	0.202	0.230	
2003	11.6	5.6	3.7	8.0	0.011	0.020	0.040	0.068	0.222	0.239	
2004	11.8	5.7	3.7	8.1	0.014	0.023	0.043	0.064	0.230	0.233	
2005	11.9	5.7	3.8	8.2	0.032	0.042	0.043	0.061	0.271	0.239	
2006	11.9	5.7	3.8	8.2	0.050	0.060	0.048	0.065	0.279	0.245	
2007	11.7	5.7	3.8	8.1	0.050	0.059	0.046	0.065	0.280	0.241	
2008	11.6	5.8	3.8	8.1	0.019	0.024	0.037	0.075	0.224	0.203	
2009	11.7	6.1	3.9	8.4	0.002	0.005	0.033	0.073	0.179	0.167	
2010	12.0	6.2	4.0	8.6	0.002	0.007	0.032	0.060	0.201	0.188	
2011	12.3	6.3	4.0	8.7	0.001	0.008	0.028	0.057	0.196	0.193	
2012	12.5	6.2	4.0	8.8	0.001	0.008	0.018	0.049	0.211	0.195	
2013	12.6	6.2	4.1	8.9	0.001	0.008	0.024	0.051	0.217	0.201	
2014	12.7	6.1	4.1	8.9	0.001	0.008	0.025	0.049	0.234	0.219	
2015	12.8	6.1	4.1	8.9	0.001	0.008	0.021	0.050	0.251	0.241	

15. Historical-cost average age of private nonresidential structures, Table 2.10, line 36.
16. Historical-cost average age of private nonresidential equipment, Table 2.10, line 3.
17. Historical-cost average age of private nonresidential intellectual property products, Table 2.10, line 77.
18. Historical-cost average age of private nonresidential investment, Table 4.10, line 1.
19. Effective Federal Funds Rate, not seasonally adjusted, observation period first of the year, Federal Reserve Bank of St. Louis, Series FEDFUNDS, 1955-2015. Data earlier than 1955 are 12-month averages from the Series m13009 of U.S. Discount Rates, Federal Reserve Bank of New York 11/1914-07/1969, NBER Macrohistory: XIII. Interest Rates.
20. Discount Rate for United States, not seasonally adjusted, observation period first of the year. Federal Reserve Bank of St. Louis, Series INTDSRUSM193N. Data earlier than 1950 are 12-month averages from the Series m13009, U.S. Discount Rates, Federal Reserve Bank of New York 11/1914-07/1969.
21. Long-Term Government Bond Yields, 10-year, not Seasonally Adjusted. Federal Reserve Bank of St. Louis, Series IRLTLT01USM156N. Data earlier than 1955 are 12-month averages from the Series m13033b, U.S. Yield on Long-Term United States Bonds 10/1941-12/1967, NBER Macrohistory: XIII. Interest Rates.
22. Moody's seasoned Baa corporate bond yield, not seasonally adjusted. Federal Bank of St' Louis, Series BAA.
23. Rate of corporate taxes derived as (Profits - Profits after taxes)/ Profits, both series *with* inventory valuation and capital consumption adjustment. The series were extracted from the database of the Federal Bank of St' Louis and come originally from BEA, account codes A551RC1 and A051RC1, respectively.
24. Rate of corporate taxes derived as (Profits - Profits after taxes)/ Profits, both series *without* inventory valuation and capital consumption adjustment. The two series were extracted from the Federal Bank of St' Louis and come originally from BEA, account codes A055RC1 and A053RC1, respectively.