High-Skilled Compensation and the Intangible Capital Stock*

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September 10, 2007

Abstract

This paper reexamines the enormous increase in intangible capital stock in the late 90s as found by Hall (2001) followed by its documented puzzling collapse after 2000. The original model is extended to accommodate for the production of intangible investment goods by skilled workers and executives to account for the existence of two unmeasured complementary capital goods: knowledge capital and organizational structure. As a result, the price of aggregate investment reflects two secular stylized facts: the larger role for intangibles in production and the rise in their cost of production as illustrated by the growth in compensation of skilled labor and executives.

The intangible rationalization of these labor market events deepens the skill-biased technical change explanation found in the literature without requiring it to rely on (unobserved) rapid TFP growth. This explanation is supported by the model's empirical findings, which elucidate the documented puzzle and are in agreement with the behavior of the aggregate value of securities.

Keywords: Intangible Capital, Skill-biased Technical Change, Executive Compensation, Skilled Premium.
JEL classifications: E22, G3, J31, J44, O16.

*Preliminary and Incomplete. I am grateful to Huw Lloyd-Ellis for his invaluable advice throughout this project. I would like also to thank Allen Head, Frank Milne and Jan Zabojnik for their helpful insights and constructive criticisms, Carola Frydman and Raven Saks for sharing with me their data on CEO compensation, Carol Corrado for sharing and answering questions on the intangible expenditure data and seminar participants at Queen's University for helpful comments.

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Contents

1 Introduction

For some time now, there has been a growing perception among academics and policy makers that a significant and increasing part of total business investment is directed towards intangible investments. While to some, this phenomenon is "what put the New in the new economy" (Nakamura (1999)) others acknowledge that "although investment in intangible capital is not counted as capital investment in the national income and product accounts, they appear to be quantitatively important." (Bernanke (2005))

This paper documents the extent to which the composition of the stock of capital in the economy has been shifting over time towards the inclusion of more intangible capital at the expense of tangible capital. Since most of intangible investment is not accounted for in national income accounts, it will be shown that this state of mismeasurement has had two major consequences: productivity was overestimated in the 90s and the price of aggregate investments contrast markedly with that reported by national accounts.

Intangibles are mainly produced by executives and skilled labor. Firms accumulated increasing amounts of this intangible stock as illustrated by the movement in the gap between the aggregate value of securities and the installed stock of physical capital. By bringing together the evidence on the rise of the skill premium, the evidence on the increasing importance of intangible capital in production and the behavior of aggregate securities, this paper gives a consistent account of this compositional change that has been taking place for the last 50 years.

Investment by firms is modeled as a two stage optimization problem: a static decision over combining intangible and tangible investment goods to produce a composite investment good and then a dynamic decision over the amount of the composite investment good to be used over time. As a result, the price of aggregate investment reflects two secular stylized facts: the larger role for intangibles in production and the rise in their cost of production as illustrated by the growth in compensation of skilled labor and executives.

Figure 1 depicts the main finding of Hall (2001) which uncover a first unappealing feature: the negative volume of intangibles.

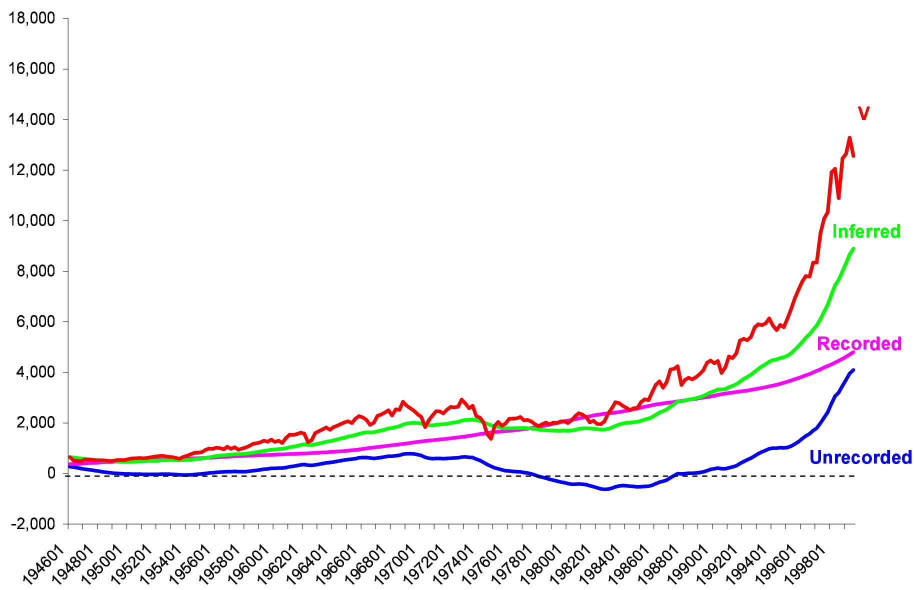

Figure 1: Decomposition of the Aggregate Value of Firms.

Figure 2 update these findings which uncovers another unappealing features: a very volatile intangible series. This paper will address these two anomalies.

2 Stylized facts

There are three major stylized facts that this paper focuses on. Taken together under the framework of the model outlined below, these facts give a consistent account of the events of the past 25 years in both the capital and the labor market.

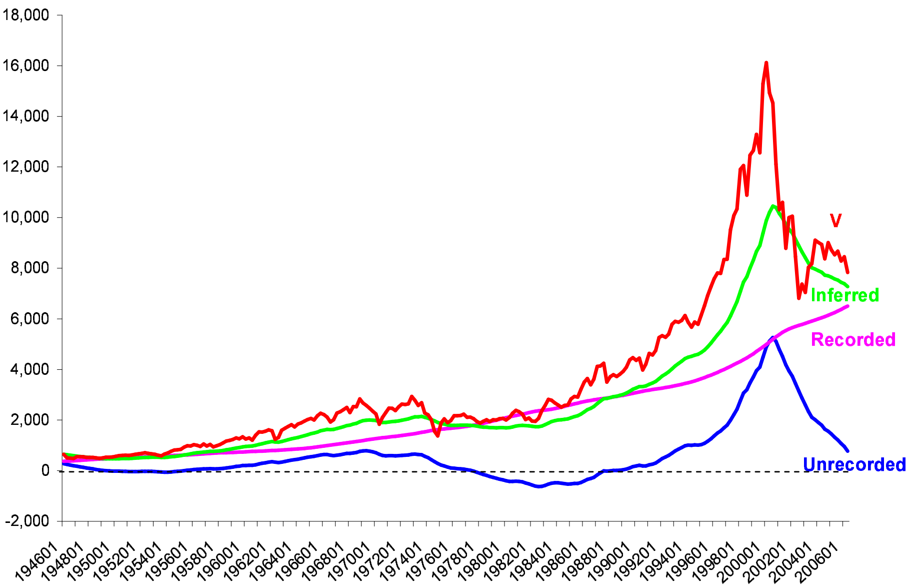

Figure 2: Decomposition of the Aggregate Value of Firms. Source: Hall (2001) and author's calculations

The first of these facts is reported in Corrado *et al.* (2005) (CHS therein). National income accounts view most business expenditures on intangible goods as acquisitions of intermediate inputs that get fully used up in the production of final output. CHS (2005) examine the implications of treating intangible spending as an acquisition of final (capital) goods on GDP growth and labor productivity. Using different data sources, they construct a data set to document the spending of U.S. firms on an identified list of intangible inputs. This list is made of three big categories: computerized information, innovative property and economic competencies[1]. A consensus emerged overtime among national income accountants on what those items should be (See Vosselman (1998)). CHS report that by mid-90s, investment in intangible capital was as large as the investment in physical capital. Taking a longer view perspective, Corrado *et al.* (2006) report the evolution of the share of the intangible capital investment since 1950 in overall investment. Figure 6 shows the ratio of intangible expenditures to tangible expenditures.

[1]See their Table 1.2. for the items included in each group

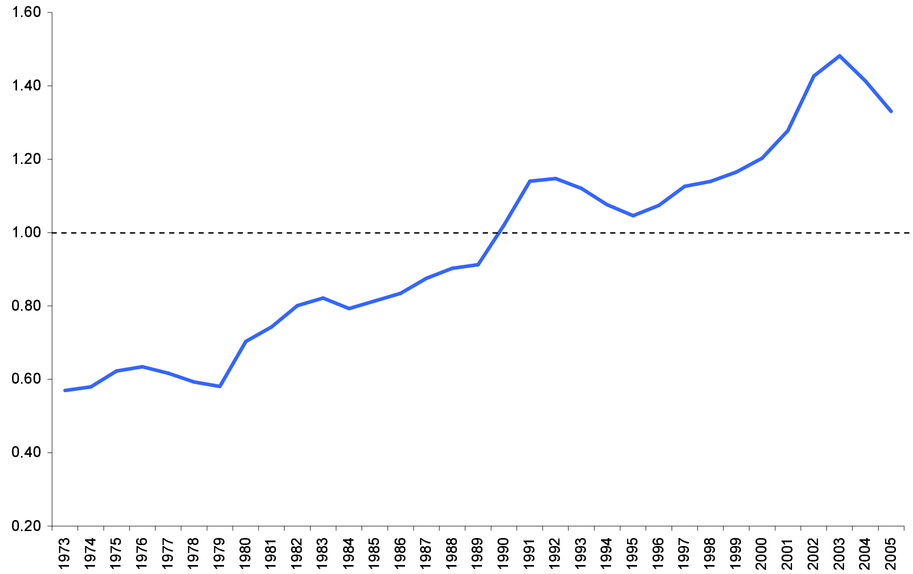

Figure 3: Ratio of Intangible to Tangible Expenditure. Source: Corrado, Hulten and Sichel (2006) and author's calculations

There is a striking upward trend starting as early as in the 50s. By early 1990, firms' investment in intangibles matched the investment in tangible investment goods. For the purpose of this paper, this fact is important in constructing an accurate measure of aggregate investment. Indeed, because the share of expenditure of firms in intangibles has been shifting overtime, the reported aggregate investment by national income accounts which consists mainly in tangible investment is not an accurate reflection of the investment activity of firms.

The second salient fact that this paper highlights is related to the cost of intangibles. Since national income accounts do not collect information on the investment of firms in intangibles, and because the market for intangibles is extremely thin[2],

[2]Some R&D spending leads to the creation of a patent which will carry a price if commercialized. However, the market for patents is extremely thin: very few patents change hands. For example, Serrano (2006) documents that only about 20% of all U.S. patents issued to small innovators (i.e., firms that were issued no more than five patents in a given year) are traded once or more.

little is known about their aggregate price. A major input however to the creation of intangibles is skilled labor. Because of the rapid increase in demand of intangibles that was documented by CHS (2005), this category of workers experienced a widely documented increase in their wage premium starting in the early 80s. (See Katz and Autor (1999) and Lemieux (2007) for an up-to-date review of this literature). Another category of workers which experienced an impressive rise in their wages is executives. Frydman and Saks (2007) report data from 1935 on CEO compensation. Figure 4 reproduces their findings.

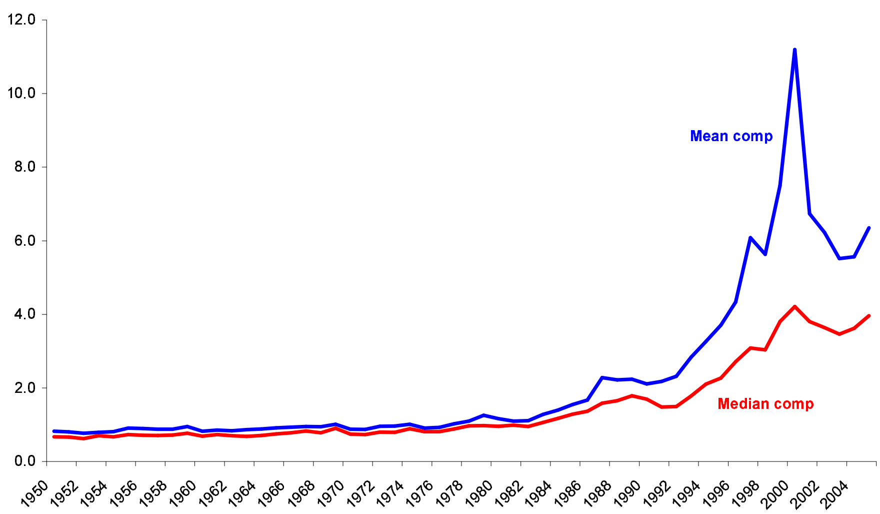

Figure 4: Mean and Median Compensation of a CEO (Millions of 1996). Source: Frydman and Saks (2007)

There is an upward trend starting in the early 80s. The rise and fall in the stock market around 2000 seems to have had an important effect on the compensation trend. This documented evolution in the labor market for high-skilled workers is important in valuing the competitive price of produced intangible goods and hence accurately constructing an index for the price of aggregate investment.

Finally, the capital market evolution of the last 30 years shed light on the composition of the accumulated capital stock by firms. The net value of securities reflects under rational valuation the value of the installed capital stock. Figure 5 shows that the net value of securities departed markedly through time from the tangible capital stock constructed using the perpetual inventory method.This is further evidence for the accumulation of intangible capital by firms. The information from the capital market is used to infer the shadow price of the overall capital stock in order to uncover the size of the accumulated intangible capital.

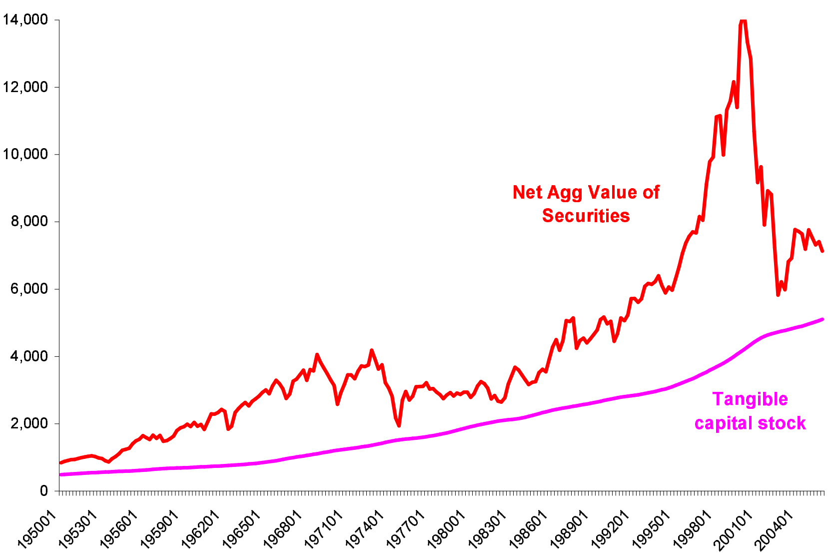

Figure 5: Aggregate Value of Securities and Tangible Capital Stock. Source: author's calculations

3 Literature Review

There is a growing body of literature that attempts to evaluate the size of unrecorded capital investment at the aggregate level. At the root of most these investigations lies a dissatisfaction with the practice of national income accounts in treating expenses on intangibles as intermediate inputs or operational costs. Given that intangibles are assets, they should be capitalized and treated as investment goods instead of being expensed as intermediate consumption goods. Nakamura (1999) and Corrado *et al.* (2005) attempt to calculate the size of intangible capital investment using a similar approach. Corrado *et al.* (2005) identify a list of intangible items and investigate different data sources to inform the investment of US firms on intangible capital goods. They show that by the end of the 90s, the size of the investment in intangible capital was as big as the size of the investment in physical capital.

Hall (2001) and McGrattan and Prescott (2005a) rely on the unmeasured levels of intangible capital to rationalize the rise in the stock market in the late 90s in the US and in the UK. Hall (2001) shows that the rise in the stock market coincides with an ever increasing accumulation of intangible capital. McGrattan and Prescott (2005a) are able to rationalize the size of intangible investment found in Corrado *et al.* (2005) while using the change in tax regulations to explain the different performance of the UK and the US stock markets. McGrattan and Prescott (2005b) show that by explicitly accounting for intangible capital, one can explain the productivity paradox. In particular, they argue that GDP in national income accounts is undervalued because of the expensing of intangible investment which ultimately created a downward bias in the estimates of productivity in the early 90s.

The paper of Eliades and Weeken (2004) applies Hall's methodology to the UK. These authors find no trace of intangible capital for the UK before 1990 but reach the same qualitative results as Hall (2001) for the late 90s.

Although most studies find that the size of the investment in intangible capital is substantial, the findings of Hall (2003) and Bond and Cummins (2000) are exceptions. They both show, using different data, that the returns to physical capital exhaust all payments to capital and hence, there is nothing leftover to reward the services of intangible capital. This is held as evidence for the absence of a substantial intangible capital stock which is puzzling in light of the findings in the above cited papers.

The closest paper in spirit to this work is the one of Hall (2000). That paper focuses on the period from 1990 to 2000 and tries to tie the behavior of skilled labor wages with the formation of intangible capital. This paper however fails to account for the changing structure of firms investment as done in our model. Moreover, the inclusion of executives in the class of skilled labor mark another conceptual difference. Finally, the long-term approach here illuminates the pre-1990 events.

There is a large IO literature which aims at uncovering the size or the value of some of the components of the intangible capital stock. These papers typically use panel or survey data which cover short periods of time or just some portions of the economy. The work of Atkeson and Kehoe (2007) and Atkeson and Kehoe (2006) identify an intangible capital that is related to the activity of learning by doing of plants which is referred to as organizational capital.

4 Methodology

4.1 The model

The model extends the standard neoclassical model of investment as developed in Hayashi (1982) to allow for the production and the utilization of intangibles in production. It ultimately relates the value of securities to the value of installed capital which then allows to back out the unaccounted for quantity of installed capital. Note that the empirical performance of the q-theory of investment appears to be decent but not more (See Caballero (1999) for a survey). The believe here is that past tests of the theory suffered from specification problems by not taking into account the investment of firms in intangibles (Hall (2004) pp.914-915 provides a related discussion.) Moreover, the exercise in this paper is not intended to test the theory but instead to make use of its quantitative implications.

There is perfect competition in input and output markets. The firm employs two types of labor, skilled and unskilled. Unskilled labor l^u is used for the production of output only. It is paid w^u. l^s amount of skilled labor is used for the production of output and the rest h^s is used for the production of intangibles. Skilled labor is paid w^s. The production of output proceeds according to $F(k_{t-1}, l_t^u, l_t^s)$ where $F(.)$ is assumed to be homogeneous of degree one. The price of output is p^Y and is set to be equal to one. The production of intangibles is governed by $x^I = G(h^s)$. The existence of this function is motivated by the need to capture the link between the rise in the wage paid to a class of skilled labor and the increase in the price of intangible investment goods. This will allow the ratio of the intangible to tangible price to vary over time instead of being set equal to one as in Hall (2001).

The model departs from the literature by specifying a composite investment good which is ultimately accumulated to be used for production. The firm combines intangibles x^I with tangible investment goods x^T to produce a composite investment good

$$x = (x^T)^{\gamma_t}(x^I)^{1-\gamma_t}.$$

The tangible investment goods are bought from the market at a price p^T. The price of intangible capital p^I is equal to $\frac{w^s}{G_h}$. Its expression will be discussed in the calibration part. This composite investment good is meant to capture the existence of intangible capital goods inside firms that are used together with tangible investment goods. The exponent is allowed to vary over time to capture the evidence on the increasing importance of intangibles relative to tangible investment. This composite investment function can be thought of as aggregate investment since it is a share weighted function to build an index of investment. The weighs represent the share in the overall expenditure. It is in fact a Divisia index approach to combining two investment goods together. In other words, x is the aggregate investment good.

The aggregate investment good accumulates according to

$$k_t = (1 - \delta)k_{t-1} + x_t$$

where δ is the depreciation rate. The adjustment of the capital stock is subject to output losses modeled as a cost function assumed to be quadratic and homogeneous of degree one $C(x_t, k_{t-1})$.

The problem of the firm is to choose the optimal level of labor and investment such as to maximize the net present value of future profits subject to the technology of investment accumulation, the starting level of capital and the non-feasibility of Ponzi schemes:

$$\max_{\{l^u_s, l^s_s, h^s_s, x^T_s, x_s\}} \quad \hat{v}_t = \sum_{s=t}^{\infty} \left(\frac{1}{1+r}\right)^{s-t} v_s$$

$$v_s = F(k_{t-1}, l^u_s, l^s_s) - w^u_s l^u_s - w^s_s l^s_s - w^s_s h^s_s - p^T_s x^T_s - C(x_s, k_{s-1})$$

s.t.

$$x^I = G(h^s)$$

$$x_s = (x^T_s)^{\gamma_t}(x^I_s)^{1-\gamma_t}$$

$$k_s = (1-\delta)k_{s-1} + x_s$$

$$k_{s-1}$$

$$\lim_{T\to\infty} \left(\frac{1}{1+r}\right)^T v_{s+T} = 0$$

The value function $\hat{v}_t$ is the net present value at time t of future payout to securities' holders. Indeed, after the firm pays inputs their due, the left over income is paid to owners. Their ownership materializes through the possession of titles in the form of securities. Hence, v_t is also the value of the firm.

The model can be solved through a two stage optimization procedure. The first stage is a static problem which consists in choosing x^T and x^I to minimize the expenditure on the production of x within each period. The second stage recasts the above dynamic problem accordingly such that it is solved at the start.

The static problem can be written as

$$\min_{x^T, x^I} \quad p^T x^T + p^I x^I$$

$$s.t. \quad (x^T)^{\gamma}(x^I)^{1-\gamma} \leq x$$

The minimum cost function is given by

$$\begin{aligned} p^T x^{T*} + p^I x^{I*} &= \left(\frac{p^T}{\gamma}\right)^{\gamma} \left(\frac{p^I}{1-\gamma}\right)^{1-\gamma} x \\ &= p^x x \end{aligned}$$

where p^x reflects the unit cost of an investment good.

The new dynamic problem of the firm is given by

$$\max_{\{l_s^u, l_s^s, x_s\}} \hat{v}_t = \sum_{s=t}^{\infty} \left(\frac{1}{1+r}\right)^{s-t} v_s$$

$$v_s = F(k_{t-1}, l_s^u, l_s^s) - w_s^u l_s^u - w_s^s l_s^s - p_s^x x_s - C(x_s, k_{s-1})$$

s.t.

$$k_s = (1-\delta)k_{s-1} + x_s$$

$$k_{s-1}$$

$$\lim_{T\to\infty} \left(\frac{1}{1+r}\right)^T v_{s+T} = 0$$

The Hamiltonian $\mathcal{H}$ at time t and the first order conditions are given by

$$\begin{aligned} \max_{\{l_s^u, l_s^s, x_s, k_s, \mu_s\}} \mathcal{H}_t = \sum_{s=t}^{\infty} \left(\frac{1}{1+r}\right)^{s-t} &\{F(k_{t-1}, l_s^u, l_s^s) - w_s^u l_s^u - w_s^s l_s^s \\ &-p_s^x x_s - C(x_s, k_{s-1}) - \lambda_s[k_s - (1-\delta)k_{s-1} - x_s]\} \end{aligned}$$

$$\begin{aligned} \frac{\partial \mathcal{H}_t}{\partial x_s} &: \quad \lambda_s = p_s^x + C_x(x_s, k_{s-1}) \\ \frac{\partial \mathcal{H}_t}{\partial l_s^u} &: \quad w_s^u = F_{l^u}(k_{t-1}, l_s^u, l_s^s) \\ \frac{\partial \mathcal{H}_t}{\partial l_s^s} &: \quad w_s^s = F_{l^s}(k_{t-1}, l_s^u, l_s^s) \\ \frac{\partial \mathcal{H}_t}{\partial k_s} &: \quad \lambda_s(1+r) = F_k(k_{t-1}, l_s^u, l_s^s) - C_k(x_{s+1}, k_s) + (1-\delta)\lambda_{s+1} \\ \frac{\partial \mathcal{H}_t}{\partial \lambda_s} &: \quad k_s = (1-\delta)k_{s-1} + x_s \end{aligned}$$

where λ is the costate variable or the shadow price of an additional unit of capital. The first equation illustrates the equality of the lifetime return to increasing capital by one unit with its marginal cost given by the price of a unit of capital plus the marginal adjustment cost of installing this unit of capital. This equation determines the optimal investment amount to be chosen by the firm. The second and third equation state the usual equilibrium condition for the labor market whereby the real wage is equal to the marginal product of labor. The next equation shows the dynamic equilibrium equation of λ with its continuation value. The last equation recasts the investment technology constraint.

In order to obtain sharper results with respect to the investment decision of the firm, the adjustment cost function will be specified as

$$C(x_t, k_{t-1}) = \frac{\alpha}{2}\left(\frac{x_t}{k_{t-1}}\right)^2 k_{t-1}.$$

Assuming $s = t$ and substituting this cost function into the first order condition that described the equality of λ with the marginal cost of augmenting capital by one unit, we obtain the following equation:

$$\frac{x_t}{k_{t-1}} = \frac{1}{\alpha}(\lambda_t - p_t^x).$$

This is known as the investment equation since it relates the behavior of investment to the shadow price of capital λ_t. Investment is positive when the lifetime return to increasing capital by one unit exceeds its price. This equation has limited empirical use since $lambda_t$ is by definition unobservable.

We can combine this result with the famous finding of Hayashi (1982) that

$$v_t = \lambda_t k_t$$

to derive an expression for investment that can be estimated

$$\frac{x_t}{k_{t-1}} = \frac{1}{\alpha}(\frac{v_t}{k_t} - p_t^x).$$

We then follow Hall (2001) in solving this problem. This relationship is combined with the expression for the investment term x_t as given by the capital accumulation expression to obtain the following quadratic equation:

$$\alpha k_t^2 + \left([p_t^x - \alpha(1-\delta)]k_{t-1}\right) k_t - v_t k_{t-1} = 0$$

Hall (2001) shows that a unique solution exists for a general convex cost function with constant returns to scale. This equilibrium is stable and is therefore not sensitive to initial conditions in the long-run. The positive root expresses the law of motion of the capital stock:

$$k_t = \frac{-[p_t^x - \alpha(1-\delta)]k_{t-1} + \sqrt{\left([p_t^x - \alpha(1-\delta)]k_{t-1}\right)^2 + 4\alpha v_t k_{t-1}}}{2\alpha}$$

All variables are observable and v_t is a sufficient statistic to back out the stock of capital in the economy. k_t is therefore the endogenous variable to be calculated at each point in time. The stock of intangibles can then be recovered in the following way $k_t^I = k_t - k_t^T$. This holds given perfect competition and constant returns to scale in the production function.

This model departs from Hall's model by not assuming that $p^x = p^T$ and by allowing x^T and x^I to not be perfectly substitutable.

4.2 Data Description and calibration

The parameters in the law of motion of the capital stock need to be specified. For the sake of comparison, the same parameters as those in Hall (2001) are used.

In order to account for irreversibility in investment, it is assumed that the cost function is piece-wise quadratic :

$$C(x_t, k_{t-1}) = \begin{cases} \frac{\alpha^+}{2}\left(\frac{x_t}{k_{t-1}}\right)^2 k_{t-1} & \text{if } x_t > 0 \\ \frac{\alpha^-}{2}\left(\frac{x_t}{k_{t-1}}\right)^2 k_{t-1} & \text{if } x_t < 0 \end{cases}$$

where the adjustment-cost parameter α^+ (α^-) represents the time it takes for the capital stock to double (halve) when λ doubles (halves). To see this, note that if

λ doubles permanently, say from one to two, it will cause initially the investment-capital ratio to increase by $\frac{1}{\alpha}$. For the investment-capital ratio to double, the increase in $\frac{1}{\alpha}$ must be repeated for α periods. By allowing the downward adjustment-cost parameters to be higher than the upward adjustment-cost parameter, this asymmetry in the investment decision will reflect irreversibility of investment.

Hall (2001) cites the work of Shapiro (1986) to justify the choice of a doubling time parameter of 8 quarters. α^- is set arbitrarily to be ten times higher than the upward adjustment-cost parameter. The depreciation rate of 2.6% per quarter is used by national income accounts for physical capital. Finally, to start the iteration on the law of motion of capital, the value of the initial capital stock k_{t-1} needs to be set. We will assume that the economy is in equilibrium at the pre-initial quarter, i.e. λ_{t-1} takes its equilibrium value of 1. Since investment will be nil at this pre-initial quarter, the relationship $v_t = \lambda_t k_t$ implies that $k_{t-1} = v_{t-1}$. Because the recursion was shown to be insensitive to initial condition, this equilibrium assumption is not going to affect the behavior of the system in the long-run.

Table 1 summarizes the parameter values used and the rationale for the choice of each value.

Table 1: Parameter values

Name	**Parameter**	**Value**	**Rationale**
Upward adjustment-cost	α^+	8	Shapiro (1986)
Downward adjustment-cost	α^-	80	Hall (2001)
Depreciation rate	δ	0.026	Hall (2001)
Initial capital stock	k_{t-1}	v_{t-1}	Assuming $q_{t-1} = 1$ at $s = t-1$

The market value of net financial claims (financial liabilities minus financial assets) is used as the measure of v_t since the value of the ownership claims are a reflection of the installed capital inside the firm. Indeed, v_t was defined as the present value of payouts to securities' holders. Assuming that investors are rational, it follows that the present value of payouts v_t will equal the value of securities on the market. Since for all t, $v_t = \lambda_t k_t$, then the value of securities equals the value of the installed capital stock.

Notice that v_t includes all financial claims towards firms net of financial assets that firms hold against others: equity, bonds and all other other liabilities (loans and mortgages, short-term paper, trade payables, life insurance and pensions). This represents a departure from the way the literature in the q-theory of investment interpreted v_t as covering only equity values or as being made of equity plus bonds. This departure is mainly due to the type of data that is possible to use today.

Most of the data to measure v_t is taken from the national balance sheet account at market value from 1950Q1 to 2005Q4. Equity is reported at market value and all the other liabilities are at book value. These were converted by Hall (2001) into market value. When conducting the data analysis, the focus will be on the non-farm, non-financial corporate sector. This sector is chosen because it is the most amenable to fit the perfectly competitive framework of this paper. The removal of the farming sector aims to control for the presence in the overall capital stock of land, a capital input in fixed supply, which therefore earns rents. The choice of the corporate sector ensures that securities are continually priced to reflect accurately new information regarding the value of the capital stock. This would not be true for the installed capital of unincorporated businesses. Another reason to focus on this sector is dictated by the fact that the farming sector, the non-corporate sector and the financial sector suffer from data quality problems. The use of the non-farm, non-financial corporate sector is not restrictive given that this sector owns around 90% of the non-residential fixed capital stock in the economy.

The paper takes the view that intangibles are being produced by a class of skilled workers. This class is made of two broad categories of people: on the one hand scientists and middle managers that we categorize as knowledge workers and denote (h^K) who create raw intangibles and on the other hand executives (h^{CEO}) who create organizational designs and structures. Raw intangibles and organizational designs are combined to produce intangibles implied by the way the function $G(h)$ is specified. We allow for

$$G(h^s) = (h^{CEO})^{\phi}(h^K)^{1-\phi}.$$

Assuming perfect competition, the expression of the unit cost of an intangible capital good is then given by

$$p^I = \left(\frac{w^{CEO}}{\phi_t}\right)^{\phi_t}\left(\frac{w^K}{1-\phi_t}\right)^{1-\phi_t}$$

where ϕ is allowed to vary to reflect the variable weight that characterized executives compensation overtime

$$\phi_t = \left(\frac{w^K h^K}{w^{CEO}h^{CEO}} + 1\right)^{-1}$$

Note that in using the share of these two classes of workers to infer the weights, we have implicitly assumed that the fraction of time spent in producing intangibles rather than output is the same for both types of worker.

The initial value of p^I is obtained by assuming that the firm is at the steady-state at $t = 0$:

$$\frac{x_0}{k_{-1}} = \frac{1}{\alpha}(\frac{v_0}{p_0^x k_0} - 1) \Leftrightarrow p_0^x = \frac{1}{\alpha\gamma}.$$

Using $p_0^x = \left(\frac{p_0^T}{\gamma_0}\right)^{\gamma_0}\left(\frac{p_0^I}{1-\gamma_0}\right)^{1-\gamma_0}$ we back out the value of p_0^I. p_0^I is then made to grow at the rate of change of p_t^I.

The variable w^{CEO} is taken to be the average compensation to a CEO as reported by Frydman and Saks (2007). h^{CEO} is the number of chief executives. This is taken from the Bureau of Labor Statistics, Occupational Employment Statistics (OES) Survey. $w^K h^K$ is the wage bill of skilled labor taken from U.S. Census Bureau, Current Population Survey.

Figure **??** depicts the behavior of ϕ_t overtime.

The final parameter to calibrate is γ_t in the expression of aggregate investment $x = (x^T)^{\gamma_t}(x^I)^{1-\gamma_t}$. γ is calibrated to conform to the first order condition of the static problem:

$$\frac{x^T}{x^I}\left(\frac{1-\gamma}{\gamma}\right) = \frac{p^I}{p^T} \Leftrightarrow \gamma = \left(\frac{p^I x^I}{p^T x^T} + 1\right)^{-1}.$$

CHS (2006) report expenditures on intangibles $p^I x^I$. The national income and product accounts (NIPA) recorded 20% of the reported expenditures in intangibles by CHS. $p^T x^T$ is the private fixed investment as recorded by NIPA from which the recorded intangibles are subtracted. These consisted in software, mineral exploration and architectural and design services. The time series behavior of this ratio captures the biased technological change which resulted in the use of relatively more x^I. Figure **??** shows the behavior of γ overtime. This conforms to the discussion earlier on in the stylized fact section.

5 Results

Figure 8 depicts the components of the price of aggregate investment. This illustrates the striking difference in the behavior of aggregate investment which is implied by accounting for intangibles.

Figure 9 shows the inferred capital stock. To remove the noise that remains from the use of the aggregate value of securities, the inferred capital stock is smoothed using an exponential function since this is the closest to depicting the evolution of a capital stock

Figure 10 is the main result which shows the series of intangibles and tangible capital. Notice the accumulation of intangible has been substantial.

6 Implications for productivity measurement

The model above implies the following aggregate production function:

$$y_t = A_t F(k_t, l_t^u, l_t^s)$$

when separating the contribution of each item in the growth of GDP, it can be shown that

$$\frac{\dot{y}}{y} = \frac{\dot{A}}{A} + \frac{r_t k_t}{C_t}\frac{\dot{k}}{k} + \frac{w_t^u l_t^u}{C_t}\frac{\dot{l^u}}{l^u} + \frac{w_t^s l_t^s}{C_t}\frac{\dot{l^s}}{l^s}$$

where

$$C_t = r_t k_t + w_t^u l_t^u + w_t^s l_t^s.$$

TFP will naturally be lower given that the size of the capital stock almost doubled compared to the tangible capital stock. Given the hypotheses of the model of the accumulation of both forms of capital, we can allow the technology to be AK. This follows Hall (2001). Payouts to the owners of firms d_t are paid out at the beginning of period t out of output. What remains is then used to accumulate capital, pay depreciation and the adjustment costs:

$$A_{t-1}k_{t-1} = d_t + (k_t - k_{t-1}) + \delta k_{t-1} + c(\frac{k_t}{k_{t-1}})k_{t-1}.$$

This can be re-written as

$$\widehat{A_{t-1}}k_{t-1} = d_t + (k_t - k_{t-1})$$

where $\widehat{A_{t-1}}$ is productivity net of adjustment cost and deterioration of capital. The value of the net productivity index can be calculated from:

$$\widehat{A_{t-1}} = \frac{d_{t+1} + k_{t+1} - k_t}{k_t}.$$

Table **??** summarizes the productivity levels uncovered when using the capital stock that includes only tangibles versus the one that includes both intangibles and tangibles.

Table 2: Net Productivity

Period	**Old Productivity**	**New Productivity**
1950's	0.051	0.06
1960's	0.059	0.07
1970's	0.048	-0.02
1980's	0.071	0.09
1990's	0.134	0.12

7 Conclusion

This paper examined the enormous increase in intangible capital stock in the late 90s as found by Hall (2001) followed by its documented puzzling collapse after 2000. The original model was extended to accommodate for the production of intangible investment goods by skilled workers and executives to account for the existence of two unmeasured complementary capital goods: knowledge capital and organizational structure. As a result, the price of aggregate investment reflects two secular stylized facts: the larger role for intangibles in production and the rise in their cost of production as illustrated by the growth in compensation of skilled labor and executives.

The intangible series was shown to behave in a more appealing fashion which underscored the important to properly measure the price of aggregate investment. The link between the labor market for high-skilled workers and the capital markets was shown to be key in obtaining these results.

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Appendix

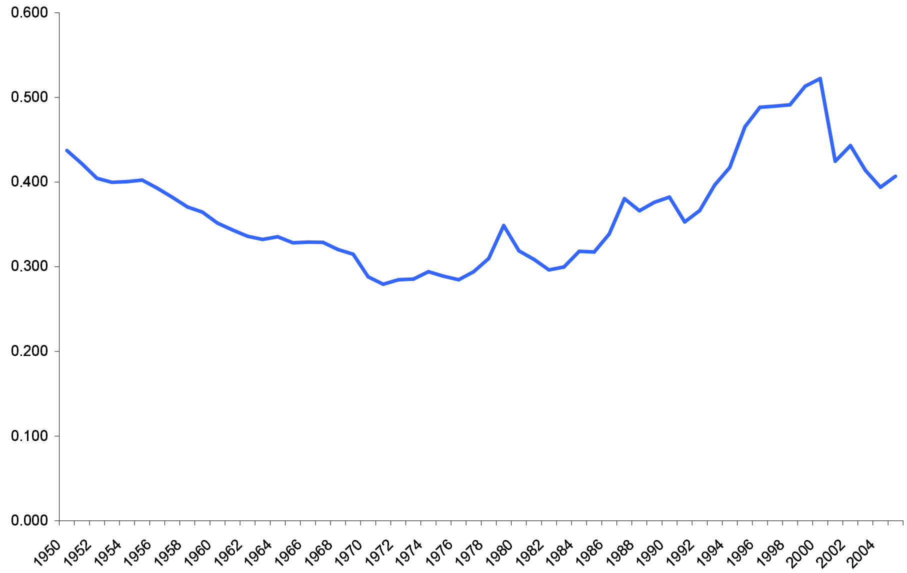

Figure 6: Behavior of ϕ_t

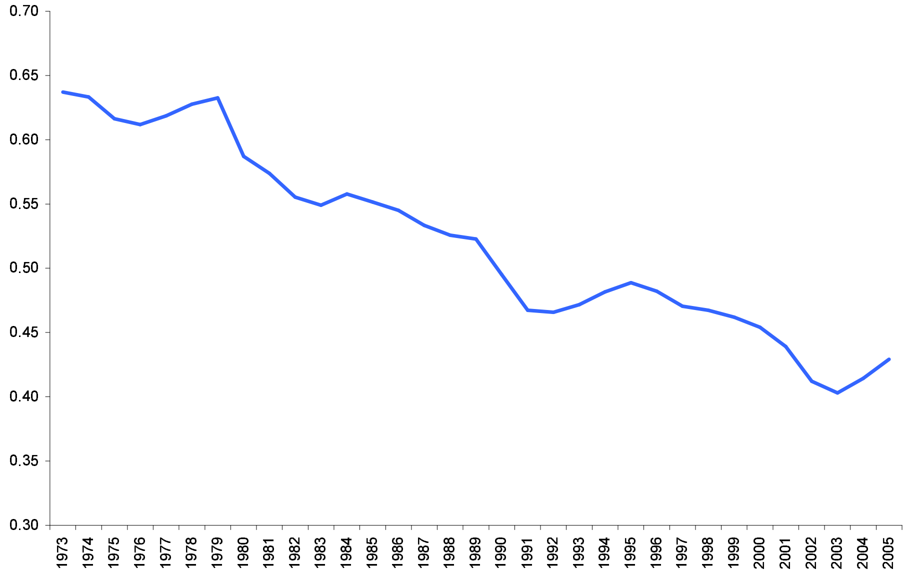

Figure 7: Behavior of γ_t

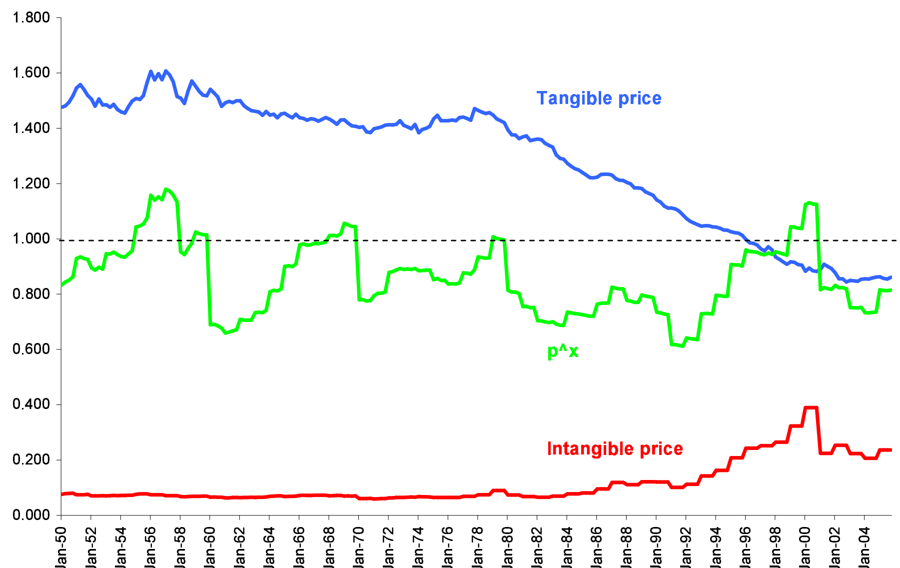

Figure 8: Real Prices Behavior. Author's calculations and NIPA.

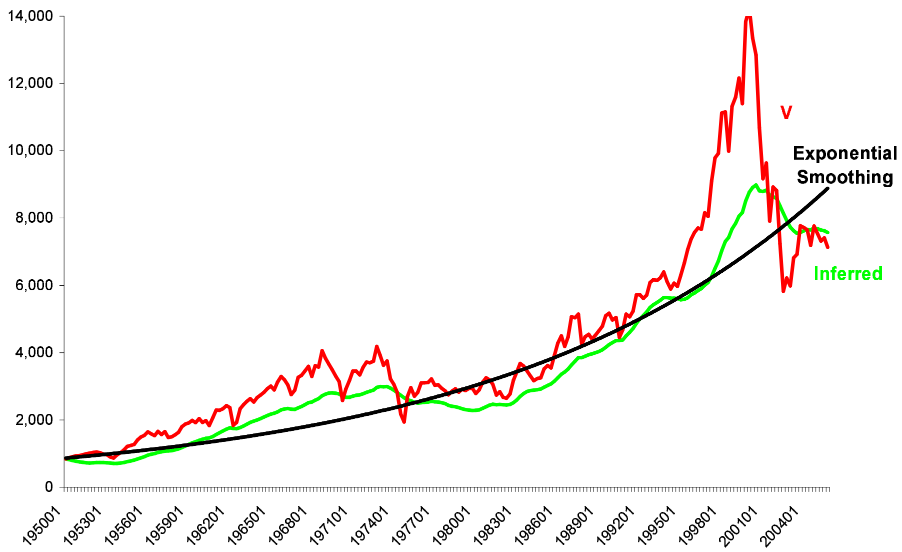

Figure 9: The Inferred Capital Stock from the Aggregate Value of Firms

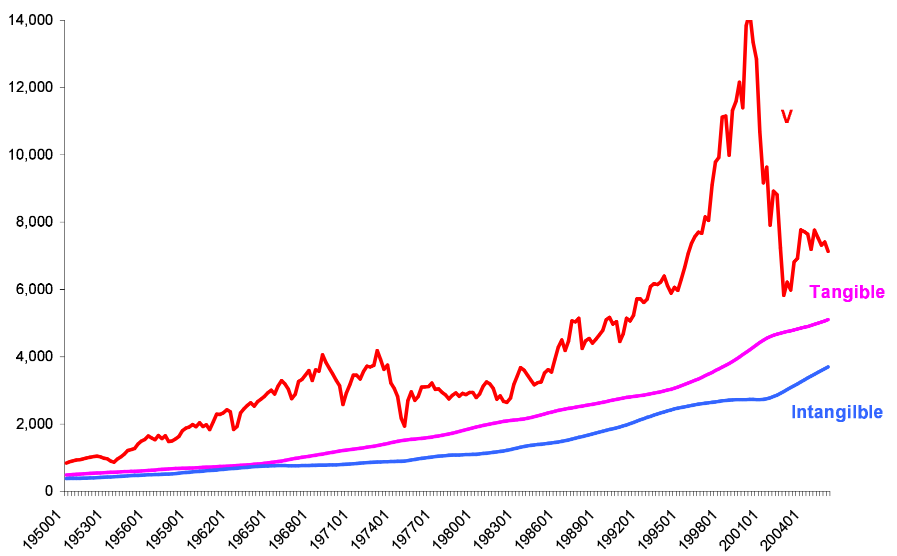

Figure 10: Decomposition of the Aggregate Value of Firms