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Department of Economics and Statistics "Cognetti de Martiis"
Campus Luigi Einaudi, Lungo Dora Siena 100/A, 10153 Torino (Italy)
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OUT OF EQUILIBRIUM AND INTANGIBLE ASSETS

CRISTIANO ANTONELLI, GIANLUCA ORSATTI and GUIDO PIALLI

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OUT OF EQUILIBRIUM AND INTANGIBLE ASSETS

Cristiano Antonelli, Università degli Studi di Torino & Collegio Carlo Alberto.

Gianluca Orsatti,[1] Università degli Studi di Torino

Guido Pialli, University College London

ABSTRACT

The new evidence provided by the codification of intangible assets in national accounts and firm statistics offers the opportunity to test the Schumpeterian creative response hypothesis that: i) the generation and exploitation of knowledge are characterized by high levels of risk; ii) firms in equilibrium are reluctant to undertake risky activities; iii) the farther away from equilibrium conditions, the stronger the commitment to innovation efforts by firms iv) that are heterogeneous in their reactivity and entrepreneurship levels. Empirical evidence for US listed companies over the period 1977-2016 confirms a U-shaped relationship between out-of-equilibrium performance and growth in the intensity of intangible capital. Entrepreneurship levels, measured by the extent of the firm creative response, differs with firm size, age, and industry. Precisely, we estimate a deeper U-shaped relationship between performance and growth in intangibles intensity for small and young firms and, on average, for firms in high-tech industries. Our results are robust to different econometric tests performed on alternative samples, and we also propose an original instrumental variable strategy that further strengthens the validity of our results. We conclude that the firm creative response is an out-of-equilibrium phenomenon, stronger in the case of disappointing performances and sharper for small, young, and high-tech firms.

KEY-WORDS: UNCERTAINTY AND RISKS; CREATIVE RESPONSE; OUT-OF-EQUILIBRIUM AND INNOVATION; ENTREPRENEURSHIP.

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[1] Corresponding author. gianluca.orsatti@unito.it

1. INTRODUCTION

The reform of national accounting rules, appreciating the enduring contribution of an extensive array of intangible assets, offers new opportunities to explore the determinants of innovation efforts. Intangible assets include the full array of firms' innovation efforts and represent a profound transformation in the US economy (Corrado, Hulten and Siegel, 2009; Haskel and Westlake, 2018). Corrado, Hulten and Sichel (2005) observed that traditional accounting data excluded more than $3 trillion of intangible assets from the standard capital stock measure. By including intangible capital in growth accounting, they showed that capital deepening is the main source of productivity growth.

This paper formulates and tests the hypothesis that firms in equilibrium are reluctant to commit resources to the high-risk activities required to introduce innovations. Firm knowledge, described as intangible capital in the firm's balance sheet, is accumulated through the firm's intentional decision to innovate to confront out-of-equilibrium position in its level of performance.

Historically, research on the determinants of innovative activity, at the firm and system levels, is categorized in the literature as either New Growth theory or evolutionary blind rule of thumb. New evidence showing the importance of intangible capital enables us to test the Schumpeterian hypothesis of innovation as an intentional response to out-of-equilibrium conditions in both product and factor markets (Schumpeter, 1947a, 1947b). In a Schumpeterian framework, innovation activities are implemented by firms that want to innovate to cope with performance that is below or above equilibrium, while firms in equilibrium are reluctant to invest in such efforts.

We test the hypothesis that the rate of increase of intangible capital intensity is higher when firm performance is either very low or very high. Moreover, we study the heterogeneity in the magnitude of the firm's creative responsiveness (or level of entrepreneurship), based on firm size, age and industry. On the one hand, if performance falls below a minimum threshold the firm will react by investing in innovative activities and trying to change its product mix (Antonelli, 1989). On the other hand, the liquidity provided by excess and extra-profits can be used to fund further innovative activities to cope with transient monopolistic rents (Kurz, 2008).

This paper makes two contributions. First, the existing literature provides a great deal of evidence on the effect of innovation on firm performance (Geroski, Machin and Van Reenen, 1993; Aghion et al., 2005; Lööf and Heshmati, 2006), but only a few papers study the inverse relationship and investigate whether firm performance affects firm innovation efforts. We draw on the Schumpeterian notion of creative response and on the insights from prospect theory (Kahneman and Tverski, 1979) to propose an analytical framework to investigate the role of out-of-equilibrium performance in determining firm innovation efforts.

Second, we use an original database to investigate the firm's decision to invest in intangible assets. Extant empirical studies analyse the firm's propensity to use intangible capital based on survey data or balance sheet intangible assets, and cross-section analyses (Arrighetti, Landini and Lasagni, 2014; Montresor and Vezzani, 2016). In the present paper, we rely on a sample of 5,874 US listed companies observed over the period 1977-2016, for which we exploit financial data extracted from the Compustat database, complemented by data on intangible capital, including research and development, organizational capital and externally purchased intangible assets (Ewens, Peters and Wang, 2020). Hence, we examine the firm's investment in intangible capital over a long-time horizon, including the capitalization of internally created intangible assets that are not directly accounted for in balance sheets.

Our results show a robust U-shaped relationship between firm performance and the growth of intangible capital intensity. Small, young, and high-tech firms show the highest levels of responsiveness to out-of-equilibrium conditions. Indeed, small, young and high-tech firms that try to access external funds to finance innovation efforts face high transaction costs when in equilibrium. This is due to the reluctance of financial markets to bear the costs of uncertainty, which applies more severely to small firms and firms operating in sectors characterized by high profit volatility (Panagiotidis and Printzis, 2021).

We test the robustness of our results to alternative samples and by performing different econometric exercises. Then, to further challenge possible endogeneity issues, we propose an original instrumental variable strategy that strengthens the validity of our main findings.

The remainder of the paper follows a common structure. Section 2 discusses the basics of the three contending theoretical approaches and formulates the main working hypothesis of the paper. Section 3 describes the database and the empirical strategy. Section 4 reports and discusses the main results and the robustness tests. Section 5 concludes.

2. THE DETERMINANTS OF INNOVATION EFFORTS

The analysis of knowledge as an economic good is a rich field of investigation. The identification of knowledge as an essential innovation input paved the way for a large and successful literature. Fundamental to the analysis of the determinants of firms' innovation efforts is the notion of limited appropriability of knowledge, originally proposed by Nelson (1959) and Arrow (1962). Nelson (1959) distinguishes between the private and social benefits of knowledge as an economic good. Arrow (1962) extends this analysis by recognizing that inventors cannot appropriate all economic returns from the knowledge they generate. Here, the limited appropriability of knowledge reduces the incentive to produce new technological knowledge, leading to undersupply of knowledge. In contrast, the technology production function elaborated by Griliches (1979 and 1992) focuses on the positive effects stemming from the inability to retain all the knowledge returns. The knowledge that is not appropriated by its inventors spills over into the system and benefits third parties.

The distinction made by Nelson (1959) between the social and private benefits of knowledge – together with the role of knowledge in the production of other economic goods – led to the emergence of the New Growth theory and of the idea of the endogenous character of innovation activities. Technological knowledge enters the technology production function as an input alongside tangible capital and labour. In this context, firms are supposed to be fully aware of the partial appropriation of the knowledge output and, therefore, to select the optimal amount of technological knowledge that maximizes their innovation efforts. The intrinsic uncertainty of innovation activities and, specifically, the high levels of risk associated with the generation and exploitation of knowledge are ignored. According to the New Growth theory, firms handle the generation and exploitation of knowledge as if they were standard economic activities. Therefore, the New Growth theory assumes that firms maximize the resources invested in innovation efforts, pricing that a substantial portion of the knowledge outcomes of their efforts will benefit the rest of the system due to the limited appropriability of knowledge. The part of the output elasticity of knowledge that the firm cannot appropriate is considered a positive, but unintended effect, which accounts for the increased total factor productivity (Romer, 1986). Long-run growth of advanced economies is shown to depend on past stocks of accumulated knowledge, which spill over to the rest of the system in the form of knowledge externalities (Grossman and Helpman, 1991; Aghion and Howitt, 1992).

This outcome is positive but suboptimal and, at the aggregate level, there is an undersupply of innovation efforts. In other words, the maximization at the firm level does not yield the desired level of innovation efforts at the system level. This is because the private incentives to support innovation activities are lower than the social incentives. Therefore, the outcome of firm level maximization does not coincide with system level maximization.

The New Growth theory provides a consistent framework for the analysis of the determinants of total factor productivity at the aggregate level. However, at the firm level, the New Growth theory is less able to capture what determines the large variance of changes in the levels and in the growth rates of total factor productivity across time, firms, sectors and regions. As the so-called second generation models acknowledge, a semi-exogenous account of the effects of innovation seems necessary. Their implications for the analysis of the determinants of innovation efforts, however, have not been elaborated (Jones, 1995; Ang and Madsen, 2011).

Indeed, the New Growth theory assumes that firms have the capabilities required to assess the portion of the output elasticity of knowledge that can be appropriated, and the actual cost of generating knowledge. Maximization requires that firms possess full information, which enables them to balance the costs and benefits of producing knowledge, by comparing wages, capital expenditure on rents and knowledge costs to their respective outputs.

Early evolutionary theorizing implements an opposite view: firms are spontaneous and automatic innovators. The generation of knowledge is the spontaneous outcome of learning processes implemented by routines that enable the accumulation of competence and, eventually, provide the capability to innovate. In the early evolutionary approaches, firms are blind to the changing conditions in product and factor markets. Relative product and factor prices matter only ex-post: they shape the selection of specific techniques in the selection phase, but do not affect the differential rates of technological change and knowledge pools of firms (Nelson and Winter, 1982). All firms continuously try to innovate and commit resources to innovation activities based on a rule of thumb (Dosi and Nelson, 2010).

These automatic and blind innovative efforts are not equally successful for all firms: some firms are better able to introduce productivity-enhancing innovations whereas others are able to produce only novelties. A variety of factors such as location, age, past innovation records and human capital endowments have been identified as important determinants of success in producing innovations for given levels of blind innovation efforts (Audretsch, 1998; Acs et al., 2009).

The pervasive effect of Generalized Darwinism and its application in evolutionary economics have been used to identify the role played by selection mechanisms, which allow the marketplace to identify and sort novelties that do not increase total factor productivity, from real innovations (Aldrich et al., 2008; Hodgson, 2019). However, the reliance of evolutionary economics on Generalized Darwinism has impeded the identification of the mechanisms enabling the reproduction of variety and, specifically, the determinants of the wide variety of both innovation efforts and innovation outcomes across firms.

Recent advances in the economics of knowledge allow a better understanding of the intentional decision making that is requested to generate new knowledge and innovate. The high levels of risk – almost radical uncertainty – that characterize both the generation and exploitation of technological knowledge and the appropriation of its economic benefits are now better clear. Analyses of the generation of knowledge reveal the quasi-radical uncertainty of this activity in terms of i) outcomes, ii) timing and iii) content. The outcome of a research project is uncertain: the project may fail or it may succeed, within an often unpredictable time frame, and deliver a result that could be different from the original goal and from what the firm was looking for (Foster and Metcalfe, 2012; Cantner, 2016; Massenot and Pettinicchi, 2018). It is difficult to foresee either the timing of the output of the resources invested in the generation of new knowledge or its scope of application and use. There is a large body of empirical evidence on the pervasive role of serendipity in managing the research process which makes its outcomes unpredictable (Amoroso, Moncada-Paternò-Castello and Vezzani, 2017).

This new understanding of the high level of risk associated to the generation of knowledge, which is close to uncertainty, adds to the common knowledge appropriation risks. The appropriation risks depend on two factors: first, the extent to which rivals imitate the innovation or take advantage of its knowledge base to produce further innovations; second, the rate of decline of the rents stemming from the innovation (Arrow, 1962 and 1969).

The joint assessment of knowledge generation and knowledge exploitation risks explains why firms in equilibrium are reluctant to engage systematically in innovation activities. Risk aversion matters: firms in equilibrium may have occasional opportunities to innovate but will be hesitant about committing resources to efforts to change their products and processes, involving activities that are highly risky and border on uncertainty (Hirshleifer, 1961; Antonelli, 2019).

The limits of financial markets and frequent credit rationing further curb the capability of, especially, small firms in equilibrium conditions to invest resources in intangible and risky activities such as the generation of new technological knowledge and its exploitation *via* the introduction of innovations (Freel, 2007; Savignac, 2008).

The distinction between uncertainty and the Knightian notion of risk as "measurable uncertainty" is key (Knight, 1921). While an economic agent may know the probability distribution of the events in a risky situation, uncertainty entails insufficient information which hinders decision making. Consequently, firms in equilibrium conditions have few incentives to invest resources in uncertain activities with unpredictable outcomes, whose specific *a priori* probability distribution is unknown. Recent and growing evidence confirms that the firm's decision to invest in knowledge is hampered by the uncertainty surrounding its returns (Hirshleifer, 1961; Czarnitzki and Toole, 2011; Hussinger and Pacher, 2019; Montresor and Vezzani, 2022; Lee et al., 2023).

Knowledge and innovation are strictly sequential and complementary: no innovation can be introduced without previous generation of new knowledge. The assessment of the high levels of risk that characterize the generation and exploitation of technological knowledge calls for the elaboration of an analytical framework where innovation is neither the outcome of an optimization procedures, as in the New Growth theory, nor the by-product of automatic, spontaneous blind decision making, as in the early evolutionary vision.

Schumpeter's two major contributions in this context are "Theoretical problems of economic growth" and "The creative response in economic history", both published in 1947 in the *Journal of Economic History*. They provide the essential elements required to articulate a comprehensive evolutionary approach that impinges upon the Lamarckian legacy. In this "second generation evolutionary approach" firms engage intentionally in innovation efforts as a creative response to conditions of imbalances in both factor and product markets.

The two 1947 papers by Schumpeter generalize the basic intuitions in *Capitalism Socialism and Democracy*, according to which firms innovate to cope with: i) changing conditions in their context of action, including changes in factor and product markets; ii) all out-of-equilibrium conditions as drivers of innovation efforts (Antonelli and Scellato, 2011).

The creative response framework developed by Schumpeter in his 1947 essays provides a context that combines the assessment of the intentional decision making in relation to innovation activities and the recognition of the specific external conditions that push firms to engage in hazardous activities and allow them to generate new technological knowledge required to produce innovations (Antonelli, 2017a, 2017b and 2018).

Firms decide about how much knowledge they want to generate to innovate as a response to out-of-equilibrium conditions in factor and product markets. Firms make plans based on expectations that are not always fulfilled about the (realized) product and factor market conditions. Firms are myopic about unexpected events and, therefore, are induced to react actively to situations that either threaten their survival or present opportunities to enhance their competitive position. Operationally, out-of-equilibrium conditions occur if the firm performance is enough either above or below the average performance, resulting in either losses or accumulation of extra profits.

Firms in equilibrium have instead no incentive to engage in innovation efforts or to commit resources to fund the introduction of innovations. Financial markets are reluctant to provide the funding required and managers are hesitant about undertaking risky, quasi-uncertain ventures. In contrast, firms in out-of-equilibrium conditions will try to innovate to either survive, in the case of losses, or take advantage of internally available excess liquidity, in the case of large profits.

Let us explore this in more detail by applying the tools of prospect theory (Kahneman and Tversky, 1979). Firms – and agents in general – fear the risks of losses more than they appreciate the chances of profits. Below average performance and actual losses push the firm to try to change its products and its production process to solve these unsatisfactory conditions and gloomy prospects. The risks of failure outweigh the risks related to knowledge generation and exploitation (Bolton, 1993; Erixon, 2016; Manzaneque et al., 2020). In contrast, firms that experience above average performance fear performance decline and, thus, are prepared to accept the risks related to the generation and exploitation of knowledge to delay potential decline. The risks related to prospective losses are perceived as larger than the risks related to innovation activity.

The decision to innovate takes place in a context of out-of-equilibrium conditions, which pushes the firm to find ways to cope with uncertainty: only firms in out-of-equilibrium conditions have a strong incentive to undertake risky activities. A new definition of entrepreneurship closes the analytical loop created by Schumpeter's 1947 contributions. Only firms that are highly entrepreneurial – that is, firms that have the capability to manage high levels of risks and cope with uncertainty – are able to respond creatively to out of equilibrium conditions by generating the necessary technological knowledge to introduce innovations (Decker et al., 2014).

Based directly on their performance, firms choose how much new knowledge to produce and, thus, they choose *the rate of innovation*. The farther the firm from an equilibrium condition, the greater will be its commitment to articulate a creative response. Hence, the relationship between the firm's performance and its effort to innovate is convex, or U-shaped.

If *T* is the amount of knowledge generated, and Π is the level of performance, we obtain:

$$T = -a\pi + b\pi^2 \tag{1}$$

The greater the firm's gains or losses, the larger will be the amount of knowledge generated and exploited by the firm. Conversely, the amount of knowledge generated and exploited by firms in equilibrium will be negligible.

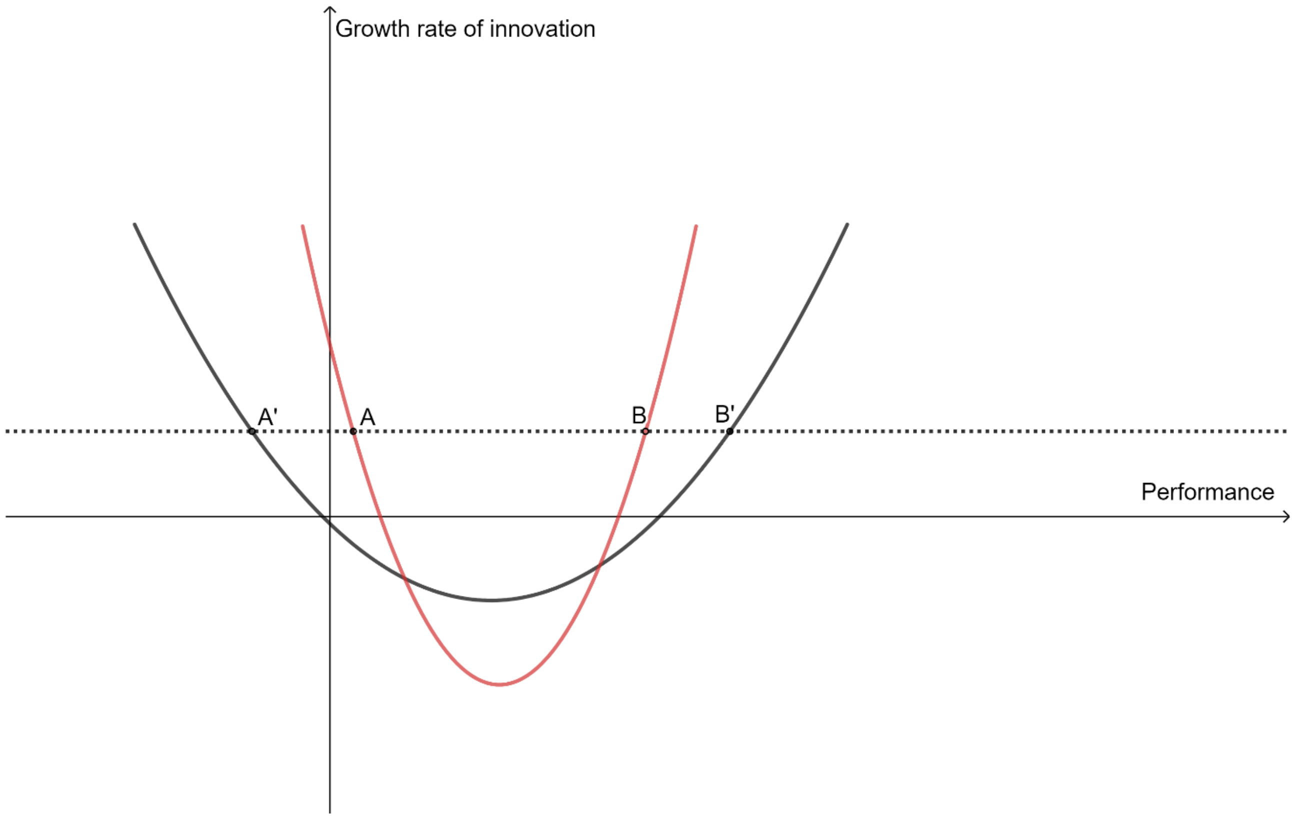
The width of the U-shaped relationship between performance and innovative efforts measures the level of entrepreneurship of a firm caught in out-of-equilibrium conditions. Therefore, a deep U-shaped relationship means high reactivity, while a flatter relationship means limited reactivity.

Schumpeter's 1947 essays make another and very important contribution by proposing a new inclusive definition of entrepreneurship. According to Schumpeter (1947a and 1947b), the notion of entrepreneurship identifies the level of reactivity of the firm to the emerging out-of-equilibrium conditions in its product and factor markets. The 1947 Schumpeter's essays rectify his 1934 analysis of entrepreneurship proposed in *Theory of Economic Development.* In that volume, entrepreneurship is associated exclusively to the entry of new firms. In his 1947 essays, instead, entrepreneurship – defined as the capability to operate in conditions of uncertainty – applies to the full range of firm reactions and includes also incumbent firms. In this new context, it becomes important to investigate which firm characteristics are most closely associated to entrepreneurship.

We systematically explore the scope of application of the creative response, whether it applies more to: i) large or small firms; ii) old or young firms; iii) firms in high-tech or in low-tech industries. Specifically, we empirically investigate the firm's level of entrepreneurial responsiveness by examining the width of the U-shaped relationship between its performance and its intangible capital intensity.

Figure 1 highlights that entrepreneurship is a key element to characterize the heterogeneity in the firm's responsiveness to out-of-equilibrium conditions. The two curves show that the innovation response will be the largest when firm performances are either very low or very high. However, we observe that the same level of innovation is associated with different distances between points A and B, and between points A' and B'. Specifically, a narrower arc of the parabola (the distance between A and B) is associated with lower extreme values of performance than a flatter arc (the distance between A' and B'). In other words, firms that are characterized by a narrower parabolic arc, invest in knowledge more reactively when facing out-of-equilibrium conditions, while firms characterized by a flatter parabola are less responsive if their performance is either low or above the norm. Similarly, for a given level of performance, the level of innovation will be higher if the parabolic arc is narrower, whereas a flatter curve indicates lower innovation efforts when performance is either very low or very high.

Figure 1: Heterogeneous U-shaped relationships between innovation and performance.



3. EMPIRICAL ANALYSIS

3.1. Knowledge assets

The aim of the empirical analysis is to test the hypothesis of a U-shaped relationship between firm performance and the intensity of knowledge generated. We measure the amount of knowledge generated by the firm with its stock of intangible assets and we focus on the growth rate of this stock. The notion of intangible capital is strictly related to the character of knowledge as a non-exhaustible economic good. The repeated use of extant knowledge to produce further technological knowledge and other economic goods does not affect the knowledge productivity itself. Therefore, knowledge can be stored by the firm and should be recorded in the balance sheet according to its prolonged contribution to the firm performance.

Corrado, Hulten and Sichel (2005, 2009) were the first to underline the need to consider a range of knowledge items that contribute persistently to productivity, and not to consider them simply as intermediary or cost inputs. Indeed, organizational and R&D expenses and intellectual property products have been recently recognized by the 2008 System of National Accounts as worthy of inclusion in both national accounts and firm balance sheets.

Therefore, the firm's capitalization of intangibles accounts for the expenses that contribute to productivity for more than one fiscal year. Consequently, the value recorded in the firm's balance sheets will depend on the value of the intangible item and the related depreciation rate applied. While the main reference in the literature is the 20% depreciation rate set by Hall (2005), De Rassenfosse and Jaffe (2018) estimated the depreciation rate of Australian patents as in the range 2%-7%. Hence, the measure of accumulation of knowledge as capital seems even larger than suggested by standard measures.

The recognition of this characteristic of the accumulation of knowledge capital paved the way for many micro-economic studies aimed at assessing the effects of firm investments in intangible assets (Marrocu, Paci and Pontis, 2012; Cucculelli and Bettinelli, 2015; Bontempi and Mairesse, 2015). Several papers also establish a relationship between accounting for intangibles and productivity growth, at the industry or macro-levels (Borgo et al., 2013; Piekkola, 2018).

However, with some exceptions (e.g., Arrighetti, Landini and Lasagni, 2014; Thum-Thysen et al., 2019), much less attention has been paid to the determinants of the accumulation of intangible capital. The empirical analysis proposed by this paper aims at filling this gap. Precisely, we focus on the relationship between the firm's performance and the amount of intangible capital, and its variance across firms depending on age, size and sector of activity. Our hypothesis is that the firm performance and growth in intangible intensity are in a curvilinear, U-shaped relationship. To test this hypothesis, we rely on an original database that combines firm financial data and a newly constructed series on intangible capital measures for US-listed companies.

3.2. Data

We rely on financial data of a selected sample of US-listed companies extracted from the Compustat North America database over the period 1977-2016. The Compustat database contains detailed financial information on US-listed companies, and its use has several advantages compared to other data sources in terms of time span (data are available since the 1950s), sector and geographic coverage. Importantly, we complement standard firm-level financial data with detailed information on intangible capital from the recent contribution by Ewens, Peters, and Wang (2020).

Our sample is restricted to US firms conducting business in US dollars, with at least two consecutive years of observations for the main financial items. We remove from the sample regulated utilities (SIC Codes 4900-4999), the financial sector (6000-6999), and firms categorized as public services, international affairs or non-operating establishments (9000+). To remove outliers that could introduce noise in our estimates, we winsorize our regression variables at the 1% level.[2] The resulting (unbalanced) panel includes 5,874 firms observed over the period 1977-2016.

Firm-level intangible capital stock is measured as the sum of externally purchased and internally created intangible assets. Externally purchased intangible capital is reported in the firm balance sheet with the item Intangible Assets (Compustat item *intan*). We set missing values for this item to zero.[3]

[2] Winsorization at the 1% is a common practice in the literature to minimize the influence of possible spurious outliers (Borisova and Brown, 2013; Green, Louis and Sani, 2022).

[3] Reporting the value of acquired intangible assets in the balance sheet is compulsory for US-listed companies. Therefore, we assume that observations in the Compustat database with missing values for purchased intangible assets at time t did not purchase any intangible asset in that fiscal year. We set these cases to zero.

We retain Goodwill in Intangible Assets since Goodwill includes the fair cost of acquiring intangible assets not separately identifiable (Peters and Taylor, 2017). Internally created intangible capital is the sum of organizational capital and knowledge capital. The measures of these two components of firm-level internally created intangible capital stock are from Ewens, Peters and Wang (2020). Based on original capitalization parameters for intangible capital – computed by exploiting the price paid for intangible assets in firm acquisitions – Ewens, Peters and Wang (2020) impute values of off-balance sheet firm-year stocks of knowledge and organizational capital for the universe of firms in Compustat over the period 1975-2016. Firm-level physical capital stock is given by gross plant, property and equipment recorded in Compustat under the item *ppegt*.

We measure firm's performance with the Asset Turnover ratio, defined as the ratio between sales (item *sale* in Compustat) and total assets (item *at* in Compustat), averaged over t and $t-1$. This variable measures the efficiency through which the firm converts its assets into sales and can be interpreted as a proxy of the firm's performance, which is strongly related to its profitability (Soliman, 2008).

3.3. Econometric model

The econometric analysis tests the hypothesis of a U-shaped relationship between firm performance and growth in intangible assets intensity. We also assess the heterogeneity of this relationship with respect to firm size, age and industry of operation – low-tech or high-tech. Precisely, to distinguish between large and small companies, we rely on the US Small Business Administration (SBA) threshold of 500 employees (Knott and Vieregger, 2020). To distinguish between old and young companies, we use a 10-year threshold since foundation (the median age in our sample). Lastly, we divide firms between high-tech and low-tech following Ewens, Peters and Wang (2020).

Formally, we estimate the following econometric model:

$$Growth\_INTINT_{it} = \alpha_0 + \beta_1 Perf_{it-1} + \beta_2 Perf_{it-1}^2 + \beta_3 Size_{it-1} + \beta_4 Age_{it-1} + \beta_5 Leverage_{it-1} + \mu_i + \delta_{jt} + e_{it} \quad (2)$$

where $Growth\_INTINT_{it}$ is the yearly growth rate of intangible assets intensity (i.e., the ratio between knowledge capital and total assets) for firm i between t and $t-1$; $Perf_{it-1}$ is firm i's performance, averaged over t and $t-1$, measured as the ratio between sales and total assets; $Size_{it-1}$ is the natural logarithm of the number of employees of firm i at year $t-1$; Age_{it-1} is the natural logarithm of firm age at $t-1$; $Leverage_{it-1}$ is the ratio between debts (long-term debt, item *dlt*, plus debt in current liabilities, item *dltt*) and total assets at $t-1$. The model includes firm fixed effects (μ_i) and industry-by-year fixed effects (δ_{jt}). Firm fixed effects account for time-invariant unobserved characteristics and allow the estimates of β_1 and β_2 to reflect within-changes in the firm's growth of intangible intensity over time. Industry-by-year fixed effects reflect transitory industry-specific macroeconomic conditions, capturing the effect of deregulation policies, changes in the relative prices of factor inputs and investment opportunities that simultaneously affect the firm's propensity to invest in intangibles and the firm's performance (Gutierrez and Philippon, 2017; Zwick and Mahon, 2017).[4] We cluster standard errors at the firm level to account for heteroskedasticity and autocorrelation within firms.

According to our hypothesis, we expect the coefficient β_1 to be < 0 and the coefficient β_2 to be > 0. We also test the magnitude of the coefficients β_1 and β_2 across different subsamples based on firm size, age and industry (low and high-tech). The differences in the magnitudes of the coefficients of

[4] We also estimate different specifications that include fiscal year fixed effects, together with firm fixed effects, instead of industry-by-year fixed effects. As reported in Section 4, the main results are robust also in this case.

interest across alternative samples will show the expected heterogeneity of both the extent and the width of the U-shaped relationship according to firm size, firm age and industry characteristics.

Precisely, the magnitude of the coefficient β_2 indicates the width of the U-shaped curve and, hence, the extent of the firm's creative response. The greater the value of β_2, the narrower the parabolic arc and, hence, the more reactive the firm to out-of-equilibrium conditions. In other words, for the same level of performance, a higher value of β_2 indicates a stronger firm response in terms of intangible capital intensity. We do expect to estimate larger coefficients in the subsamples of small and young firms, and in the subsample of firms active in high-tech industries.

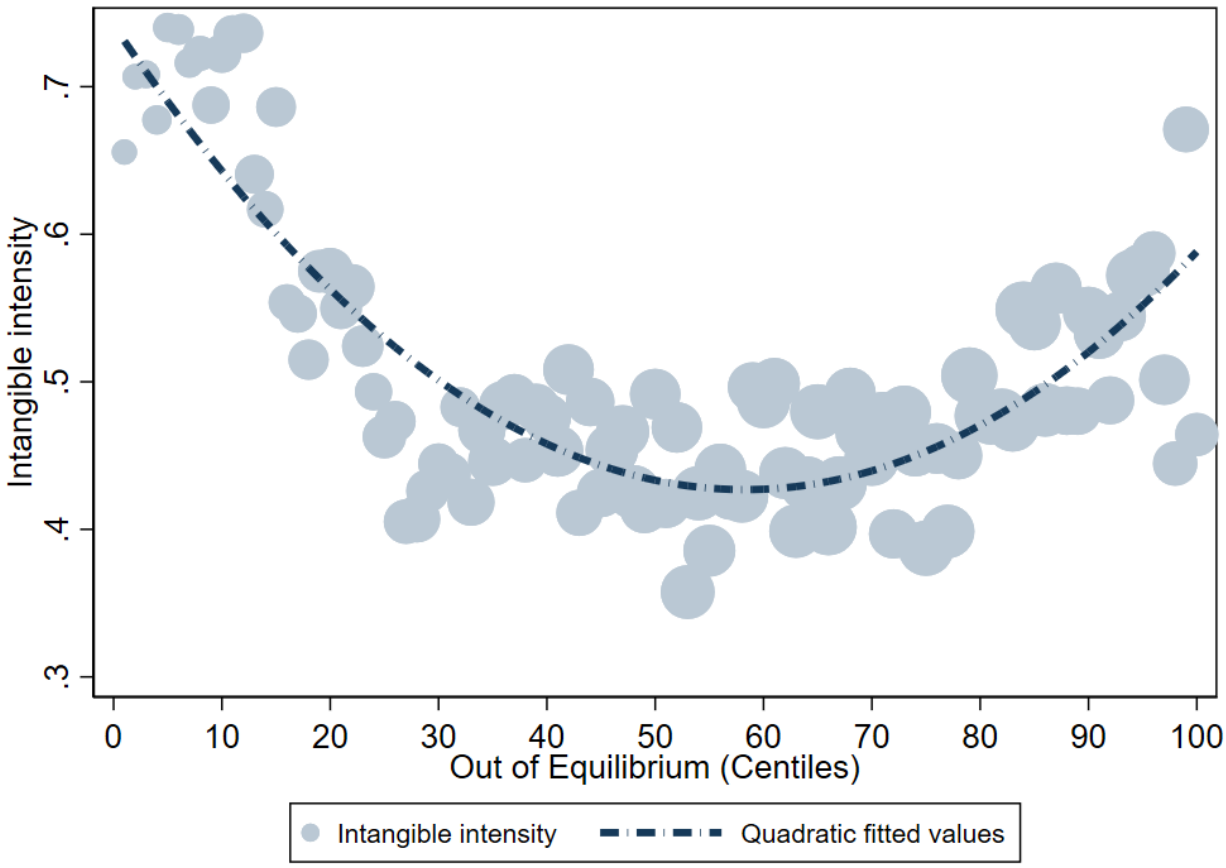
Table A1 in the Appendix reports the descriptive statistics of the variables used in the empirical exercise. Figure A1 in the Appendix plots the trend of the average share of intangible capital over total capital between 1977 and 2016 across the US-listed companies considered. The increase of the intangible intensity at the US firm level has been sharp and nearly steady over the forty years considered. Precisely, the intangible intensity increased from 0.32 in 1977 to 0.62 in 2016.

4. RESULTS

4.1 Stylized evidence

We start with a preliminary exploration of the cross-sectional relationship between firms' out of equilibrium conditions and intangible capital intensity. In Figure 2, we group firms into average performance centiles and graphically show their relationship with the average growth of intangible intensity, measured as the growth rate of the ratio between intangible assets and total assets. The plot shows a U-shaped relationship: on average, when firm performance is far from the median (both below and above), the growth of intangible intensity reaches its highest levels. This is more marked for firms below than for those above median performance levels. In other words, the composition of total assets leans more towards intangible capital for firms facing poor performances. The effect fades as firms approach median performance levels and increases again when performance is well above the median, albeit with lower intensity compared to firms facing poor performance. This stylized evidence suggests a U-shaped relationship between firm's performance and its level of entrepreneurship (i.e., its innovative responsiveness), as we hypothesized in the theoretical section. The next sections will provide robust econometric evidence of this relationship.

Figure 2: Out-of-equilibrium and intangible intensity.



Note: The x-axis is the out-of-equilibrium measure for the full sample. Firm performance is grouped into centiles based on average values over the entire period. Each centile is weighted by its size (i.e., number of firms). The y-axis shows the average growth rate of intangible intensity, defined as intangible capital over total assets, for each centile.

4.2. Main results

Table 1 reports the baseline results obtained estimating Equation (2) on the full sample. We confirm the expected U-shaped relationship between the growth of intangible intensity and firm performance. Column (1) reports the results of a baseline specification in which we do not include any fixed effects and we regress intangible intensity growth only against performance and its squared term. The estimated coefficients suggest that the relationship between the intensity of intangible capital and performance is characterized by a quadratic function. Indeed, the opposite signs of the coefficients of performance (significant and negative) and of its squared term (significant and positive), together, draw a U-shaped relationship between intangible intensity growth and firm performance. Therefore, firms show a higher growth of intangible capital intensity when their performance is either well below or above average.

Table 1: Baseline results.

	(1)	(2)	(3)	(4)
Perf	-0.017***	-0.085***	-0.091***	-0.088***
	(0.003)	(0.010)	(0.010)	(0.010)
Perf^2	0.001***	0.006***	0.006***	0.006***
	(0.000)	(0.002)	(0.002)	(0.002)
Size				0.055***
				(0.006)
Age				-0.039***
				(0.009)
Leverage				-0.019
				(0.012)
Firm FEs	No	Yes	Yes	Yes
Year FEs	No	Yes	No	No
Industry-by-Year Fes	No	No	Yes	Yes
N	48,962	48,962	48,962	48,962
R^2	0.001	0.178	0.184	0.277

Notes: The dependent variable is the yearly growth rate of intangible intensity (ratio between intangible capital and total assets). Firm performance is measured by the Asset Turnover ratio (ratio between sales and total assets) averaged between t and $t\text{-}1$. Standard errors clustered at the firm level are in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

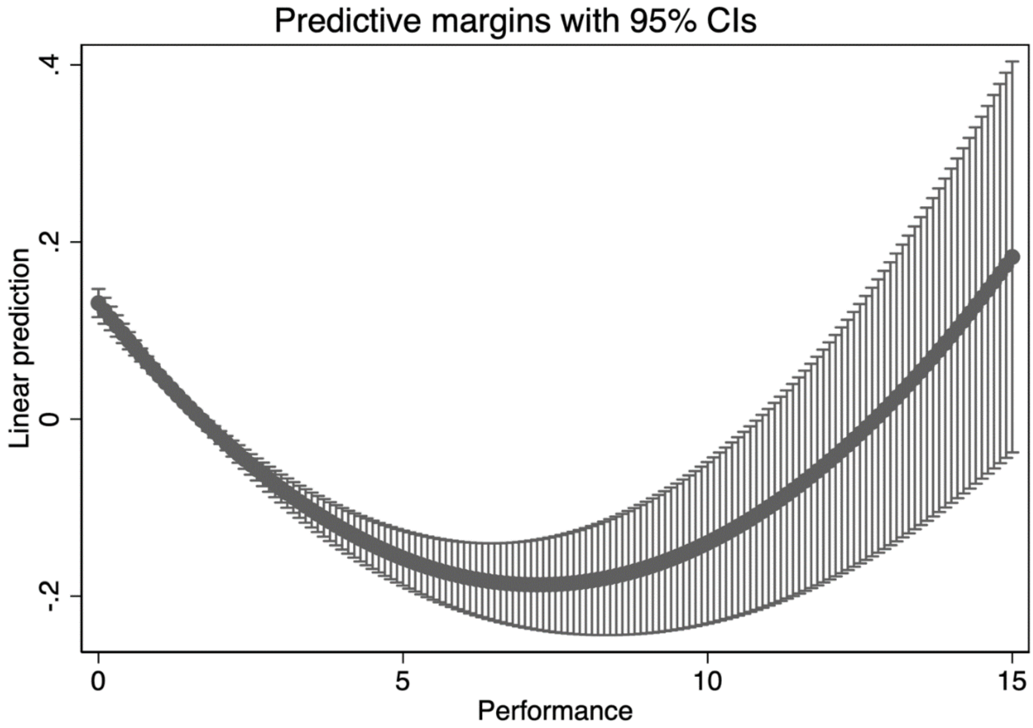
These exploratory results are confirmed when we include both firm and year fixed effects, which account for unobserved heterogeneity across firms and business cycles effects, respectively, as reported in Column (2). The main findings are confirmed also when we include industry-by-year fixed effects, which account for industry-year specific shocks affecting the propensity to invest in intangible capital, as reported in Column (3), and when we include selected time-variant control variables, as reported in Column (4). Concerning the estimated coefficients for the control variables reported in Column (4), firm size shows a positive and statistically significant coefficient, while age shows a negative and significant coefficient. Lastly, we estimate a non-significant coefficient for leverage. Overall, the results for the control variables largely confirm the findings of previous related empirical studies (Antonelli, Orsatti and Pialli, 2022; Montresor and Vezzani, 2022).

Figure 3 plots the predictive margins of firm performance, according to the results reported in Column (4), showing a strong estimated U-shaped relationship between firm performance and growth in intangible intensity.

We then test this estimated nonlinear U-shaped relationship relying on the U-shaped test of Lind and Mehlum (2010). The turning point of the estimated quadratic relationship reported in Table 1, Column (4), is 7.216.[5] This point falls between the minimum and maximum values of the average Asset Turnover ratio in our sample, as reported in Table 1 (Haans, Pieters and He, 2016). We test whether, at this turning point, the slope is sufficiently steep at both ends of the data range. The results of this test, reported in Table A2, confirm the existence of a U-shaped relationship between performance and growth of intangible intensity.

[5] Taking the relationship $Y = \alpha + \beta_1 X + \beta_2 X^2$, the value of the turning point is equal to $-\beta_1/2\beta_2$. See Haans, Pieters and He (2016) for the mathematical proof.

Figure 3: Predictive margins plot.



Note: The figure shows the linear prediction of performance on intangible intensity growth, with confidence intervals at the 95% level.

In Table 2, we turn to the results of the heterogeneity tests. Column (1) reports the same results as Table 1, Column (4), for comparison with the other columns. Columns (2) to (7) report the results for the sample-splits, based on firm size, age and industry. Precisely, Columns (2)-(3) refer to large and small firms, Columns (4)-(5) to old and young firms, and Columns (6)-(7) to firms in high-tech and low-tech industries, respectively. Looking at the squared term of performance, the comparison between the coefficient reported in Column (2) with the coefficient reported in Column (3) suggests that small firms (Column 3, coefficient 0.021) react more readily to out-of-equilibrium than larger firms (Column 2, coefficient 0.003). Comparing Column (4) with Column (5), we observe that young firms (Column 5, coefficient 0.007) respond more reactively than old firms (Column 4, coefficient 0.005, not significant at the standard confidence levels). Lastly, Columns (6) and (7) show that firms in high-tech industries (Column 6, coefficient 0.036) are more reactive than firms in low-tech industries (Column 7, coefficient 0.004).

Overall, the results reported in Table 2 suggest that small and young firms, and firms in high-tech industries are more responsive to out-of-equilibrium conditions in terms of knowledge intensity than, respectively, large, old and low-tech firms.

Table 2: Baseline results – Sample splits: firm size, age, and industry.

	All (1)	Large (2)	Small (3)	Old (4)	Young (5)	HT-industry (6)	LT-industry (7)
Perf	-0.088***	-0.053***	-0.168***	-0.100***	-0.088***	-0.220***	-0.059***
	(0.010)	(0.010)	(0.036)	(0.025)	(0.020)	(0.026)	(0.010)
Perf^2	0.006***	0.003***	0.021**	0.005	0.007***	0.036***	0.004***
	(0.002)	(0.001)	(0.009)	(0.006)	(0.003)	(0.006)	(0.001)
Size	0.055***	0.038***	0.112***	0.043***	0.117***	0.075***	0.041***
	(0.006)	(0.006)	(0.015)	(0.007)	(0.013)	(0.009)	(0.007)
Age	-0.039***	-0.039***	-0.069***	0.055*	-0.067*	-0.017	-0.052***
	(0.009)	(0.011)	(0.022)	(0.028)	(0.035)	(0.018)	(0.011)
Leverage	-0.019	0.057***	-0.085**	-0.010	-0.010	-0.055**	0.000
	(0.012)	(0.016)	(0.035)	(0.021)	(0.024)	(0.024)	(0.016)
N	48,962	31,484	14,722	23,937	22,769	14,813	34,149
R^2	0.277	0.319	0.364	0.279	0.383	0.207	0.327

Notes: The dependent variable is the yearly growth rate of intangible intensity (ratio between intangible capital and total assets). Firm performance is measured by the Asset Turnover ratio (ratio between sales and total assets) averaged between *t* and *t-1.* All the specifications include firm and industry-by-year fixed effects. Standard errors clustered at the firm level are in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

4.3. Additional results and robustness checks

In this section, we report the results of several robustness checks that challenge the validity of the main evidence reported above. First, we remove firms in the 99th percentile of performance distribution to show that these few overperforming firms do not drive our main findings. Second, we exclude entrant firms from the main sample to rule out that the firm creative response to out-of-equilibrium conditions is only a matter of entry dynamics. Third, we link the firm performance to the average sectoral performance to show that our results are not driven by profit dynamics in specific sectors. Fourth, we show that our results hold both at the extensive and at the intensive margins. Fifth, we show that our results hold for different timespans and are robust to the inclusion of both state-by-year dummies and state-specific control variables. Lastly, we further challenge the exogeneity of our analysis by testing different lags of firm performance and by proposing an original instrumental variable strategy. The results of all these tests confirm the robustness of the main reported findings. Therefore, we conclude that the hypothesis of a curvilinear U-shaped relationship between firm performance and growth of intangible intensity is largely confirmed. Still, since we cannot rule out all forms of endogeneity, as common in these empirical settings, the claim of causality must be taken with caution.

The following six sub-sections report and discuss the results of the sequential robustness checks.

4.3.1 Excluding overperforming firms

The turning point of the U-shaped relationship is in the proximity of the extreme right tail of firm performance distribution. This implies that only a few firms are at the right of the turning point and benefit from the 'extra-profits' effect. To demonstrate that the U-shaped relationship is not driven only by these few overperforming firms, we replicate the analysis of Table 2 excluding the observations above the 99th percentile of the Asset Turnover ratio distribution.

Table 3 shows that the main findings are robust to this sample restriction (Column 1), also when we split the sample by firm size, age and industry, respectively (Columns (2)-(7)). Overall, the estimated quadratic relationship between intangibles and performance is robust to the exclusion of overperforming firms, and small, young and high-tech firms react more than large, old and low-tech firms, respectively.

4.3.2 Removing entrant firms

Often new entrant firms may invest heavily in intangible assets in their early stage to catch-up with incumbents (Czarnitzki and Kraft, 2004), experiencing profit losses and below-than-average performances. To rule out the possibility that this is the main mechanism explaining our results, we restrict our sample to firms with an age of at least 3, 5 and 7 years, alternatively.[6] Table 4 reports the results of these robustness checks. Columns (1), (2) and (3) test the U-shaped relationship for the firms with age since the foundation of at least 3, 5 and 7 years, respectively. The results of these tests confirm a U-shaped relationship between performance and growth in intangible intensity, as the coefficient of the squared term of firm performance is positive and statistically significant across all models (Columns 1 to 3). Therefore, the U-shaped relationship estimated in the main analysis seems not to be dependent on out-of-equilibrium positions of small and young innovative entrant firms.

Table 3: Growth in intangible intensity and performance – Excluding firms above the 99th percentile of the performance distribution.

	All (1)	Large (2)	Small (3)	Old (4)	Young (5)	HT-industry (6)	LT-industry (7)
Perf	-0.186***	-0.114***	-0.307***	-0.195***	-0.232***	-0.279***	-0.131***
	(0.017)	(0.020)	(0.036)	(0.023)	(0.034)	(0.034)	(0.021)
Perf²	0.033***	0.019***	0.063***	0.032***	0.044***	0.057***	0.022***
	(0.004)	(0.005)	(0.009)	(0.005)	(0.007)	(0.010)	(0.004)
Size	0.055***	0.038***	0.113***	0.041***	0.119***	0.074***	0.040***
	(0.006)	(0.006)	(0.015)	(0.007)	(0.013)	(0.009)	(0.007)
Age	-0.036***	-0.037***	-0.063***	0.059**	-0.067*	-0.016	-0.048***
	(0.010)	(0.011)	(0.022)	(0.028)	(0.035)	(0.018)	(0.011)
Leverage	-0.016	0.056***	-0.116***	-0.009	-0.013	-0.055**	0.012
	(0.015)	(0.016)	(0.032)	(0.021)	(0.030)	(0.025)	(0.017)
N	48,431	31,072	14,616	23,826	22,369	14,802	33,629
R^2	0.278	0.320	0.368	0.279	0.385	0.207	0.328

Notes: The dependent variable is the yearly growth rate of intangible intensity (ratio between intangible capital and total assets). Firm performance is measured by the Asset Turnover ratio (ratio between sales and total assets) averaged between *t* and *t-1.* All the specifications include firm and industry-by-year fixed effects. Standard errors clustered at the firm level are in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

[6] The average firm age in our sample is around 15 years, with a standard deviation of more than 18 years.

Table 4: Growth in intangible intensity and performance – Different age thresholds.

	(1) Age>=3	(2) Age>=5	(3) Age>=7
Perf	-0.089***	-0.099***	-0.104***
	(0.010)	(0.012)	(0.019)
$Perf^2$	0.006***	0.007***	0.008*
	(0.001)	(0.002)	(0.004)
Size	0.051***	0.054***	0.049***
	(0.005)	(0.005)	(0.006)
Age	-0.028***	-0.002	0.032
	(0.010)	(0.015)	(0.020)
Leverage	-0.016	-0.019	-0.023
	(0.014)	(0.017)	(0.017)
N	44,849	38,080	32,558
R^2	0.271	0.272	0.272

Notes: Columns (1), (2) and (3) consider firms with age since the foundation of at least 3, 5 and 7 years, respectively. The dependent variable is the yearly growth rate of intangible intensity (ratio between intangible capital and total assets). Firm performance is measured by the Asset Turnover ratio (ratio between sales and total assets) averaged between *t* and *t-1.* All the specifications include firm and industry-by-year fixed effects. Standard errors clustered at the firm level are in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

4.3.3 Linking the firm performance to the sector performance

Firm performance shows high variability across industries. However, the measure of firm performance we proposed in the main analysis ignores this aspect. Although we control for industry-by-year fixed effects in our main analysis, one can argue that the within-firm dynamics of out-of-equilibrium are influenced by – and deeply connected – to the sector in which firms operate. Indeed, firms may respond differently to out-of-equilibrium based on the average performance of competitors. Therefore, we link our preferred measure of firm performance to the distribution of performance in the sector, measured at the 3-digit SIC code. Precisely, we define a dummy variable that takes a value equal to one if the firm performance is either above the 75^{th} or below the 25^{th} percentile of the sector performance distribution, zero otherwise.[7]

[7] Dummy variables at alternative cut-offs, such as the 80^{th} and 20^{th}, or 85^{th} and 15^{th} percentiles, provide robust findings. The results obtained with these alternative cut-offs are available upon request.

Table 5: Growth in intangible intensity and performance – Dummy variable accounting for the sector performance.

	All	Large	Small	Old	Young	HT-industry	LT-industry
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
OutOfEquil	1.541***	0.881*	3.032***	1.032**	2.362***	2.533***	1.037**
	(0.397)	(0.454)	(0.953)	(0.480)	(0.807)	(0.752)	(0.456)
Size	5.604***	3.801***	11.498***	4.379***	11.937***	7.698***	4.108***
	(0.556)	(0.601)	(1.545)	(0.659)	(1.330)	(0.896)	(0.718)
Age	-4.190***	-3.963***	-7.425***	5.431*	-7.403**	-2.468	-5.352***
	(0.940)	(1.125)	(2.213)	(2.852)	(3.507)	(1.707)	(1.110)
Leverage	-2.044	6.016***	-9.189**	-0.453	-1.294	-6.882***	0.195
	(1.258)	(1.634)	(3.700)	(2.094)	(2.442)	(2.512)	(1.721)
N	48,962	31,484	14,722	23,937	22,769	14,813	34,149
R^2	0.274	0.318	0.359	0.274	0.381	0.198	0.325

Notes: The dependent variable is the yearly growth rate of intangible intensity (ratio between intangible capital and total assets) expressed as percentage change. The variable OutOfEquil is defined as a dummy variable taking value one if the firm's Asset Turnover ratio is either below the 25th or above the 75th percentiles of the sector's Asset Turnover ratio, measured at the 3-digit SIC code. All the specifications include firm and industry-by-year fixed effects. Standard errors clustered at the firm level are in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 5 replicates Table 2, relying on this new measure of out-of-equilibrium performance. The dependent variable is the yearly growth rate of intangible intensity (expressed as percentage change to make the interpretation of the coefficients easier). Column (1) reports the results obtained on the full sample. Columns (2) to (7) divide the full sample between large and small firms (Columns (2) and (3), respectively), young and old firms (Columns (4) and (5), respectively), high-tech and low-tech firms (Columns (6) and (7), respectively). The coefficient for the dummy variable *OutOfEquil* is positive and statistically significant across all models, confirming that the growth in intangible intensity is larger when the firm performance is either below (i.e., in the bottom quartile) or above (i.e., in the top quartile) the median firm performance in the sector. Moreover, Columns (2) to (7) confirm that the creative response to out-of-equilibrium is prompter for small (Column 3, coefficient 3.032) than large firms (Column 2, coefficient 0.881), for young (Column 5, coefficient 2.362) than old firms (Column 4, coefficient 1.032), and for high-tech (Column 6, coefficient 2.533) than low-tech firms (Column 7, coefficient 1.037).

On average, being in out-of-equilibrium with respect to the median firm in the same sector leads the firm to increase its growth rate of intangible intensity by around 1.5%, which is economically meaningful. Moreover, our results show that, in out-of-equilibrium, small firms invest about three times more than large firms, and that high-tech firms invest 2.5 times more than low-tech firms.

4.3.4 Extensive vs. intensive margin

Table 6 reports the results of the investigation of the quadratic effect of performance at the extensive and intensive margins of intangible intensity. First, we look at the quadratic effect of performance on the likelihood of observing a positive rate of growth of intangible intensity, using a linear probability fixed-effects model (Panel A). The results of this analysis refer to the extensive margin, namely whether firms increase or not their share of intangible capital when they face out-of-equilibrium performances. We replicate the main analysis reported in Table 1 and we find confirmation of the quadratic effect of performance on the likelihood that a firm increases its share of intangible capital. A firm increases its share of knowledge capital when it is either below or above average performance levels. Then, we study the effect of performance on the growth in intangible intensity, conditional on observing a positive growth rate of intangible intensity (Panel B). In this case, we look at the intensive margin, namely the firm's decision on how much to invest in intangible capital. Again, we find a quadratic U-shaped effect of performance on intangible intensity.

Overall, the results reported in Table 6 confirm that performance and intangible intensity are in a curvilinear U-shaped relationship.

Table 6: Growth in intangible intensity and performance – Extensive vs Intensive margins of intangible intensity.

	(1)	(2)	(3)	(4)
		Panel A: Extensive margin		
Perf	-0.030***	-0.105***	-0.103***	-0.097***
	(0.004)	(0.014)	(0.015)	(0.015)
$Perf^2$	0.002***	0.007***	0.008***	0.007***
	(0.001)	(0.002)	(0.002)	(0.002)
Size				0.106***
				(0.007)
Age				-0.070***
				(0.015)
Leverage				0.107***
				(0.031)
Firm FEs	No	Yes	Yes	Yes
Year FEs	No	Yes	No	No
Industry-by-Year Fes	No	No	Yes	Yes
N	48,962	48,962	48,962	48,962
R^2	0.001	0.193	0.310	0.317
		Panel B: Intensive margin		
Perf	-0.040***	-0.070***	-0.075***	-0.071***
	(0.007)	(0.010)	(0.012)	(0.012)
$Perf^2$	0.003**	0.005***	0.005***	0.005***
	(0.001)	(0.001)	(0.002)	(0.001)
Size				-0.024***
				(0.006)
Age				-0.083***
				(0.010)
Leverage				-0.044***
				(0.014)
Firm FEs	No	Yes	Yes	Yes
Year FEs	No	Yes	No	No
Industry-by-Year FEs	No	No	Yes	Yes
N	26,873	26,873	26,873	26,873
R^2	0.009	0.393	0.521	0.526

Notes: Panel A refers to the extensive margin and the dependent variable is a dummy taking a value equal to one if the yearly growth rate of intangible intensity (ratio between intangible capital and total assets) is positive. Panel B looks at the intensive margin by considering only firms with a positive growth rate of intangible intensity. Here, the dependent variable is the yearly growth rate of intangible intensity (ratio between intangible capital and total assets). Firm performance is measured by the Asset Turnover ratio (ratio between sales and total assets) averaged between *t* and *t-1* both in Panel A and Panel B. Standard errors clustered at the firm level are in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

4.3.5 Time and regional heterogeneity

As a further robustness check, we control for innovation trends over time and State specificities. Table 7 reports the results of these tests.

Two states, California and Massachusetts, host the bulk of innovative activity in the US during our period of investigation, with the most innovative firms in our sample locating their headquarters there. To show that our results have generalized meaningfulness, we removed from the sample firms whose headquarter is in California or Massachusetts. The results of this analysis, reported in Table 7, Column (1), confirm that our main findings are unaltered when we remove firms located in these states. Precisely, we estimate a negative and statistically significant coefficient for performance and a positive and statistically significant coefficient for its squared term. This confirms a curvilinear U-shaped relationship between performance and growth in intangible intensity. Moreover, it is worth to notice that the magnitude of the estimated coefficients is consistent with the main analysis reported in Table 1, Column 4.

The initial period of our analysis is characterized by institutional changes strengthening property rights and leading to the explosion of patents. This may have influenced the dynamics of intangibles and the firm's performance. For these reasons, analogously to Bena, Ortiz-Molina and Simintzi (2022), we check whether the results hold when splitting the sample between before and after-1990. The results for these two sub-periods are reported in Table 7, Columns (2) and (3), respectively, and confirm the expected U-shaped relationship between firm performance and growth in intangible intensity over time. Interestingly, the estimated curvilinear relationship is steeper for the pre-1990 period.

Table 7: Growth in intangible intensity and performance – Additional robustness checks.

	(1) Excluding CA & MA	(2) Pre 1990	(3) Post 1990	(4) State-Year fixed effects	(5) State controls
Perf	-0.075***	-0.114***	-0.092***	-0.088***	-0.088***
	(0.011)	(0.024)	(0.012)	(0.011)	(0.016)
$Perf^2$	0.005***	0.013***	0.006***	0.006***	0.006***
	(0.001)	(0.004)	(0.002)	(0.002)	(0.002)
Size	0.048***	0.115***	0.054***	0.057***	0.057***
	(0.007)	(0.013)	(0.007)	(0.005)	(0.006)
Age	-0.046***	-0.108***	-0.027**	-0.037***	-0.042***
	(0.011)	(0.025)	(0.012)	(0.010)	(0.009)
Leverage	-0.013	0.105**	-0.042***	-0.020*	-0.012
	(0.013)	(0.042)	(0.014)	(0.012)	(0.013)
StateGDP					0.012
					(0.031)
StatePatents					-0.017
					(0.015)
Firm FEs	Yes	Yes	Yes	Yes	Yes
Industry-Year FEs	Yes	Yes	Yes	Yes	Yes
State-Year FEs	No	No	No	Yes	No
N	38,356	16,462	32,343	48,962	46,841
R^2	0.294	0.375	0.259	0.314	0.283

Notes: Column (1) excludes firms whose headquarter is in California or Massachussets. Column (2) considers the period before or equal to 1990. Column (3) considers the period after the 1990. Column (4) includes state-by-year fixed effects. Column (5) includes the State GDP per capita and the number of patents per inhabitant as additional controls. The dependent variable is the yearly growth rate of intangible intensity (ratio between intangible capital and total assets). Firm performance is measured by the Asset Turnover ratio (ratio between sales and total assets) averaged between t and t-1. Standard errors clustered at the firm level are in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Legal changes in intangible property rights or the introduction of policies regarding the firm capitalization of intangible assets may have exerted larger effects in states with high concentration of innovation activity, determining differential trends in innovation across states that may bias our estimates. To control for this, in Column (4) we report the results of a more demanding specification in which we include state-by-year fixed effects alongside firm and industry-by-year fixed effects. State-by-year fixed effects enable us to estimate our coefficients of interest by comparing firms subject to shocks within the same state and year. Lastly, in Column (5) we include two additional control variables measured at the state-year level: GDP per capita and the number of patents per inhabitant.[8]

Estimates of both models, reported in Columns (4) and (5), confirm a U-shaped relationship between firm performance and intangible intensity growth.

4.3.6 Performance lags and instrumental variable strategy

The identifying hypothesis of our regression model is that firm's performance is not correlated with unobserved firm, industry, and state-specific determinants of the growth in intangible assets. Support for this assumption comes from showing that our results are not altered by the inclusion of industry-by-year fixed effects, state-by-year fixed effects and additional control variables, and that they are stable across different time-periods and robust to several sample-splits. Moreover, by comparing Column (2) in Table 1 with Column (4) in Table 7, we notice that our coefficients of interest are almost unaltered as the R-squared increases from 0.178 to 0.314, suggesting that the impact of unobservable factors is likely to be negligible compared to the impact of observable factors (Oster, 2019). Nonetheless, in this section we provide further evidence of the robustness of our main results.

A first endogeneity concern stems from reverse causality since intangibles growth may directly increase firm performances (Crouzet and Eberly, 2019). Therefore, we consider a different lag structure of performance. Precisely, we estimate the same specifications as in Table 1, and we regress the yearly growth rate of intangible intensity on, alternatively, the average level of performance between t-1 and t-2, and between *t-2* and *t-3*, plus our control variables. Table 8 reports the results of

[8] Data on real GDP are from the Bureau of Economic Analysis (BEA) regional accounts, while population counts are from the Bureau of Labour Statistics (BLS). Data on patents are from PatentsView (https://patentsview.org/). We assign patent applications to US States (fractional count) according to the address of the inventor listed in the patent document.

these robustness checks. Panel A reports the results when we consider the average performance between *t-1* and *t-2*. Panel B refers to the average performance between *t-2* and *t-3*. In both cases, we estimate robust coefficients for performance and for its quadratic term, confirming the U-shaped relationship between performance and intangible intensity reported in the main analysis.

Table 8: Growth in intangible intensity and performance – Performance lagged.

	All (1)	Large (2)	Small (3)	Old (4)	Young (5)	High-tech (6)	Low-tech (7)
	Panel A: Performance between *t-1* and *t-2*						
Perf	-0.166^{***}	-0.126^{***}	-0.313^{***}	-0.190^{***}	-0.251^{***}	-0.271^{***}	-0.128^{***}
	(0.010)	(0.011)	(0.027)	(0.017)	(0.020)	(0.027)	(0.011)
$Perf^2$	0.010^{***}	0.007^{***}	0.032^{***}	0.020^{***}	0.013^{***}	0.025^{***}	0.007^{***}
	(0.001)	(0.001)	(0.007)	(0.003)	(0.002)	(0.007)	(0.001)
Size	0.040^{***}	0.025^{***}	0.100^{***}	0.035^{***}	0.089^{***}	0.041^{***}	0.038^{***}
	(0.005)	(0.006)	(0.012)	(0.006)	(0.016)	(0.010)	(0.006)
Age	-0.037^{***}	-0.040^{***}	-0.055^{**}	0.040	0.004	-0.035^{*}	-0.035^{***}
	(0.011)	(0.012)	(0.026)	(0.027)	(0.056)	(0.020)	(0.012)
Leverage	-0.013	0.004	-0.020	-0.009	0.004	-0.002	-0.018
	(0.015)	(0.018)	(0.041)	(0.017)	(0.042)	(0.026)	(0.018)
N	42,224	28,132	11,620	22,472	17,614	12,798	29,426
R^2	0.292	0.315	0.403	0.288	0.413	0.217	0.342
	Panel B: Performance between *t-2* and *t-3*						
Perf	-0.097^{***}	-0.062^{***}	-0.227^{***}	-0.113^{***}	-0.100^{***}	-0.210^{***}	-0.070^{***}
	(0.009)	(0.009)	(0.029)	(0.015)	(0.023)	(0.041)	(0.010)
$Perf^2$	0.006^{***}	0.003^{***}	0.032^{***}	0.012^{***}	0.005^{***}	0.030^{**}	0.004^{***}
	(0.001)	(0.001)	(0.008)	(0.003)	(0.002)	(0.015)	(0.001)
Size	0.047^{***}	0.028^{***}	0.116^{***}	0.035^{***}	0.136^{***}	0.051^{***}	0.042^{***}
	(0.005)	(0.006)	(0.014)	(0.006)	(0.016)	(0.010)	(0.005)
Age	-0.025^{*}	-0.033^{**}	-0.026	0.029	-0.092	-0.020	-0.025
	(0.014)	(0.016)	(0.036)	(0.029)	(0.112)	(0.024)	(0.016)
Leverage	0.018	0.069^{***}	-0.022	0.040^{**}	0.029	0.009	0.021
	(0.018)	(0.018)	(0.021)	(0.019)	(0.036)	(0.037)	(0.022)
N	36,352	24,879	9,214	20,998	13,391	11,003	25,349
R^2	0.283	0.306	0.388	0.281	0.419	0.199	0.342

Notes: The dependent variable is the yearly growth rate of intangible intensity (ratio between intangible capital and total assets). Firm performance is measured by the Asset Turnover ratio (ratio between sales and total assets) averaged between *t-1* and *t-2* in Panel A and between *t-2* and *t-3* in Panel B. All the specifications include firm and industry-by-year fixed effects. Standard errors clustered at the firm level are in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Second, we cannot rule out that unobserved time-varying firm-specific factors may bias our estimates. Unfortunately, our empirical setting based on a quadratic relationship and the unavailability of quasi-natural experiments prevent us to find a suitable exogenous variation that could instrument both the linear and the quadratic term of interest at the same time. Therefore, we elaborate an alternative solution to implement an original Instrumental Variable analysis. As noticed in the previous section, performances below the average level seem to be a stronger determinant for intangible investments than above-average performances. In other words, the creative response to out-of-equilibrium conditions is mainly driven by firms with performances below the average. For these reasons, in this last exercise we focus only on the left side of the turning point of the firm performance distribution in our sample and we directly instrument the linear level of performance. To do so, we rely on the exposure of US firms to Chinese import penetration. To this purpose, we adapt the approach implemented by Autor, Dorn and Hanson (2013 and 2019) and Hombert and Matray (2018) to our empirical setting. Precisely, we use data on Chinese import penetration in the US and in eight selected high-income countries (Australia, Denmark, Finland, Germany, Japan, New Zealand, Spain and Switzerland), aggregated at the four-digit SIC level for the period from 1991 to 2007.[9] Data are available mainly for manufacturing industries. We then define China's import penetration in the US and other high-income countries as imports normalized by the industry employment level in 1991. We then construct the predicted import penetration by regressing China's import penetration in the US to China's import penetration in other high-income countries, using year and 3-digit SIC industry fixed effects. The predicted values of this regression are then used to instrument the firm performance in our regression model.

The use of our instrument is motivated by a wide literature studying the exposure of US firms to Chinese competition (Autor et al., 2015; Autor et al., 2020). The increased global levels of openness

[9] Data on China's import penetration are from UN Comtrade and have been extracted from the David Dorn's website: https://www.ddorn.net.

to trade have increased the import penetration of labour-abundant countries in capital-abundant and high-income countries. As documented in Hombert and Matray (2018), manufacturing imports from China increased 12-fold in the US during the period from 1991 to 2007. The increased levels of China's import penetration have negatively affected the performance of US firms.

Our identification strategy relies on the exogeneity of China's import penetration in other high-income countries to US firms' productivity shocks. Using China's import penetration in other high-income countries should reduce endogeneity concerns generated by using import penetration directly in the US. In fact, in the latter case, import penetration may be caused directly by lower productivity of US firms because of negative shocks. On the other hand, import penetration in other high-income countries may be mostly due to the internal changes in China's productive system and to global events such the China's annexation to the WTO in 2001 (Hombert and Matray, 2018).

Therefore, we construct our two measures of China's import penetration (to the US and to the other selected eight high-income economies) by using imports in US dollars normalized by the industry employment level in 1991, the beginning of our sample in this exercise.[10] Figure A2 in the Appendix shows that China's import penetration into both the US and the eight high-income countries rose steadily during the 1991-2007 period.

Then, we regress China's import penetration in the US against the China's import penetration in high-income countries, including 3-digit SIC industry fixed effects and time fixed effects, and clustering standard errors at the industry-by-year level. Table A3 in the Appendix shows the results of this specification. As expected, import penetration in high-income countries is highly predictive of the

[10] Since employment is endogenous to trade shocks, we use the pre-sample industry level of employment in 1991, the beginning of our period of analysis in this case. Employment data are from the County Business Patterns repositories.

China's import penetration in the US. Hence, we use the predicted values of this relationship as an instrument for the firm's performance.

Table 9: IV estimation of the linear effect of performance.

	OLS (1)	OLS (2)	IV (3)	IV (4)
Perf	-0.143***	-0.150***	-0.900**	-0.777*
	(0.021)	(0.021)	(0.436)	(0.425)
Size		0.071***		0.061***
		(0.013)		(0.014)
Age		-0.012		0.005
		(0.027)		(0.033)
Leverage		-0.039		-0.069
		(0.034)		(0.042)
N	7,077	6,708	7,077	6,708
			First stage:	
Exposure			-0.350 (0.134)***	-0.340 (0.136)**
F-stat			10.92	10.28

Notes: The dependent variable is the yearly growth rate of intangible intensity (ratio between intangible capital and total assets). Firm performance is measured by the Asset Turnover ratio (sales over total assets) averaged between *t* and *t-1*. All the specifications include firm and state-by-year fixed effects. Standard errors, clustered at the industry-by-year level, are in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 9 reports the results of this Instrumental Variable (IV) analysis, where firm performance is instrumented with the predicted values of the regression just described. The analysis is limited to the 1991-2007 period and to manufacturing firms. Moreover, it considers only observations below the turning point of the U-shaped relationship. However, only 183 observations (out of 6891) are lost when considering only the left side of the turning point; hence, our analysis applies to the vast majority of our sample. Column (1) reports the results of the OLS regression in which the growth rate of intangible intensity is regressed against the firm performance. As expected, the relationship between the two variables is strongly negative. Column (2) includes control variables, but the coefficient of the firm performance is unaffected. On the other hand, Columns (3) and (4) estimate the same specifications as Columns (1) and (2), respectively, with the 2SLS. As shown in Columns (3) and (4), the impact of firm performance is negative and statistically significant. Albeit the precision of the estimates reduces if compared to Columns (1) and (2), our empirical setting suggests that our estimates should be interpreted as causal: out-of-equilibrium conditions push firms to undertake risky strategies, increasing their innovation effort. Moreover, the negative coefficient obtained in the first stage of the IV analysis confirms the harmful effects of China's import penetration for US firms, as pointed out by previous empirical studies (e.g., Autor, Dorn and Hanson, 2015).

5. CONCLUSIONS

This paper articulated and tested the Schumpeterian hypothesis of innovation as a creative response. The understanding of the very high levels of risk which border on uncertainty is central for the analysis of innovation efforts as a creative response. The approach proposed in this paper contrasts with both the assumptions of the new growth theory that models knowledge as if it were a standard economic good, after accounting only for its limited appropriability, and the early evolutionary approach, which considers firms to be blind innovators that try to innovate based on rules of thumb that apply to all conditions.

The new evolutionary approach implemented in this paper assumes that firms are risk-averse and decide to innovate mainly, if not exclusively, as a response to out-of-equilibrium conditions in product and factor markets. Out-of-equilibrium triggers the decision to try to cope with unexpected market conditions by introducing innovations. Firms in equilibrium are reluctant to deal with the high levels of uncertainty associated with the generation of knowledge and its exploitation by means of innovation. The extent to which firms are able to implement innovation activities to cope with out-of-equilibrium conditions indicates their level of entrepreneurship.

We test the expected U-shaped relationship between intangible capital intensity, which proxies for the effort devoted to innovation activities, and the extent of the out-of-equilibrium conditions, as measured by the firm's level of performance, on a large sample of US-listed companies observed along the period 1977-2016. The empirical results – robust to alternative sample-splits and to several different econometric tests – confirm our hypothesis of a U-shaped relationship between firm performance and growth in intangible assets intensity, which is steeper for small and young firms and for firms in high-tech industries. Therefore, we conclude that the firm's creative response is an out-of-equilibrium phenomenon whose extent differs across firms according to their size, age and sector of activity.

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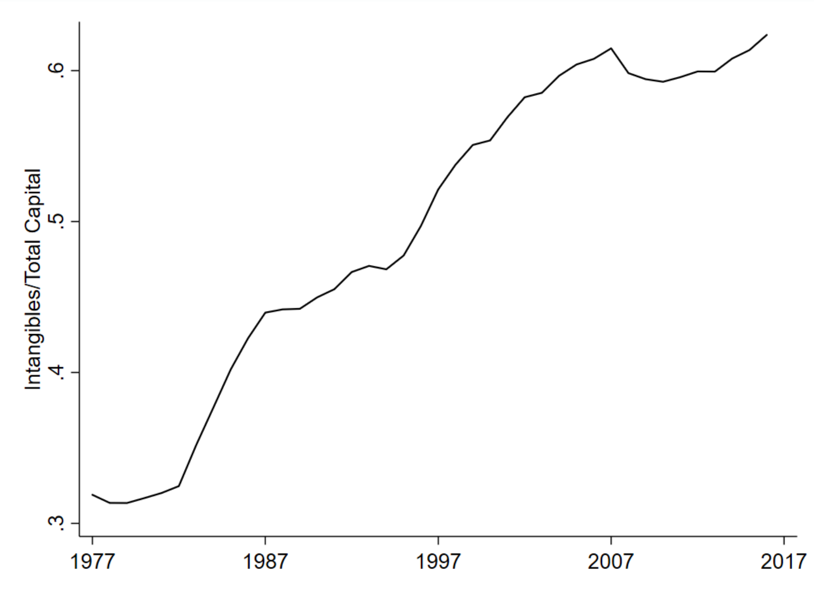
APPENDIX

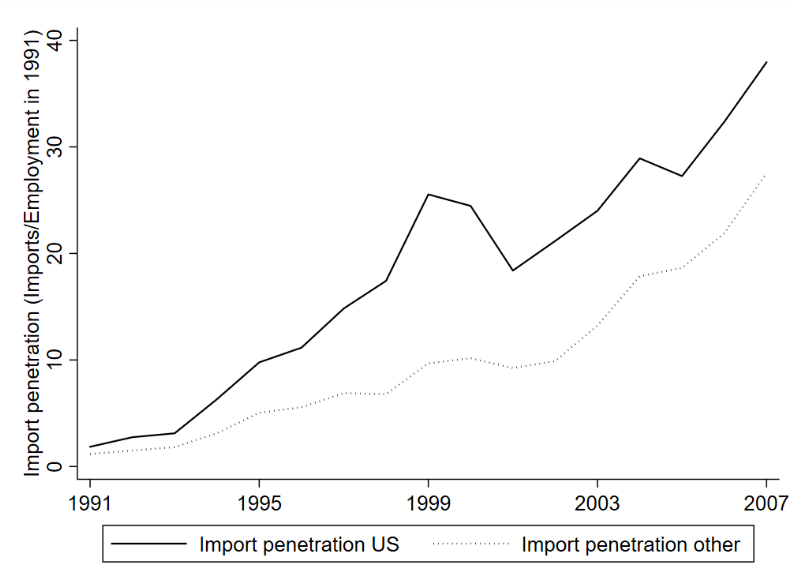
Figures

Figure A1: Intangible intensity evolution.



Notes: The figure plots the trend of the average ratio between intangible capital and total capital over the period 1977-2016, measured on the sample of US listed companies used in the analysis. Source: Authors' elaboration on Compustat financial data complemented with data on intangible capital from Ewens, Peters and Wang (2020).

Figure A2: China's import penetration.



Notes: The figure plots the trend of the China's import penetration in the US and in eight selected high-income countries. Source: Authors' elaboration on data from UN Comtrade (accessed through David Dorn's website) and County Business Patterns databases.

Tables

Table A1: Descriptive statistics.

Variable	Mean	Std. Dev.	Min	Max
Growth_INTINT	0.025	0.281	-5.803	9.285
Perf	1.395	0.929	0.006	21.502
$Perf^2$	2.81	6.374	0	462.355
Size	0.084	1.748	-6.215	5.561
Age	2.48	0.839	1.099	5.165
Leverage	0.23	0.269	0	14.41

Table A2: U-shaped test for the relationship between growth in intangible intensity and performance.

	Lower bound	Upper Bound
Interval	0	21.502
Slope	-0.088	0.175
t-value	-8.579	2.820
P>|t|	0.000	0.002

Notes: The turning point is 7.216. Overall test for the presence of a U-shaped relationship: t-value=2.82, P>|t|=0.0024

Table A3: Predicted values from import penetration.

	Import Penetration in the United States
Import penetration in other high-income countries	1.979^{***}
	(0.123)
N	8,426
R^2	0.98

Notes: The dependent variable is the China's import penetration in the US (in 2007$) normalized by industry employment in 1991. The regressor is the China's import penetration in other high-income countries (in 2007$) normalized by industry employment in 1991. The regression includes year and 3-digit SIC industry fixed effects. Standard errors clustered by industry and year are in parentheses. *** $p < 0.01$

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