Research Article

Innovation Capability and Globalization Propensity in India's Information Technology and Software Industry

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Abstract

This article examines the impact of R&D spending on firms' export earnings patterns, for a panel data set of several Indian information technology and software sector firms, over the period of fiscal years 2000–2001 to 2005–2006. The results of the analysis show that R&D spending has been associated with a significant rise in firms' average export earnings levels. These results point to the need for a substantial increase over the current levels of R&D currently being undertaken by information technology and software firms in India.

1. Introduction

For several centuries, since Ricardo (1817), an important theme has been the positive and significant role that engagement in foreign markets has played in engendering growth (Chhibber & Majumdar, 1998). Exports are important in explaining the long-run growth of firms and countries (Balassa, 1978; Frankel & Romer, 1999; Marin, 1992). The broad explanations consider demand effects, externalities, and trade (Feder, 1982) as vehicles for faster diffusion of knowledge via spillovers (Aghion & Howitt, 1992; Grossman & Helpman, 1991). More micro level explanations assess the impact of domestic innovation efforts on competitiveness (Fagerberg, 1988; Soete, 1981), and in the literature, these concerns have been important.

Based on the fundamental concepts of returns to scale (Young, 1928) and endogenous growth (Kaldor, 1957), commencing with the work by Posner (1961), much work (Dollar, 1986; Hirsch, 1974; Krugman, 1986; Grossman & Helpman, 1989) has highlighted the role that firms' innovative activities, such as the undertaking of research, product development, and knowledge acquisition, play in making a significant, positive impact on figures reflecting their international market performance.[1]

Since the 1991 onset of economic reforms in India, the internationalization of Indian firms has increased substantially. An important main explanation is the liberalization of trade and capital flows across borders.

1. The literature on the link between innovative activities and exports has become quite large (Barrios et al., 2003; Braunerhjelm, 1996; Buxton et al., 1991; Cotsomitis et al., 1991; Estrada & Heijs, 2006; Flor & Oltra, 2005; Greenhalgh, 1990; Greenhalgh et al., 1994; Hasan & Raturi, 2003; Hirsch & Bijaoui, 1985; Hughes, 1986; Ito & Pucik, 1993; Keesing, 1967; Krugman, 1979; Kumar & Siddharthan, 1994; Lachenmaier & Wößmann, 2006; Lefebvre et al., 1998; Magnier & Toujas-Bernate, 1994; Mansfield et al., 1979; McGuiness & Little, 1981; Nassimbeni, 2001; Roper & Love, 2002; Parry, 1974; Schlegelmilch & Crook, 1988; Soete, 1987; Sterlacchini, 1999; Wakelin, 1998).

Besides changes in policies, however, the development in the export share of firms depends substantially on their own competitive advantages. Thus, the use of physical and human capital is an important factor behind the export performance of firms. Research and development activities are human capital-intensive, and firms engaging in these activities can have advantages in exporting.

This article examines the impact that the undertaking of research and development activities has on the propensity of firms in the Indian information technology and software industry to engage in global business. A focus on the Indian software industry is useful. Because of government policies, these firms have focused on exporting from the very start (Desai, 2005; Dossani, 2008). Still, not much is known about the issue of Indian software and information technology firms' predilections for research and development, or about the impact that such activities might have on the firms' subsequent globalization performance.

As such, these software and information technology firms are born global firms. This provides a unique opportunity to study international engagement in an entire industry of a country. It is a sector that has been subject to the exigencies of government policy in a major way. The industry comprises a combination of both new and established firms that have been operating internationally since their inception due to government policies.

Born global is defined in the broad sense of firms that are international at their inception. While this definition departs from the literature's focus on smaller, "new" international ventures to the exclusion of other types (Knight & Cavusgil, 2004), it is still consistent with the definition of born global firms being those that engage in international activities from the start.

This article reports the results of a study that examines the impact of research and development (R&D) spending on the dynamics of export earnings of Indian software and information technology firms. Based on a large proprietary dataset on Indian software and information technology firms, the relative impact of research and development spending on export earnings is evaluated for a large panel of software and information technology firms. The panel data relate to the six fiscal years between 2000–2001 and 2005–2006. These data have been used for prior analysis in the sector.

An important question is addressed in this paper. Namely, have variations in innovative activity engagement by firms, measured as the amount spent on research and development, affected the extent of engagement in the global market for India's software firms? The time period is one of the most recent in the history of the Indian economy. The paper unfolds as follows: The next section deals with the conceptual linkages between firms' R&D spending and their relative success in generating income from exports. Then, the industry is described. The section thereafter provides details of the analysis carried out. That is followed by a discussion of the results and a conclusion.

2. The Link Between Innovation and Globalization

For the last several decades, the role of innovation in determining the patterns of global trade has been emphasized. A particularly important theme in both the international trade and international investment literatures has been the role of unique advantages that are predicated by the possession of knowledge and capabilities that provide firms the platform for the overseas expansion of their activities.

In general, firms' research and development activities create a substantial knowledge infrastructure. Such an infrastructure creates an appropriate environment that enables firms to conduct business efficiently, productively, and proactively (Morrison & Siegel, 1999). The broad theoretical approach toward such an assessment relies on the concept of spillovers (i.e., of technological and knowledge capabilities), which is derived from the Marshall (1890) concept of externalities, and which now forms a staple ingredient of endogenous growth theory (Romer, 1990).

According to this theory, general investments made in an economy, which will include the aggregation of firms' research and development spending, result in both growth and knowledge development. As this investment and knowledge development process intensifies, both across the economy and in specific locations and sectors, the outcome is an enhancement of knowledge transmission. Such transmission may occur as a result of employees from different firms exchanging ideas about new products and services, as well as new ways to produce these things (Bartlesman et al.,

1994). Knowledge development and transmission then helps firms become globally proactive.

Originally, the technology gap model (Hufbauer, 1966; Posner, 1961) postulated that countries placed at the technological frontier would export technologically advanced products. These export advantages were temporary. Knowledge, as a public good, could flow freely and create mimetic effects. The reaction of foreign producers in producing the new goods with cheaper labor would obviate export market advantages.

The product life cycle model (Vernon, 1966; Hirsch, 1974) had similar conclusions. Innovations would generate new products passing through different stages of maturity. Initially, the new item would be produced by the innovator country. Once the item was standardized, the production could be located where labor costs were lower.

Simultaneously, another important literature has highlighted the role that firms' innovative activities, such as the undertaking of research, product development, and knowledge acquisition, play in the making of their significant foreign direct investments. Firms' superior capabilities and product advantages lead them to become international players (Caves, 1971; Dosi et al., 1990; Hymer, 1960). These capabilities, permitting international expansion of firms' activities, are accruing specific advantages for the firm based on their investments in intangibles.

A literature (Buckley & Casson, 1976; Dunning, 1979; Grossman & Helpman, 1991; Gruber et al., 1967; Helpman, 1984; Lall, 1992) has discussed the varied empirical and theoretical contours of these concerns. In fact, Caves (1996) articulates the view that firms' motives for overseas forays, and successes thereof, are significantly predicated on the possession of technology and intangible assets that have been developed by the firm.

Thus, successful firms making overseas investments possess not only liquid and tangible assets, such as cash and equipment, but also substantial intangible technological and managerial assets. The ownership of these technological assets serves to enhance the competencies and capabilities that firms possess, and the availability of a stock of capabilities helps firms successfully leverage these in environmental contexts other than those of the parent country.

Nevertheless, these intangible technological and managerial capabilities have to be developed, in the first instance, before any leverage can take place. Hence, firms that actually undertake a relatively substantial amount of research and development activities will also succeed in their overseas operations. In fact, the line of thinking, that the development of intangible assets and competencies is also associated with successful overseas expansion, can be taken as axiomatic.

Intangible assets include, critically, the availability of superior technologies, knowledge, and know-how. These can take the form of patented designs or processes, or of manufacturing or research know-how shared among a critical mass of employees. The experiences of the human capital pool that a firm has access to gives it the ability to exploit market opportunities, using the technologies that are superior, at least for the time being.

When deployed in a host country firm, these assets also help to give foreign firms decided operational and cost advantages. This attribute makes their products competitive in a global market. As a consequence, their earnings from foreign business activities can be substantial. Hence, firms that undertake relatively higher amounts of R&D will also have higher levels of export earnings. Is this hypothesis valid for Indian information technology and software sector firms? That is the question evaluated in the article. It is a topic on which little work has been done so far, though the success story of the sector, per se, has aroused considerable interest among scholars and policy makers.

3. The Information Technology and Software Industry in India

The Indian information technology and software industry has a number of characteristics that make it an interesting context (for further details see Majumdar, 2010). First, from its beginnings, the industry has focused on international markets. In the early 1970s, the Indian government was highly protectionist and bureaucratic, making it difficult and expensive to import the hardware needed to build the industry.

It had also been time-consuming to obtain approval for software exports. Thus, in 1973, the *Santa Cruz Electronic Exports Processing Zone (SEEPZ)* was set up near the Mumbai airport specifically to create a fully export-oriented software

sector. This is where India's software and information technology industry was born.[2]

In addition, infrastructure issues throughout the county, such as lack of power or good communications, plus the lack of an adequate market, made it difficult for Indian software firms to compete domestically. However, in the mid 1970s and early 1980s, import duties were reduced, and export applications were cleared faster. The government *Computer Policy* of 1984 called for the development of agencies regarding software promotion, as well as for the liberalization of imports for necessary inputs (Arora et al., 2001).

The government also subsequently established seven *Software Technology Parks (STPs)* around the country to be resource centers for software exporters (Correa, 1996). In the 1990s, liberalization continued, with more reductions on import duties, as well as income tax exemptions for software exports. This liberalization of software policy by the government during a time of low-cost labor in India, as well as increased worldwide demand, allowed Indian firms to develop and grow through exporting abroad.

The domestic market, in contrast, has never been a major focus for the industry. The Indian software industry has had limited links to the domestic Indian market, with more than 85% of sales arising from exports in recent years (Desai, 2005). The Indian government's focus on the export market, as well as limited domestic demand for software products and services, are both some likely reasons for low domestic sales.

Firms comprising the Indian software industry, therefore, have been born global firms, with a focus on international markets. Moreover, these firms have all originated in India. Domestic Indian firms which have been resourced and set up by Indian entrepreneurs operating from India, and which are not subsidiaries of foreign firms, are responsible for the growth of the Indian software industry (Kumar & Joseph, 2005). In sum, the external environmental factors of policy designed to encourage exports in the Indian software industry, as well as increased international demand for such services, are major reasons for the development of a born global software industry in India.

Apart from its born global nature, a second reason to focus on India's software industry has been its success. The Indian software industry has been recognized as one of high growth, at over 50% a year (Arora et al., 2001). The output value in this industry has increased more than 18 times in a decade. In 1999, the Indian software industry was estimated to have 18.5% of the world market (Kumar & Joseph, 2005), and in 1996, it was used for outsourcing by over 100 Fortune 500 companies (Arora et al., 2001).

The industry accounts for 20% of India's exports (Kumar & Joseph, 2005), was expected to contribute about 20% to India's incremental GDP between 2001 and 2008, and was estimated to account for 7% of India's GDP in 2008 (Ambastha & Momaya, 2004). By studying a successful industry in an emerging economy, important insights are provided into the behavior of firms in a highly competitive and growing industry.

Another important reason for studying the Indian software industry is the interest in high-tech, born global firms. As Rialp et al. (2005, p. 152) point out, "a significant portion of the current literature on these businesses deals directly with high-tech businesses." By focusing on the Indian software industry, further insights are provided into the strategic behavior of born global firms in the high-tech sector.

4. Analysis

4.1 Data

A data set drawn from a Reserve Bank of India database on financial accounts of nongovernmental public limited companies has been used to test the relationship between the undertaking of research and development activities and the propensity of software and information technology firms to engage in global business. The Reserve Bank of India database is an elaborate and consistent database on Indian companies maintained by the

2. I am grateful for several conversations on the SEEPZ and the Indian software industry phenomenon with S. Rajgopal, the founding Development Commissioner of the SEEPZ. He later was Industries Secretary in the Government of Maharashtra, Energy Secretary with the Government of India, and finally, the Union Cabinet Secretary. His policy role was substantial, and his insights into all phases of the Indian information technology and software phenomenon have been invaluable.

Reserve Bank of India from fiscal year 1950–1951 onward, based on the companies' balance sheets, profit and loss accounts, and annual reports.

Aggregates based on these accounts inform policy, primarily the monetary policy of India, and have been used for the compilation of national accounts. They have also been used for estimating the growth of the real sector of the economy. Given the needs of the Reserve Bank of India, only selected variables are available in this database, and not all firm-level details may be found. Nevertheless, for the purpose of this analysis, the database was useful.

The data relate to companies that are public limited, according to the definitions of the Companies Act of 1956; some of these public limited companies may be listed on stock exchanges. The Reserve Bank of India also collects similar data on private limited companies, as defined in the Companies Act of 1956, but these datasets are never released to outsiders. The Reserve Bank of India public limited company data represent approximately 85% of the paid-up capital of 86 three-digit industries (Feinberg & Majumdar, 2001).

The consistent coverage over a long period has contributed to database quality. In the recent past, from fiscal year 2000–2001 onward, service sector firms have been added to the database. Of these firms, several belong to the information technology and software sector. Additionally, to maintain consistency, the data have been standardized into a common reporting format across companies and time by the Reserve Bank of India.

It was important that the coverage be not only representative of the population in each year, but that it was consistent over the period of time covered. Second, it was necessary to use a database taking adequate care of changes in accounting norms over this period. While the data are proprietary, the Reserve Bank of India database has been used for related policy work on the Indian corporate sector by various government bodies to report on policy matters. Private use of it is rare, though it was recently made available for use on an allied topic by Majumdar (2010).

To construct the data set, an unbalanced panel of 112 software and information technology sector firms for the continuous six-year period between 2000–2001 and 2005–2006 was used. Between 1,600 and 3,000 companies are surveyed each year. However, while the Reserve Bank of India has systematically collected data on large public limited firms, its coverage of the smaller public limited companies is somewhat sporadic and sketchy. Entries in and exits out of the sample often represent the smaller firms, which that may not submit data, rather than actual entries and exits. The total number of firm-year observations over the continuous years 2000–2001 to 2005–2006 was 373. One aspect of firms not covered in this data set is the nature of ownership—i.e., whether a firm has any foreign ownership component.

The Reserve Bank of India database included several diversified firms. However, profits and other financial characteristics for the different business units of these firms were not separately recorded in the database. State-owned enterprises and privately held limited companies were excluded. Further, the analysis was confined to the information technology sector. The effect of the business cycle and institutional factors, such as credit availability, the impact of fiscal policy, and fluctuations in interest and exchange rates, would all be similar for public limited firms in the sector. All firms that were assessed are represented with at least two years of continuous data, which permits the use of dynamic panel data analysis in first differences. This technique is described subsequently.

4.2 Variables

The dependent variable was the firm's ratio of export earnings to sales *(exports).* The primary explanatory variable was the ratio of the firm's research and development spending to sales *(R&D).* The *R&D* measurement is not always transparent, especially in small firms (Kleinknecht, 1987), and care is used to ensure that the measure has been adequately measured. In the past, data on export earnings and research and development spending have not typically been reported by Indian companies in their financial statements. In fact, data on Indian software and information technology firms' research and development spending have not yet been systematically analyzed, to this author's knowledge.

For the sake of compiling India's balance of payments statistics, the Reserve Bank of India has been acquiring comprehensive and accurate data on the export earnings and research and development spending variables. The availability of these export earnings and research and development spending

Table 1. Regression Results of Indian Information Technology and Software Firms' Export Earnings for the Fiscal Years 2000–2001 to 2005–2006.

	Dependent Variable: Export Sales Ratio	
	Coefficient (Standard Error)	***t* statistic**
Constant	−100.596 (52.565)	1.91**
$Exports_{t-1}$	0.254 (0.022)	11.34***
R&D	0.702 (0.358)	1.96**
Capital Intensity	−0.252 (0.101)	2.49**
Size	7.255 (3.789)	1.91**
Profits	0.011 (0.009)	1.14
Margins	−0.049 (0.074)	0.67
Imports	−0.470 (0.154)	3.06***
Capital	0.530 (0.182)	2.92***
Cash	0.272 (0.130)	2.09**
Leverage	0.363 (0.760)	0.48
Foreign	0.048 (0.118)	0.41
Wald χ^2	447,638.00	
N	138	

*** $p < 0.01$, ** $p < 0.05$, $p < 0.10$

variables for the bulk of India's firms has been a major innovation in data collection. Their use in analysis has been rare.

Another variable, the ratio of fixed assets to the firm's total assets, has been used to measure capital intensity *(capital intensity).* In the context of a labor-rich country such as India, overseas ventures are likely to have embodied human capital inputs, rather than physical capital inputs, if one takes note of the Heckscher-Ohlin (Heckscher, 1950; Ohlin, 1933) reasoning.

Other covariates have been firm size *(size),* measured as the log of total revenues; overall profitability *(profits),* measured as the ratio of net profits to net worth; sales margins *(margins),* measured as the ratio of gross profits to value of production; and the level of firm imports *(imports).* An environmental control variable added to the analysis has been the extent of domestic capital formation in the economy *(capital),* measured as the ratio of net domestic capital formation to gross domestic product.

Recent literature (Hall, 2002; Hao & Jaffe, 1993; Harhoff, 1998; Mayer, 1990) highlights the role of liquidity and heterogeneity in firms' finances as influencing R&D activities. Thus, the ratio of cash to total assets *(cash),* the ratio of financial leverage or debt to equity *(leverage),* and the ratio of foreign borrowings *(foreign)* as a percentage of total debt raised have been used as control variables.

4.3 Estimation and Results

Because unbalanced panel data have been used, dynamic panel data estimation is required. Addi-

tional instruments include variables indicating segment participation—i.e., whether firms have participated in the hardware consulting, software consulting, data processing, or database management segments. Details are provided in the appendix. The Sargan test result provides support for the use of the instruments.

An additional clarification is useful. Where the data relate to a firm for only one year's observation, that observation is dropped. Where the time periods are not continuous, those observations are also not used. Given the structure of the data set—an unbalanced panel, but with continuity in observations for specific firms—the dynamic panel data method is also the most relevant technique to use. It is the most stringent of all panel data techniques. It is particularly useful for such unbalanced panels, where standard panel data techniques may tend to give misleading results.

The regression estimates are given in Table 1. The magnitude of the positive *R&D* variable estimate has been substantial, and the estimate has been highly significant ($p < 0.05$). Thus, the statistical test results of the relationship between the extent of research and development spending and exports, or expressed another way, between innovation and globalization, has been robust. The implications of the results are discussed in the next section.

5. Discussion

R&D spending has been associated with both industrial capability development and economic growth. A recent compilation of studies of the impact of R&D (Jones & Williams, 1998) suggests that the social rates of return to R&D are around 100%. The studies evaluated include Scherer (1982), Terleckyj (1980), Griliches (1994), and Griliches and Lichtenberg (1984). The results, which are robust in their inclusion of important variables that capture firm effects considered of importance in the contemporary literature, are of considerable overall significance.

The magnitude of the R&D variable has been substantial in influencing levels of Indian information technology and software sector firms' export earnings. The fundamental result established is that those firms that have undertaken higher levels of research and development activities, relative to other firms, have benefited from higher levels of exports sales.

Thus, the creation of a domestic knowledge base in India has led to the leverage of such knowledge capabilities in overseas markets. This is an important consideration, since the globalization process for Indian industry is just under way. In this process, the information technology and software sector firms have set the pace for other firms to follow. Thus, as a whole, the results are of some policy consequence for the entire Indian economy.

As has been conclusively documented, the payoffs from research and development activities are high, whether these are evaluated in general terms, in terms of impact on export levels, or in terms of impact on investment levels. The results for the Indian information technology and software sector firms studied show that the research and development pay-offs in generating export earnings from overseas are also high. This finding further mandates the necessity for Indian firms to enhance their research and development activities by a large amount, so as to further reap the benefits of the expenditures on innovation-related activities.

The fact that India is an important place to locate information technology- and software-related research activities is brought home by the experiences of several global companies. Take Microsoft, which employs several thousand persons on research activities in India. Work related to both its search engine and its new operating system was performed in India.

Similarly, SAP Labs has its largest research center outside of Germany in India, employing several thousand persons working on enterprise resource planning development. Google's first research center outside the United States was in India, where its staff worked on the Google Maps projects. IBM has invested several hundred million dollars across India, and in its own laboratories, as have Intel and HP, while Cisco Systems has filed more than 600 patents from India. Clearly, the experiences of the global information technology and software firms in using India as a research location ought to be of much importance to the domestic firms operating in India.

The mimetic and learning outcomes from these examples ought to be high. If the domestic firms that have been studied were to ramp up their research and development activities substantially, many of them, and not just a handful like the half-dozen companies that are so at present, would become the global giants in the sector. As it is, the

research and development and export earnings relationship is positive. Hence, the translation of additional substantial research and development spending into global revenues would be equally substantial.

6. Conclusion

Based on a sample of important Indian information technology and software sector firms, this article has examined the impact of research and development spending, as well other factors, on firms' overseas export earnings patterns. The results of the analysis have shown that enhanced R&D spending carried out by these firms has been associated with a significant rise in these information technology and software sector firms' average overseas earnings levels from exports. Thus, investment in capabilities by information technology and software sector firms has significantly impacted their propensities to engender overseas earnings from exports. These results point to the need to substantially enhance the levels of research and development currently being undertaken by firms in India, so that Indian firms can continue to enjoy, in increasing quantities, the substantial economic and financial benefits of being engaged in the global economy. The consequence of a higher level of innovation is a higher level of globalization.

Appendix: Estimation Technique

The type of dynamic panel data regression considered has the following general form:

$$y_{it} - y_{i,t-1} = \alpha + \beta y_{i,t-1} + X'_{it}\delta + \lambda_t + u_{it}$$

or equivalently

$$y_{it} = \alpha + \tilde{\beta} y_{i,t-1} + X'_{it}\delta + \lambda_t + u_{it}, \quad i = 1, \ldots, N;\ t = 2, \ldots, T \tag{1}$$

where y is the logarithm of the dependent variable, i is a each firm specific observation, t is a period of time that is a year, $\tilde{\beta}$ is a scalar ($\tilde{\beta} = \beta + 1$), X_0 represents the set of explanatory variables $1 \times K$, and δ is $K \times 1$; λt is the time-specific effect; $u_{it} = \mu_i + \upsilon_{it}$, where μ_i is the unobservable firm-specific effect, and υ_{it} is an error term.

The presence of firm-level heterogeneity in panel data models with lagged dependent variables tends to generate biased and inconsistent estimates if the time dimensions of the panel are fixed and not of very substantial length (Nickell, 1981; Judson & Owen, 1999). Thus, a generalized method of moments (GMM) estimator is appropriate. Nevertheless, two problems exist with the dynamic panel regression in (1). First, the lagged dependent variable as a regressor leads to autocorrelation; second, firm-specific effects characterize inherent heterogeneity (Baltagi, 2008).

As y_{it} is a function of μ_i, thus $y_{i,t-1}$ would also be a function of μ_i. Hence, $y_{i,t-1}$, which is a right-side regressor, will be correlated with the error term. This yields biased and inconsistent OLS estimators, even if the υ_{it} are not serially correlated. The initial step is to first-difference (1) to eliminate the individual effects (Arellano & Bond, 1991). This procedure yields

$$y_{it} - y_{i,t-1} = \tilde{\beta}\,(y_{i,t-1} - y_{i,t-2}) + (X'_{it} - X'_{i,t-1})\delta + (\lambda_t - \lambda_{t-1}) + (\upsilon_{it} - \upsilon_{i,t-1}) \tag{2}$$

This method of eliminating firm-specificity, however, introduces another issue. The first-differencing causes the new error term, $\Delta\upsilon_{it} = \upsilon_{it} - \upsilon_{i,t-1}$, to be correlated with the lagged dependent variable, $\Delta y_{i,t-1} = y_{i,t-1} - y_{i,t-2}$. This correlation, combined with the potential endogeneity of the explanatory variables, leads to the consideration of the use of instrumental variables as suggested by Arellano and Bond (1991), under the assumptions that υ_{it} is not serially correlated, and with the moment restrictions $E\,[y_{i,t-s}\Delta\upsilon_{it}] = 0$ for $t = 1, \ldots T$, and $s \leq 2$.

For instance, for equation $\Delta y_{i3} = \delta\Delta y_{i2} + \Delta\upsilon_{i3}$, the instrument available is y_{i1}; for $\Delta y_{i4} = \delta\Delta y_{i3} + \Delta\upsilon_{i4}$, the instruments available are y_{i1}, y_{i2}, and so on. If the regressors in X_{it} are endogenous, in the sense that $E\,[X_{it}\upsilon_{is}] = 0$ for s > t and $\neq 0$ otherwise, the moment conditions $E\,[X_{i,t-s}\Delta\upsilon_{it}] = 0$ for $t = 1, \ldots T$, and s ≤ 2 are available. The estimator that uses those moment conditions is known as the difference estimator (Arellano, 2003; Baltagi, 2008).

The validity of the instruments is tested by means of the Sargan test of over-identifying restrictions. The Sargan test is distributed as $\chi 2$ with $(J - K)$ degrees of freedom, J being the number of instruments, and K, the number of regressors. For instrument validity, the null hypothesis denoted by a high p-value is accepted. The generic instruments used are the past values of each explanatory variable. ■

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