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THE GENERATION AND EXPLOITATION OF TECHNOLOGICAL CHANGE: MARKET VALUE AND TOTAL FACTOR PRODUCTIVITY

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THE GENERATION AND EXPLOITATION OF TECHNOLOGICAL CHANGE: MARKET VALUE AND TOTAL FACTOR PRODUCTIVITY [1]

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Abstract

In this paper we articulate and test the hypothesis that TFP is a reliable and relevant measure of firm's innovation capabilities, and, as such, accounts for Tobin's q indicator. With this aim, we investigate empirically the relationship between firm level total factor productivity and the Tobin's q. Measuring Tobin's q allows inferring the actual value of knowledge capital from stock market valuation. We use a panel of companies listed on UK and the main continental Europe financial markets (Germany, France and Italy) for the period 1995 - 2005. Our results confirm that TFP is a reliable indicator of firm's innovative capabilities. When we control for firm's R&D investments, the effects of TFP on market value remain highly significant. This suggests that TFP is a broader measure of innovation capability than R&D is. The validation of the Tobin's q and TFP relationship has important implications concerning firm's technological innovation measurement.

Key words: Tobin'q; Innovation; Total Factor Productivity

JEL classification: O33

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1. Introduction

According to James Tobin (1978) the q ratio, which is computed as firm's market value divided by the replacement costs of firm's assets, is a measure of profitable investment opportunities. Hence, the Tobin's q is widely used as an indicator of innovation. The idea behind this framework is that Tobin's q can better approximate firms' actual performances with respect to accounting profit indicators. This is especially true when out-of-equilibrium conditions take place.

When a public company is able to earn extraprofits stemming from the successful introduction and exploitation of technological and organizational innovations, investors are keen to buy its shares in the stock market. The price of the shares and hence the market value of the firm increase until its profitability, i.e. the ratio of the extraprofits to the new increased market value, matches average levels. The dynamics of capitalization in the stock markets, in other words, enables to restore equilibrium conditions.

When perfect conditions of competitive equilibrium apply, even after the introduction of an innovation, the immediate entry of new competitors and imitators in the product and factor markets would impede the appropriation of the benefits of innovations at the firm level and sweep away all extraprofits. Hence the relationship between innovation and profits would not take place. When imperfect competition prevails, instead, innovators can take advantage from transient monopolistic power and appropriate a share of the benefits of innovations in terms of profits. The basic conditions of equilibrium at the system level are altered and out-of-equilibrium conditions risks to spread through the markets (Antonelli and Teubal, 2008).

Financial markets, with the dynamics of capitalization, provide a remedy to imperfect competition and substitute for product and factor markets in absorbing the out-of-equilibrium conditions engendered by the introduction of innovations. Capitalization converts 'extraprofits' in 'extracapital' and in so doing restores equilibrium conditions in the relationship between profits and rates of return. As a consequence, however, it is clear that the endowments themselves become endogenous. Now the market value of the company depends upon its profits. In equilibrium conditions on the product and factor markets the relationship works the other way around: the profits of the firm depend upon the price of capital. When the introduction of innovations alters the equilibrium conditions of competitive markets a divide and a discrepancy widens between the market value and the book value of a public company until the dynamics of capitalization in the stock markets enables to restore equilibrium conditions as described.

This conceptual relationship between market value and innovation has been much investigated. Starting with the seminal work of Griliches (1981), an array of works has related Tobin's q with the intangible capital that enables firms to generate technological knowledge and introduce technological and organizational innovations and the profitability that stems from the appropriation of the stream of profits secured by their exploitation (Cockburn and Griliches 1988, Hall 1993, Menga and Klock 1993, Shane and Klock 1997, Hall et al. 2005, Coad and Rao, 2006, Hall and Mairesse, 2006, Bloch, 2008).

Different measures of intangible assets related with the firm's knowledge capital have been used, in particular R&D investments and patents stock. More recently, much work has been done in order to better qualify patents in terms of citations. The main conclusion of the works relating market value and innovation is that all these indicators enable to identify innovative capabilities as a form of intangible capital and, above all, that each indicator gathers different elements and sheds light on different aspects of the generation of technological knowledge. Thus, empirical analysis should include all of them when analyzing firm's knowledge base.

Yet, the question as to what aspects of the innovation process are captured by empirical measures available has not been fully addressed. Due to the limits of most common indicators, the debate on technological innovation measurements is still open. We assume that there is a component of knowledge which is not captured by R&D and patent statistics and we argue that the central issue of the actual appropriation of the stream of benefits stemming from the introduction of innovations has not been properly considered.

As it is well known the appropriation of the stream of benefits stemming from the introduction of innovations differs widely across firms. Patents provide a biased indicator of the actual appropriation conditions. Relevant innovations, although protected by patents, may have a weak effect on the profitability of firms that have introduced them because of fast imitation and entry of new competitors that are able to 'invent around'. On the opposite, technological and organizational innovations with low scientific content, and hence not eligible to apply for intellectual property protection, may engender long lasting quasi-rents. This may depend on, the compactedness of the knowledge base that delays imitation and hence increase appropriability and, the market structure characterized by high barriers to entry and hence to imitation. The capability of firms to exploit its technological knowledge differs also for idiosyncratic and organizational factors that are specific to each firm (March, 1991). Hence, it is clear that the appreciation of the actual levels of exploitation of technological and organizational knowledge is as crucial as the identification of the capability to generate technological and organizational innovations to explain the capitalization of knowledge that Tobin's q measures.

For these reasons, in this paper we contend that total factor productivity (TFP) measures provide much a stronger and reliable indicator of the actual differences across firm in terms of their joint capability to generate and exploit technological and organizational innovations. Hence we shall articulate and test the hypothesis that TFP contains and provides valuable information on the actual amount of profitable technological innovation introduced by each firm that is not captured by R&D and patent statistics. Hence TFP is much more able to account for Tobin's q. In view of these arguments, in this paper we investigate the relationship between TFP and the Tobin's q.

The empirical analysis relies on the market value equation developed by Griliches (1981) and focuses on a panel of companies which are publicly traded in UK, Germany, France, and Italy for the period from 1995 to 2005. We find a positive and significant relationship between the Tobin's q and TFP indicators. Our results confirm that TFP can be considered a good indicator of the firm's innovation capability as reflected in firm's profits and hence market value (Cefis and Ciccarelli, 2005). When we control for firm's R&D investments, we still find a strong relationship between Tobin's q and TFP. This result suggests that TFP is a more comprehensive measure of knowledge capital than R&D.

The paper is organized as follows. Section 2 discusses the rationale behind the use of TFP as a proxy for knowledge capital. In section 3 we present the market value model. The dataset and the variables used in the empirical analysis are presented in section 4. Next, in section 5, we describe and discuss the results of the analysis. Section 6 concludes.

2. Dealing with innovation and technical change measurements

Tobin's q and the TFP can be considered two consistent and complementary indicators of the effects of out-of-equilibrium conditions engendered by innovation. As a matter of fact, both the Tobin'q and the TFP reflect and measure the effects of the introduction of innovations on the equilibrium conditions of product and factor markets. Firms able to generate new technological and organizational knowledge, to use it to introduce technological and organizational innovations and to appropriate their economic benefits, are able to produce more output with given levels of inputs and hence to experience higher performances, especially in terms of profitability. The methodologies elaborated respectively by Robert Solow (and Moses Abramovitz) and James Tobin to quantify such effects share the same basic ingenuity that consists in confronting the equilibrium values with the historic ones and to identify technological change as the main cause of possible discrepancies. The intrinsic theoretical coherence of the two indicators suggests to exploring with care their relationship. This paper thus aims to verifying the causal relationship between TFP as a reliable and comprehensive measure of the effects of the introduction and exploitation of innovation and technical change and the Tobin's q, as an indicator of the capitalization of the extraprofits generated by the appropriation of the benefits of innovation.

The theory underlying the Tobin's q asserts that in equilibrium the market value of firm's assets equals its book value. If this equation is not satisfied, some sources of extraprofit are at work and market value goes beyond the book value of firm's assets. Thus, Tobin's q can be considered a measure of the extraprofit that stems from the introduction of technological and organizational innovations. The market value in excess of the book value, in other words, is nothing else but the capitalization of the extraprofits, beyond the normal ones, that firms earn because of the introduction of an innovation. Hence the Tobin's q is a direct measure of the effects of technological and organizational innovation upon the sheer level of firm's endowments.

In line with this theory, the relationship between market value and knowledge capital statistics has been widely investigated in order to either infer the value of intangible assets or validate the effectiveness of technological innovation proxies. Less attention has been paid to financial and organizational innovation. No attention, at all, has been paid to the appropriation of the benefits associated with the introduction of an innovation. In the pioneering works, the Tobin's q has been related to R&D investments and patent counts. More recently, new effort has been done for validating the use of patent citations. Yet, we believe that these indicators only partially grasp innovation capabilities that can be reflected in market valuation. There is a considerable literature dealing with the issue of measuring innovation and technical change. Starting from the works of Mansfield (1965) and Griliches (1984), Research and Development expenditure (R&D), patents statistics and innovation counts have been widely used in empirical investigations. Nonetheless they show some limitations. Research and development indicators provide a very limited and partial account of the actual amount of inputs that are necessary for generating new knowledge. Learning activities, and specifically learning by doing, learning by using and learning by interacting, play a key role in the generation of new technological knowledge and hence the capability to introduce technological and organizational innovations. Relevant resources are necessary to mobilize and valorize tacit knowledge acquired by means of learning processes. Firms differ consistently in the capability to use their inputs for the generation of technological knowledge and extract an output: the relative efficiency of firms in performing research activities and to use their competence acquired by means of learning processes varies systematically across firms. In addition, external knowledge is an important if not indispensable input into the generation of new knowledge by each firm. The access to the knowledge generated by third parties provides key inputs into the generation of additional knowledge. Regional and professional proximity favor the access and the absorption of external knowledge: knowledge spillovers are not distributed evenly. Firms differ widely in their capability to identify and take advantage of such inputs (Cassia et al. 2009). In sum, R&D expenses measure only a fraction of the actual innovation input as they fail to account for internal learning activities, the access to external knowledge and the efficiency in performing research activities.

In a second phase, the awareness of the limitations of R&D indicators has induced to rely upon patent counts as an indicator of the actual amount of technological innovations being introduced. Patent statistics are expected to measure the value resulting from technological knowledge generated by firms and have been used as a proxy for research and development effectiveness. Yet, it became quickly evident that patent statistics suffer from many limitations. One first drawback undermining the use of patent counts is related with the fact that not all innovations are patented. The reasons are different. First, some innovations don't meet the patentability criteria. Furthermore, firms often strategically decide not to patent, especially in the case of innovations with high level of natural appropriability. Thirdly and most important, the main limitation of patent counts is related with the high heterogeneity in patent's value. While some patented innovations succeed and have an enormous economic impact, many others became "dead-end branches". Direct quantitative measures of the composition of patent portfolio of specific firms reveal high levels of variance: only a few patents out of hundreds if not thousands do have a serious technological content. To cope with this problem and following Trajtenberg (1990), empirical analysis has started to rely on patent citations as an additional variable to grasp the individual patent's and gather further information on innovation. Despite its explanatory power in capturing innovations value, this indicator still suffers from the same limitations as patent counts.

Statistical analyses of citations, performed upon large data banks, based upon the assumption that citations may be used as a proxy of the scientific value of patents, confirm very high levels of variance: only a few patents are cited by other patents. Citations, however often measure the extent to which patent races are at work (Bessen, 2008). In particular, we believe that while patent citations is a good proxy of a patent success, it is a biased indicator of firm's performance and expected profitability. Actually, we expect that as a result of the patent race firms possessing more cited patents can not perfectly appropriate the returns of their knowledge content. For this reason, financial market should give lower value to more cited patents. In our view, this suspect is confirmed by the results in Hall et. al. (2005) that self-citation receive higher valuations in the markets than external citations. Also the paper by Megna and Kloch (1993) shows a negative impact of patent from rivals firms on Tobin's q. In addition, a common limit of R&D investments and patents statistics is that these indicators fail to account for firm's organizational and financial innovation. On the contrary, it is widely understood that stock markets give high value to both organizational and financial innovation activities.

A third phase in the applied economics of innovation has been characterized by innovation counts. Innovation counts, based upon in depth statistical surveys at the firm level, have been used mainly in Europe. They rely upon the subjective self- assessment of the flows of the innovations introduced by each firm. They provide detailed information about the characteristics of the innovation process at work within each firm, the qualitative typology of the innovations being introduced and the sources of relevant technological knowledge. They fail however to account for the quantitative effects of the introduction of innovations and provide no information on the conditions of their exploitation (Crépon, Duguet, and Mairesse, 1998).

The crucial distinction between knowledge generation and knowledge exploitation plays a central role to grasping the limitations of R&D, patent statistics and innovation counts. R&D statistics provide a partial account of the amount of resources used in the generation of new technological knowledge, patents measure to some an extent the output of such activities, innovation counts enable to better explore the sources of knowledge used by firms to innovate and the qualitative features of the innovations being introduced, but neither one provides a reliable account of the actual capability of firms to exploit the technological knowledge that has been generated. The introduction of technological innovations can affect the profitability of the firm in so far as it can retain and appropriate its benefit. The issue of appropriability is clearly central to this debate. Appropriability conditions depend on the characteristics of: A) technological knowledge and B) on the market structure and forms of competition. Firms may be able to introduce many relevant innovations but can appropriate only a small fraction of the ensuing benefits because of aggressive competitors that are able to imitate quickly the innovation, enter the market place and erode price-cost-margins. This may depend, in turn, on the characteristics of technological knowledge in terms of intrinsic barriers to imitations determined by the content of tacit knowledge and the compositeness of the knowledge base, and on the height of ex-ante barriers to entry. Innovators can appropriate larger shares of the benefits stemming from the introduction of innovations when they can enjoy the protection of existing barriers to entry that prevent competitors to start imitating.

Current indicators of knowledge capital, such as R&D statistics, innovation counts and patents do not provide any information about appropriability conditions. Actually, because citations, as well as the flows of innovations, often reflect the extent to which imitators and fast followers try and take advantage of the innovations introduced by technological leaders, patent statistics adjusted for quality measures based upon citation analysis and innovation counts risk to stress the intensity of rivalrous competition based upon the sequential introduction of innovations in the same market niche and the short duration of the lead time of leaders, hence the low levels of appropriability.

The failure of the traditional indicators of innovative output suggests to try and use total factor productivity (TFP) measures to grasp the actual extent to which firms are able both to generate and exploit technological knowledge. TFP provide a reliable measure of the extent to which firms are able to increase their output beyond the expected levels based upon the increase of inputs. The residual increases as a consequence of the introduction of innovations that enable firms to produce more output per given inputs, to sell their products at higher prices, and, in some circumstances, to take advantage of monopsonistic power in factor markets. By means of the introduction of technological innovations firms are able to increase their competitive advantage and hence to increase their price-cost-margins with further positive effects on TFP levels. Moreover TFP measures can account for the positive effects of the introduction of organizational, marketing and financial innovations. Clearly TFP measures make it possible to grasp both the capability of each firm to generate and to exploit both technological and organizational knowledge.

In this paper we investigate the usefulness of TFP as a much more reliable and comprehensive indicator of firm's innovation capabilities than R&D and patent statistics. TFP indicates the effectiveness of the production process and it is a measure of firm's competitive advantage that, in our view, should be reflected in the observed market value of the firm. We thus expect a high relation between Tobin's Q and TFP.

In so doing we rely and implement the methodology used for relating market value and R&D, patents (Griliches 1981, Jaffe 1986, Cockburn and Griliches 1988, Hall 1993, Menga and Klock 1993, Coad and Rao, 2006) and patent citations (Shane and Klock 1997, Hall, Jaffe and Trajtenberg 2005). In particular, under the hypothesis that financial market can evaluate firm's innovative efforts reasonably, we mean to understand the usefulness of TFP by observing its relationship with Tobin's q. This approach enables to appreciate from a different perspective and with a different methodology the contributions of technological change to improving the performance of firms. Thus it provides an alternative and much needed set of indicators of innovation efforts and actual innovation capability.

3. Model specification: the market value equation

The model used in this paper follows Cockburn and Griliches (1988). This model is based on the assumption that financial markets value the firm by taking into accounts both its tangible&intangible assets[2] and its knowledge capital, namely its command of technological and organizational knowledge that enables the introduction and subsequent exploitation of technological and organizational innovations. Thus, if the relationship among single assets is purely additive, the market value function can be written as follows:

$$V_{it} = b_t (A_{it} + \gamma KC_{it})^{\sigma} \qquad (1)$$

where V_{it} is the market value of the firm *i* at time *t*, A_{it} and KC_{it} its tangible&intangible assets and knowledge capital respectively, b_t is the average multiplier of market value relative to the replacement cost of total assets and γ is the shadow price of knowledge capital relative to the tangible&intangible assets of the firm. The parameter σ allows for non constant scale effects in the value function.

Dividing equation (1) by A_{it}, taking logarithms and assuming constant returns to scale (σ=1) equation (2) becomes:

$$\log(q_{it}) = \log\left(\frac{V_{it}}{A_{it}}\right) = \log b_t + \log\left(1 + \gamma \frac{KC_{it}}{A_{it}}\right) \qquad (2)$$

[2] Tangible&intangible assets include all assets of the firm, both tangible and intangible. Intangible assets include goodwill and costs in excess of net assets purchased, patents, copyrights etc., but exclude R&D expenditures. In Cockburn and Griliches (1988) and subsequent works, these assets are referred to as tangible capital or tangible assets. Hall et al. (2005) name them physical capital. In empirical analyses then different approaches are used in order to compute this variable: total fixed assets is used in Cockburn and Griliches (1988); net plant and equipment, inventories, and investments in unconsolidated subsidiaries, intangibles, and other in Hall et al. (2005); sum of property, plant, and equipment, inventory, and net working capital in Megna e Kloch (1993); total tangible assets in Hall and Oriani (2006). We chose the tangible&intangible assets definition for stressing that in our model we mean to include both tangible and intangible assets.

where log(q) is the log of Tobin's q and the intercept can be interpreted as an estimate of the logarithmic average of Tobin's q for each year. Following previous works (Griliches, 1981, Jaffe, 1986, Cockburn and Griliches, 1988, Hall, 1993), we consider the approximation $\log(1+x) \approx x$ when x is small. The estimating equation thus becomes:

$$\log(q_{it}) = \log\left(\frac{V_{it}}{A_{it}}\right) = \log b_t + \gamma\left(\frac{KC_{it}}{A_{it}}\right) + \varepsilon_{it} \qquad (3)$$

which can be estimated using ordinary least squares.

In previous empirical works, the market value equation has been estimated using various measures of knowledge capital, such as R&D investments, patent stocks and patent citations. In this paper, we use TFP, which is known to be at the same time a function of both R&D and patents activities, and a good measure of the capability of the firm to exploit its technological knowledge, in order to proxy for knowledge capital in equation (3). We assume that this is a more comprehensive measure of the firm's innovation capability. While R&D and patents statistics only measure the firm's capability of generating technological knowledge, TFP is able to appraise for the capability to generate and exploit technological, organizational and financial innovations. With the aim of capturing the importance of TFP as a proxy for knowledge capital, in the empirical analysis we also control for firm's R&D investments.

4. Empirical investigation

4.1 Dataset

The sample selection has involved the main issue of the financial market choice. Anglo-Saxon and continental Europe markets are rather different: they need to be analyzed separately. Previous studies relating market value and R&D confirm that attention is required and market specificities need to be taken into account (see Hall and Oriani 2006, Bloch 2008). In this paper we use a panel dataset of firms which are publicly traded in

UK, Germany, France and Italy. For all the countries, the period of observations goes from 1995 to 2005. Our prime source of data for both market and accounting data is Thomson Datastream. We pooled the dataset by adding also information at the industry level from the Groningen Growth and Development Centre[3].

Our final dataset consist of an unbalanced panel of 6064 active companies, 1165 in UK, 4037 in Germany, 621 in France and 241 in Italy. Sample firms operate in all sectors of the economy and have been classified according to the Groningen Growth and Development Centre 10-sector classification which is based on the ISIC revision 3 one. As Thomson Datastream use the ICB industry classification at the four-digit level, in Appendix 1 we provide the sectoral concordance used to link the three classifications.

Table 1 reports the sample distribution by country and industry. Manufacturing covers about 41% observations in UK and more than 50% observations in Germany, France and Italy. Finance, Insurance, and Real Estate companies are also highly represented in our sample (about 32% observations in UK, 27% in France, 17% in Germany and 14% in Italy), while each of the other economic groups includes around or less than 10% observations in each country.

4.2 Variables definition and measurement methods

The dependent variable in the market value equation is the natural logarithm of Tobin's q, which is measured as the ratio between market value and the book value of tangible&intangible assets. The market value should be calculated as the sum of the firm's market capitalization and the market value of its debt. Since data on the market value of debt are often not available, similarly to previous studies on European countries (Blundell et al., 1992, 1999; Hall and Oriani, 2006; Bloch, 2008) we add the nominal value of long term debt to market capitalization to proxy for market value. Market capitalization is computed as the product between common shares outstanding and market price at year end. The book value of the tangible&intangible assets is computed as the sum of property, plant and equipment - net of accumulated reserves for depreciation,

[3] These data were originally published and described in Van Ark (1995).

depletion and amortization - inventories and intangible assets. The replacement costs have been computed using the perpetual inventory method. Starting from 1995, the first year available accounting data are used as actual replacement values. The subsequent yearly values are computed using a depreciation parameter of 6.5% and adding yearly capital expenditure, adjusted using sectoral deflators.

Our proxy for knowledge capital is total factor productivity. We summarize the procedure adopted in the production function estimation in what follows.

We assume the two-factor Cobb-Douglas production function as follows:

$$Y_{it} = TFP_{it} L_{it}^{\beta} A_{it}^{\alpha} \qquad (4)$$

where Y_{it} is deflated sales, where the deflator is the industry one, while L_{it} and A_{it} are the number of employees and capital stock, respectively. The capital stock has been computed using the perpetual inventory method and equals A_{it} used in the market value equation. TFP_{it} is the total factor productivity.

Transforming equation (4) in logarithms allows linear estimation of the production function:

$$y_{it} = \beta l_{it} + \alpha a_{it} + \omega_{it} + \eta_{it} \qquad (5)$$

The residual of equation (5) represents total factor productivity.

In order to estimate $\hat{\beta}$ and $\hat{\alpha}$ in equation (5), we apply the Olley and Pakes (1996) approach that allows to solve both endogeneity and selection problems. This approach has some advantages over a fixed-effect. First, while a fixed-effect estimator uses only the across time variation, Olley and Pakes estimator leaves more variance in the estimation, since it uses also the cross-section information. Second, as the assumption that ω_{it} is fixed over time may not always be reasonable, OP introduces an explicit behavioral hypothesis in the estimation procedure by looking at the investment decision as the solution of a dynamic optimization problem.

Following Olley and Pakes (1996), we consider an invertible investment function $i(a_{it}\,\omega_{it})$ and its inverse function $h(i_{it}\,a_{it})$. In order to identify the β parameter, in the first step we run an OLS on the following equation:

$$y_{it} = \beta l_{it} + \phi_t + \eta_{it} \qquad (6)$$

where ϕ_t is an (unknown) function in a_{it} and i_{it} approximated by 3rd and 4th order polynomials in log-investment and log-capital defined as follows:

$$\phi_t = \alpha a_{it} + h(i_{it} a_{it}) \qquad (7)$$

In the second stage, we estimate the following equation by non-linear least squares:

$$V_{it} = y_{it} - \hat{\beta} l_{it} = \alpha a_{it} + g(\phi_{t-1} - \alpha a_{t-1}) + \mu_{it} + \eta_{it} \qquad (8)$$

where g is an unknown function of lagged values of ϕ and a.

After estimating $\hat{\beta}$ and $\hat{\alpha}$ in the first and second stage respectively, we can fit equation (4) and find the residual which represents the logs of firm TFP.

To control for the reliability of the estimates, we also calculated the coefficients $\hat{\beta}$ and $\hat{\alpha}$ under the assumptions of constant returns to scale in production. We thus computed $\hat{\beta}$ using a fixed effect estimator and took $\hat{\alpha}$ as its complement to 1. Estimated values of $\hat{\beta}$ and $\hat{\alpha}$ are presented in Table 2. As expected, the Olley and Pakes procedure tends to yield a higher labor coefficient and a smaller capital one. In the case of Germany the estimation method makes little difference while in the case of Italy the differences are more marked. Apart from these differences, the two methods give broadly consistent results, an indication of the reliability of the estimates. In what follows we do use Olley and Pakes estimations.

We now turn to the market value model specified in equation (3). We assume that total factor productivity is a function of knowledge capital as the following:

$$TFP_{it} = f(KC_{it}) \qquad (9)$$

Our final estimating equation thus becomes:

$$\log(q_{it}) = \log\left(\frac{V_{it}}{A_{it}}\right) = \log b_t + \lambda\left(\frac{TFP_{it}}{A_{it}}\right) + \nu_{it} \qquad (10)$$

where λ is the coefficient of the ratio between TFP_{it} and A_{it} and substitutes γ, which is the coefficient of the ratio KC_{it} / A_{it} in equation (3).

In order to understand the usefulness of TFP as a measure of knowledge capital with respect to more traditional measures, we run additional regressions also including R&D investments as a control variable. Following Griliches and Mairesse (1984) and Hall (1990), we compute the measure of R&D capital as a perpetual inventory of past and present annual R&D expenditures, R, as follows:

$$R\&D_{it} = (1-\delta)R\&D_{it-1} + R_{it} \qquad (11)$$

where δ is a constant depreciation rate of 15%[4]. The first year values have been computed by using the first year available accounting data as in the following equation:

$$R\&D_t^0 = \left(\frac{1+g}{g+\delta}\right)R_t^0 \qquad (12)$$

We have assumed a constant annual growth rate, *g*, of 8%[5].

Finally, we have also included a set of control variables, specifically logarithm of sales and both year and industry dummies.

Descriptive statistics are presented in Table 3. While the statistics for Tobin's q logarithm are quite similar across countries, with the exception of Italy reporting a lower value than other countries, the mean values of the ratio between TFP and tangible assets differ. In particular, the mean values for UK and Italy are far lower than values for Germany and France. For each country, companies which report R&D expenses are only a fraction of the whole sample. In the empirical analysis we, thus, run regressions for both the entire sample and the sub-samples of R&D reporting firms. Statistics for the R&D/A ratio are similar for UK and Germany, and also France while Italy shows a low level of R&D expenditure per assets with comparison to the other countries.

5. Results

Table 4 presents the correlation matrix while the results of the econometric estimations are shown in Table 5 and 6. As it appears from the correlation matrix, no high correlations are found among the variables included in the empirical model. Table 5 presents the results of ordinary least squares (OLS) estimations for the baseline model in equation 10. In Table 6 results for the sub-sample of R&D reporting firms are shown. For each country, the first column presents the results of the basic equation while column 2

[4] While the depreciation rate value makes little difference in empirical estimations (see Griliches and Mairesse (1984) for details), a 15% depreciation rate is the most common value used in the literature.

[5] As described in Hall and Oriani (2006), different assumptions on g do not significantly affect the results

includes the ratio R&D/A as a control variable. All estimations in both Table 5 and 6 include the logarithm of sales, year dummies and industry fixed effects. When considering the sub-sample of R&D reporting firms, the values of adjusted R-squared range from 0.130 to 0.375. This is in line with previous analysis dealing with the market value equation estimation and R&D expenditure.

As already mentioned, we proxy knowledge capital by means of TFP. This measure shows a positive and highly significant impact on market value for both the estimations in each country. Results in Table 5 for each country confirm our idea that TFP can be considered a good indicator of the value of technological knowledge that each firm command and feed the introduction of technological, financial and organizational innovations and that it captures those aspects of the innovation process which are reflected in firm's market value. The magnitude of TFP/A coefficients is quite diverse among the different countries. In the baseline equation it goes from 6.926 for Germany to 8.550 in France, 13.36 in UK, and 3149 in Italy. The higher is the ratio between TFP and the other tangible&intabgible assets, the lower is the TFP/A coefficient in the market value equation, representing the relative shadow value of knowledge capital.

When we focus on the sub-sample of R&D reporting firms previous results are confirmed (Table 6, column 1). When we include the ratio R&D/A in our estimations (Table 6, column 2), TFP still shows a strong positive and highly significant impact on market value. Thus, when we control for the effect of R&D investments on market value, there is still a fraction of the knowledge capital which is not captured by the most common used proxy, i.e. R&D. This fraction is captured by TFP. This result confirms that TFP is a broader and more comprehensive measure of the firm's innovation capability than R&D.[6]

Our interpretation of these results is the following. The Tobin's q measures the effects of technological, financial and organizational innovation upon the firm's value. The well known relationship between the Tobin's q and R&D investments suggests that R&D

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[6] We also run regressions including the ratio between intangibile assets and A as a control variable. Both TFP/A and R&D/A remained highly significant for each country. Also the ratio between intangible assets and A turned out to be positively and significantly related to Tobin's q.

statistics account for the resources used in the generation process of technological innovation. TFP grasps the remaining effects of both the generation and the exploitation of technological, financial and organizational innovation.

Finally, as Tobin's q is a forward looking measure while on the other hand TFP is procyclical, it seems appropriate to check for intertemporal consistency by including the lagged values of TFP in our analysis. Results of regressions including the lagged variable were consistent to our previous results (Table 7). This confirms the robustness of our analysis.

6. Conclusions

Tobin's q captures the effects of the dynamics of capitalization in stock markets engendered by the introduction and exploitation of technological and organizational innovations. The stock markets capitalize the extraprofits that successful innovators are able to appropriate and transform them in 'extracapital'. The dynamics of capitalization in the stock markets, in other words, enables to restore equilibrium conditions that fail to apply in product and factor markets after the introduction of an innovation, when and if the innovator is able to exploit successfully its innovation and appropriate a share of the overall benefits. Tobin's q measures the extent to which financial markets are able to restore the equilibrium conditions that the introduction of innovations alters in product and factor markets.

TFP and Tobin's q are the result of the same analytical construct: i.e. the comparison between abstract equilibrium conditions and actual historic ones. TFP measures the capability to exploit innovation, both technological and organizational and financial. Tobin's q is an indicator of the market value equation that grasps firm's expected economic results of innovation activities. So far Tobin'q is nothing else than the measure of the effects of the introduction and exploitation of technological and organizational innovation on the profitability of firms and hence a direct measure of the value that financial markets, via the capitalization of extraprofits, attribute to knowledge capital.

In other words, these two indicators are two sizes of the same coin. TFP is a measure of the extent to which firms are able to increase their output beyond the expected levels as a consequence of the introduction and exploitation of both technological and organizational innovations. Tobin's q measures the market value in excess of the book value that arises from the introduction of innovations. TFP accounts for firms' capability to increase their price-cost-margins while Tobin's q accounts for firms capability to generate extraprofits.

Following this idea, this paper has articulated and tested the hypothesis that TFP contains and provides valuable information on the actual amount of technological and organizational innovation introduced and actually exploited by each firm that is not captured by R&D and patent statistics, as such TFP indicators perform much better to explain the divergence between the book and the market value of public companies. Tobin's q in fact measures the capitalization of the extraprofits of firms that have been able to generate and exploit technological and organizational innovations. In the empirical analysis, we have explored the Tobin's q and TFP relationship for a panel of companies which are publicly traded in UK, Germany, France, and Italy for the period going from 1995 to 2005. In order to validate the relationship between the two indicators and to infer the usefulness of TFP as a proxy for firm's innovation activities, we have relied on the market value function.

Our findings have confirmed that the TFP is a good proxy for knowledge capital assets and that it goes beyond R&D investments in measuring firm's innovation capability. In, sum, the results of the empirical analysis have tested the hypothesis that the discrepancy between the book and the market value of public companies is caused by the amount of technological and organizational knowledge that a firm is able to command and to exploit. The validation of the relationship between the Tobin's q and TFP has important implications concerning the measurement of firm's innovative capabilities.

Important policy implications can be drawn from these results. Private companies, whose shares are not traded in the stock markets, are likely to experience the limits of credit rationing and in any event higher costs of external funds. Hence the funding of R&D

activities and at large of innovative undertaking is constrained by internal cash flow (Bloch, 2005; Magri, 2009). Stock markets perform a key role in the direct appreciation of the actual effects of the increase of total factor productivity and hence of the introduction and successful exploitation of technological and organizational innovations. Public companies can take advantage of the dynamics of capitalization and the increasing value of the Tobin'q to attract additional financial resources and hence to fund additional research activities.

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Table 1 - Firms and observations by country and industry

	UK			*Germany*			*France*			*Italy*		
	Firms	*Obs.*	*% Obs.*	*Firms*	*Obs.*	*% Obs.*	*Firms*	*Obs.*	*% Obs.*	*Firms*	*Obs.*	*% Obs.*
Agriculture, Forestry, and Fishing	8	73	0.89	18	96	0.42	7	54	1.18	2	22	1.22
Mining and Quarrying	42	215	2.61	85	349	1.54	7	62	1.36	0	0	0
Manufacturing	457	3385	41.09	2257	13525	59.60	291	2358	51.62	133	1069	59.09
Public Utilities	17	136	1.65	117	703	3.10	13	73	1.60	18	126	6.97
Construction	29	271	3.29	61	411	1.81	12	93	2.04	7	61	3.37
Wholesale and Retail Trade, Hotels and Restaurants	104	851	10.33	226	1372	6.05	48	361	7.90	9	62	3.43
Transport, Storage, and Communication	75	487	5.91	306	1652	7.28	36	254	5.56	28	190	10.50
Finance, Insurance, and Real Estate	402	2624	31.85	851	3960	17.45	194	1227	26.86	41	259	14.32
Government Services	7	53	0.64	65	366	1.61	6	40	0.88	0	0	0
Community, Social and Personal Services	24	143	1.74	51	260	1.15	7	46	1.01	3	20	1.11
Total	1165	8238	100	4037	22694	100	621	4568	100	241	1809	100

Table 2 - Production factor elasticities:

	UK			*Germany*			*France*			*Italy*		
	β	α	$\alpha+\beta$	β	α	$\alpha+\beta$	β	α	$\alpha+\beta$	β	α	$\alpha+\beta$
Olley and Pakes	0.62	0.32	0.93	0.36	0.61	0.97	0.53	0.15	0.68	0.55	0.39	0.94
FE under HP constant returns	0.55	0.45	1.00	0.37	0.63	1.00	0.50	0.50	1.00	0.38	0.62	1.00

Note: α is the capital coefficient and β the labour one.

Table 3 - Descriptive statistics

	UK			*Germany*			*France*			*Italy*		
	obs.	*mean*	*std. dev*	*obs.*	*mean*	*std. dev*	*obs.*	*mean*	*std. dev*	*obs.*	*mean*	*std. dev*
log(q)	8238	0.966	1.316	22694	0.966	1.246	4568	0.719	1.192	1809	0.479	0.971
TFP/A	8238	0.0003	0.006	22694	0.002	0.0165	4568	0.003	0.021	1809	0.00002	0.0001
R&D/A	2920	0.951	1.832	11829	0.952	1.715	1160	0.861	1.627	605	0.457	0 .802
Ln(S)	8238	15.598	2.772	22694	13.650	3.311	4568	16.763	2.582	1809	17.682	2.479

Table 4 – Correlation matrix

	UK				*Germany*				*France*				*Italy*			
	log(q)	TFP/A	R&D/A	Ln(S)	log(q)	TFP/A	R&D/A	Ln(S)	log(q)	TFP/A	R&D/A	Ln(S)	log(q)	TFP/A	R&D/A	Ln(S)
log(q)	1				1				1				1			
TFP/A	0.188	1			0.095	1			0.353	1			0.275	1		
R&D/A	0.419	0.178	1		0.479	0.067	1		0.506	0.307	1		0.510	0.289	1	
Ln(S)	-0.261	-0.189	-0.320	1	-0.336	-0.121	-0.436	1	-0.210	-0.384	-0.367	1	-0.187	-0.490	-0.299	1

Table 5 – Basic market value OLS regression with dependent variable=log (q)

	UK	*Germany*	*France*	*Italy*
VARIABLES	(1)	(1)	(1)	(1)
TFP/A	13.36***	6.926***	8.550***	3149***
	(2.315)	(0.478)	(0.787)	(395.7)
Ln(S)	-0.0551***	-0.0774***	-0.00428	-0.0172*
	(0.00531)	(0.00247)	(0.00698)	(0.00927)
Constant	2.127***	1.923***	0.931***	0.00894
	(0.200)	(0.0858)	(0.224)	(0.241)
Time dummies	yes	yes	yes	yes
Industry dummies	yes	yes	yes	yes
Observations	8238	22694	4568	1809
Adj R-squared	0.085	0.113	0.116	0.171

*** $p<0.01$, ** $p<0.05$, * $p<0.1$
Standard errors in parentheses

Table 6 – Market value OLS regression with dependent variable=log (q) and control variable R&D/A

	UK		*Germany*		*France*		*Italy*	
VARIABLES	(1)	(2)	(1)	(2)	(1)	(2)	(1)	(2)
TFP/A	382.3***	216.2***	5.795***	5.133***	91.80***	48.65***	14411***	8379***
	(43.27)	(39.27)	(0.885)	(0.816)	(9.114)	(8.756)	(3156)	(2950)
R&D/A		0.317***		0.284***		0.288***		0.509***
		(0.0119)		(0.00624)		(0.0187)		(0.0482)
Ln(S)	-0.0694***	-0.0107	-0.103***	-0.0461***	0.0234**	0.0529***	-0.0290*	-0.0101
	(0.00747)	(0.00705)	(0.00313)	(0.00315)	(0.0110)	(0.0102)	(0.0175)	(0.0162)
Constant	0.375	-0.481	2.804***	2.031***	-0.434	-0.277	0.0644	-0.232
	(1.165)	(1.042)	(0.130)	(0.122)	(0.365)	(0.333)	(0.704)	(0.647)
Time dummies	yes	yes	yes	yes	yes	yes	yes	yes
Industry dummies	yes	yes	yes	yes	yes	yes	yes	yes
Observations	2920	2920	11829	11829	1160	1160	605	605
Adj R-squared	0.130	0.302	0.162	0.287	0.245	0.375	0.198	0.326

*** p<0.01, ** p<0.05, * p<0.1
Standard errors in parentheses

Table 7 – Market value OLS regression with dependent variable=log (q) and [TFP(t-1)/A(t-1)] as independent variable

	UK	*Germany*	*France*	*Italy*
VARIABLES	(1)	(1)	(1)	(1)
TFP(t-1)/A(t-1)	45.20***	9.898***	8.930***	3475***
	(6.199)	(0.733)	(0.896)	(339.0)
Ln(S)	-0.0413***	-0.0721***	0.0111	-0.00684
	(0.00586)	(0.00277)	(0.00751)	(0.0105)
Constant	0.874***	0.814***	0.254	-0.165
	(0.187)	(0.143)	(0.230)	(0.269)
Time dummies	yes	yes	yes	yes
Industry dummies	yes	yes	yes	yes
Observations	7230	19125	4051	1601
Adj R-squared	0.078	0.105	0.108	0.169

*** p<0.01, ** p<0.05, * p<0.1
Standard errors in parentheses

Appendix 1 - Sectoral concordance table

Sector name	Groningen Growth and Development Centre 10-sector database	Datastream	STAN
Agriculture, Forestry, and Fishing	01-05	1733, 3573	45, 01-02
Mining and Quarrying	10-14	1771-1779	10-12, 13-14
Manufacturing	15-37	533-587, 1353,1357, 1737-1757, 2353, 2713-2757, 3353-3537, 3577-3726, 3743-3785, 4535-4577, 5557, 5752, 9572-9578	5,15-36
Public Utilities	40-41	7535-7577	40-41
Construction	45	3728, 2357	45
Wholesale and Retail Trade, Hotels and Restaurants	50-55	2797, 5333-5379, 5753, 5757	51-55
Transport, Storage, and Communication	60-64	2771-2779, 5553, 5751, 5759-6575	60-63, 64
Finance, Insurance, and Real Estate	65-74	2791-2795, 2799, 5555, 8355-9537	65-70, 71-74
Government Services	75-85	4533	85
Community, Social and Personal Services	90-99	5377, 5755	80,90-93