Empir Econ (2012) 42:947–986
DOI 10.1007/s00181-011-0449-0

Knowledge sourcing and firm performance in an industrializing economy: the case of Taiwan (1992–2003)

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Received: 21 August 2006 / Accepted: 28 October 2010 / Published online: 20 March 2011

Abstract We examine the impact of R&D and technology imports on firm performance in Taiwan's manufacturing industry in a policy context of industrial upgrading. To do so, we estimate a Translog production function on two panels (covering 1992–1995 and 1997–2003), using stochastic frontier models. We find that the effects of both knowledge inputs become significant in a larger number of industries in the second panel. These results suggest that the policies encouraging innovation implemented from 1991 onwards paid off in the second half of the 1990s, with innovation driving firm sales. In traditional industries, the effect of innovation can be interpreted as an effort to catch up with the global technology frontier. In the electronics and high-technology industries, it rather testifies of the emergence of a new domain of specialization for Taiwan—which was largely enabled by the aforementioned innovation policies.

Keywords Manufacturing industries · Newly industrialized countries · Technology imports · Stochastic frontier estimation

JEL Classification L25 · L60 · O33

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0 Introduction

Since the beginning of the 1990s, Taiwan has been increasingly challenged by international competition, especially from other emerging Asian economies. A steep rise in labour costs and the adoption of a managed floating exchange rate both contributed to make Taiwanese exports less competitive. As a reaction to these difficulties, Taiwan accelerated its industrial upgrading, a process which was supported by a bundle of specific public policies. These policies were designed to make Taiwan a knowledge-based economy, by encouraging R&D and by facilitating the importation of technology. This research estimates how in-house R&D and technology imports impacted firm performance in the policy context of the 1990s and early 2000s in Taiwan.

The article is organized as follows: the first section states the objective of the research, with an emphasis on the science and industrial policies context. The second section presents the data, and the third section details the econometric analysis. Results are presented and commented in the fourth section. Conclusions are given in the final section.

1 Objective of the research

Evaluating the impact of technology imports on industrial upgrading remains an important issue, especially in countries that are in a catching-up or industrializing phase. Several authors have assumed that, in such countries, licensing agreements with foreign firms may be at least as important a source of knowledge as internal R&D. Studies which examined this assumption in the case of the Japanese economy in the 1960s and 1970s (e.g., Caves and Uekusa 1976; Odagiri 1983) did not find significant statistical evidence to support it. Subsequent studies, however, such as the one conducted for India by Basant and Fikkert (1996), suggest that technology imports may have a positive effect on productivity growth.

This research examines this question in Taiwan in the 1990s. By all accounts, the history of innovation in Taiwan is not very long: innovation expenditures (including R&D and technology imports) really took up in the mid-1980s, and grew steadily to this day, with technology imports gradually taking more importance (NSC 2002). This evolution can be directly related to Taiwan's industrial and innovation policy, the cornerstone of which has been, since 1st January 1991, the Statute for Upgrading Industry, hereafter SUI (Hou and Gee 1993; Luo 2001).

1.1 Taiwan's innovation policy in the 1990s: the SUI

Indeed, it is widely acknowledged that the bulk of Taiwan's manufacturing industry consists in small and medium enterprises (SMEs), which are particularly flexible and able to adapt quickly to changing market conditions (Hobday 1995; Aw 2002; Guerrieri and Pietrobelli 2006). However, these SMEs would probably not have been able to invest so much in innovation without the help of specific public policies actively promoting industrial and technological upgrading (Tsai and Wang 2005; Guerrieri and Pietrobelli 2006).

These policies have been formalized within the aforementioned SUI, which consists in a number of incentive measures aimed at encouraging investment and technology transfers in emerging and/or strategic industries (i.e., industries that are expected to benefit economic development in a substantial way). A first set of measures involve taxation policy and direct public spending, including: (1) tax incentives to develop investment in R&D and process innovation; (2) preferential loans (arranged through the Executive Yuan Development Funds, in conjunction with banks) for the upgrading of SMEs and the promotion of industrial R&D; (3) specialized programmes providing support for technical upgrading, new product development and R&D; (4) public institutes and centres providing extensive support to the private sector in developing new technology.

A second set of measures is oriented towards education with the objective of upgrading the stock of human capital. These measures take the form of: (1) on-the-job training provided by various academic organizations to give workers the skills to succeed in emerging industrial sectors; (2) doubling to six years the maximum period of stay in Taiwan of skilled mainland Chinese technicians; (3) increasing the employment of mainland technical personnel at innovative R&D centres; (4) enabling wider civilian employment amongst armed forces R&D personnel; (5) establishing institutes to foster talent in high-tech industries (e.g., semiconductors).

The third and final set of measures was specifically implemented to encourage technology transfers and to accelerate the flow and commercialization of innovative knowledge. The most important was perhaps the creation of science-based industrial parks (or ‘science parks’), to facilitate the development of high-tech industries such as electronics. The objective was to have places in Taiwan where R&D-intensive firms and universities could mutually benefit from each other’s presence, creating a virtuous circle of knowledge production and economic growth (Lee and Yang 2000; Guerrieri and Pietrobelli 2006). In that prospect, the science parks, built on land provided by the government and universities, were designed to provide an attractive environment for scientists and researchers (Tsai and Wang 2005; Guerrieri and Pietrobelli 2006). Another important measure, in the same vein, was the establishment of a platform for technical exchange between domestic and foreign businesses on the one hand, and academic organizations on the other (the Taiwan Technology Marketplace or TWTM).

The SUI was first designed to be effective until 31st December 1999. After 2000, due to the continued need for structural transformation and for the promotion of international competitiveness, a New SUI was implemented, with an effective period of 10 years, from 1st January 2000 to 31st December 2009.

1.2 Knowledge sourcing and productivity in the context of the SUI

Our research question becomes particularly relevant in the context of the SUI for two reasons: first, because this set of public policies was designed to help Taiwanese firms catch up with the global technology frontier. Second, because these policies consisted both in spurring firm’s R&D and in helping them acquiring foreign technologies needed for their development. This is indeed the ideal context to study the respective impact of R&D and technology imports on firm performance.

In our empirical analysis, we consider R&D expenditures on the one hand, and disembodied technology imports on the other. ‘Disembodied’ refers to technologies here that are protected by intellectual property rights, but can be purchased by a firm and used in its production process. These include patented technologies, licensed technologies and other royalties-inducing technologies. Taking into account additional sources of knowledge, such as technology embodied in products purchased on the international market, would have been very interesting. Unfortunately, the available data did not allow us to do so.

Our analysis, which relies on the estimation of a production function, will not only examine the respective impact of the two aforementioned sources of knowledge on firm performance, but also address the question of whether they are complements or substitutes. Although economic theory generally assumes that inputs are substitutes, some studies (e.g., Blumenthal 1979; Cassiman and Veugelers 2006) have found empirical evidence of complementarities between external and internal sources of knowledge. Cohen and Levinthal (1989, 1990) provide a theoretical explanation for these results. Firms that import technology must have some R&D capacity, to (i) identify and select relevant technologies and (ii) effectively integrate these technologies in their production process. In Taiwan, the primary purpose of R&D in the 1990s may have been to effectively absorb foreign knowledge, building up a knowledge base that can then be used to foster internal R&D. This leaves scope for complementaries between both sources of knowledge. However, depending on the evolution of the industry structure, we may also observe substitutability. This can be the case if the observation period coincides with the moment when firms are gradually abandoning adaptive R&D in favour of technology imports.

2 The MOEA panel data

Our article uses census data gathered by the Statistical Bureau of Taiwan’s Ministry of Economic Affairs (MOEA). The Statistical Bureau of the MOEA conducts a yearly census survey, and collects data on every plant in operation that holds a registered certificate in the manufacturing sector. In Taiwan, most manufacturing firms are single business units: in our data, on average, 90% of the manufacturing firms are actually single-plant producers. Therefore, distinguishing between plant and firm may not be as relevant in Taiwan as it is in industrialized countries, and we will refer to the MOEA data as ‘firm-level data’ hereafter.[1]

Given what was said about innovation policy in Taiwan in the previous section, it makes sense, for our purpose, to focus on the 1990s, after the implementation of the IUS. Our data consists in two different panels. The first panel covers the 1992–1995 period (the MOEA census survey was not conducted in 1991) and the second panel covers the 1997–2003 period, with a gap in 2001 (year in which the survey was not conducted).

It was impossible to match both panels, due to a break in 1996: no survey was conducted that year, and the Statistical Bureau took that as an opportunity to completely

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[1] Moreover, we can include a ‘multi-plant’ control variable in our estimations whenever it is relevant to do so.

Table 1 Breakdown by 2-digit industries

2-Digit industry name	Panel 1992–1995			Panel 1997–2003		
	2-Digit code	Frequency	%	2-Digit code	Frequency	%
Food manufacturing	(11)	3161	11.4	(08)	1761	6.3
Textile mill products	(13)	1806	1.3	(10)	1093	3.9
Wearing apparel and accessories	(14)	366	0.8	(11)	657	2.4
Leather and fur products	(15)	227	3.0	(12)	331	1.2
Wood and bamboo products	(16)	839	3.6	(13)	568	2.0
Furniture and fixtures	(17)	994	2.8	(14)	496	1.8
Pulp, paper and paper products	(18)	789	2.8	(15)	706	2.5
Printing processing	(19)	782	2.2	(16)	973	3.5
Basic chemical matter manufacturing	(21)	616	4.2	(17)	386	1.4
Chemical products	(22)	1172	0.1	(18)	880	3.2
Petroleum and coal products	(23)	13	1.2	(19)	52	0.2
Rubber products manufacturing	(24)	335	8.5	(20)	457	1.6
Plastic products manufacturing	(25)	2347	5.7	(21)	2955	10.6
Non-metallic mineral products	(26)	1592	5.4	(22)	1084	3.9
Basic metal industries	(27)	1493	11.9	(23)	791	2.8
Fabricated metal products	(28)	3313	8.4	(24)	3959	14.2
Machinery and equipment	(29)	2329	6.8	(25)	5651	20.3
Electrical and electronic machinery	(31)	1890	6.8	(26)[a]	415	1.5
				(27)[a]	672	2.4
				(28)[a]	1159	4.2
Transportation industry	(32)	1893	2.1	(29)	1397	5.0
Precision instruments	(33)	588	4.4	(30)	403	1.4
Miscellaneous industrial products	(39)	1209	1.3	(31)	1062	3.8
Total of manufacturing industries		27754	100.0		27908	100.0

[a] New industries created from former ‘Electrical and electronic machinery’, now named: (26) ‘Audio and video products’, (27) ‘Electronic parts and components’ and (28) ‘Electric machinery and parts’

reform their classification system. Not only did the industry codes change, but the electronic industry (which plays a key role in the Taiwanese economy and had rapidly grown in the early 1990s) was split up into three different industries. Moreover, after 1996, some firms were recoded as belonging to a different industry than the one they belonged to before this date. For all of these reasons, we have to analyze both panels separately. This is anyway not a bad thing, as it will give us insights on the evolution of the Taiwanese manufacturing industry across two periods of time.

Table 1 gives a breakdown of both panels by 2-digit industry. Although the names of all industries but one remain the same from one panel to the next, the contents of these industries may have changed, as some firms may have been re-categorized in other industries. Moreover, industry (31) ‘Electrical and Electronic Machinery’ in panel 1 (1992–1995) has been split, in panel 2 (1997–2003), into three new industries: (26) ‘Audio and Video Products’, (27) ‘Electronic Parts and Components’ and (28) ‘Electric Machinery and Parts’. Both panels are described in more details in what follows.

2.1 The 1992–1995 panel

Over 1992–1995, we observe a panel of 27,754 Taiwanese manufacturing firms, distributed across twenty-one 2-digit industries. This panel (hereafter panel 1) provides information on firms' sales (deflated by a wholesale price index), total value of fixed assets in operation at the end of the year, total expenditures on raw materials (deflated by an intermediate input–output price index) and wages (deflated by a consumer price index). These variables will be used as proxies for firm output, and capital, materials, and labour inputs, respectively.[2]

Additional information includes firms' yearly R&D expenditures, as well as the value of imported disembodied technologies (as defined in Sect. 1). Finally, the data includes three additional firm-specific characteristics: firm age, an indicator of whether a firm exports technologies and an indicator of whether a firm is a single- or multi-plants producer. Table 2 gives summary statistics, by industry, for all the aforementioned variables.

Coming from a census, our panel is very large, and it would not really make sense to estimate a unique econometric model on the whole panel, as the heterogeneity across industries is too important. It is more reasonable and relevant, in this case, to conduct a by-industry analysis. Industry (23) 'Petroleum and Coal Products' included only 13 firms, and was regrouped with industry (22) 'Chemical Products' for the purpose of our empirical analysis. Our estimations were therefore performed, *in fine*, over twenty 2-digit industries rather than on the original twenty-one.

2.2 The 1997–2003 panel

The second panel covers the years 1997–2003 (with a gap corresponding to year 2001) and concerns 27908 Taiwanese manufacturing firms, distributed across twenty-three 2-digit industries. This panel (hereafter panel 2) provides the same information on firms' inputs and output as panel 1. In addition, panel 2 gives information on firms' total expenditures on energy (deflated by an appropriate energy price index), which were not available before 1996. Panel 2 also contains (just like panel 1) information on yearly R&D expenditures and on the value of imported technologies, as well as firms' characteristics (age, technology exports and multiplant/single plant). Table 3 gives summary statistics, at the 2-digit industry level, for all of these variables.

We used panel 2 to conduct the same by-industry analysis as we conducted with panel 1. Again, we observed that industry (19) 'Petroleum and Coal Products' was too small to be studied on its own, and had to be merged with industry (18) 'Chemical Products' for the purpose of our empirical analysis. In panel 2, our estimations were therefore performed over twenty-two 2-digit industries rather than on the initial twenty-three.

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[2] More information about the data and the construction of variables is available upon request from the authors.

Table 2 Summary statistics, panel 1 (1992–1995)

	(11)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(21)	(22)+(23)
Q	110 (516.9)	175.6 (732.3)	72.4 (141.1)	224.2 (469.2)	31.4 (96)	39.7 (100.4)	133.6 (453.2)	25.1 (86.3)	548.9 (2036.6)	119.8 (760.8)
C	68.7 (305.9)	151.8 (764.7)	23.9 (56.4)	80.4 (154.2)	18.8 (59.9)	21.6 (70.3)	132.7 (676.6)	22.7 (100.9)	499 (1931.4)	81.4 (903.8)
L	10.6 (43.8)	24.8 (87.2)	17.6 (36.5)	31.1 (72.0)	4.5 (11.6)	8.5 (25.6)	18.6 (62.3)	6.6 (34.7)	45.2 (164.8)	14.6 (49.5)
M	33 (186.0)	56.7 (300.5)	25.1 (64.7)	80.9 (219.2)	12.7 (46.9)	13.7 (40.2)	45.7 (201.4)	6.9 (29.0)	168.4 (807.5)	39.3 (409.0)
RD	0.3 (2.7)	0.9 (6.2)	0.3 (1.8)	2.2 (10.4)	0.0 (0.3)	0.2 (2.3)	0.5 (2.9)	0.1 (1.0)	4.0 (19.4)	2 (26.1)
TI	0.1 (1.2)	0.1 (2.1)	0.0 (0.2)	1.1 (7.4)	0.0 (0.3)	0.1 (1.6)	0.2 (2.9)	0.0 (0.8)	0.8 (10.6)	0.4 (5.8)
Age	13.4 (7.5)	12.6 (6.7)	11.3 (5.6)	12 (6.1)	15 (6.3)	11 (5.5)	11.2 (6.3)	11.5 (6.1)	12.1 (7.0)	12.4 (7.4)
ET	0.00 (0.03)	0.00 (0.02)	0.00 (0.04)	0.01 (0.1)	0.00 (0.02)	0.00 (0.02)		0.00 (0.03)	0.00 (0.06)	0.00 (0.04)
MP	0.1 (0.3)	0.2 (0.4)	0.1 (0.3)	0.2 (0.4)	0.1 (0.3)	0.1 (0.3)	0.2 (0.4)	0.1 (0.3)	0.3 (0.4)	0.2 (0.4)

Table 2 continued

	(24)	(25)	(26)	(27)	(28)	(29)	(31)	(32)	(33)	(39)
Q	92.5 (322.6)	71.8 (436.7)	105.6 (372.9)	216.4 (683.9)	48.7 (169.2)	54.5 (187.9)	404.6 (1846.9)	177.8 (1476.4)	62.9 (248.6)	44.5 (120.3)
C	70.3 (310.8)	37.4 (283.1)	96.2 (487.4)	115.1 (551.8)	28 (126.6)	24.3 (97.0)	158.5 (981.1)	76.4 (472.1)	25.1 (76.6)	20.6 (66.6)
L	19.2 (66.8)	9.8 (42.5)	14.6 (36.0)	14.9 (36.8)	7.4 (20.1)	8.3 (22.4)	42.4 (153.7)	21 (108.4)	12.1 (39.3)	9.2 (23.6)
M	27.1 (124.6)	24.4 (190.2)	28 (106.9)	78.8 (323.8)	15.4 (69.7)	18.6 (82.2)	136 (939.1)	62.4 (703.2)	21.3 (125.7)	13.8 (47.9)
RD	1.2 (8.4)	0.4 (3.3)	0.4 (4.0)	0.4 (3.3)	0.3 (3.2)	0.5 (4.0)	8.5 (55.0)	2.7 (27.5)	0.8 (6.2)	0.4 (3.0)
TI	0.2 (1.6)	0.2 (1.9)	0.1 (1.7)	0.1 (2.6)	0.1 (1.2)	0.1 (1.2)	3.5 (53.1)	1.2 (19.4)	0.0 (0.5)	0.0 (0.4)
Age	12.4 (6.2)	11.5 (5.8)	12.8 (6.6)	10.9 (6.1)	10.4 (5.6)	11.5 (5.8)	9.9 (5.9)	11.5 (5.9)	9.8 (5.1)	11.5 (6.1)
ET	0.00 (0.06)	0.00 (0.03)	0.00 (0.04)	0.00 (0.02)	0.00 (0.03)	0.00 (0.04)	0.01 (0.09)	0.00 (0.04)	0.00 (0.04)	0.00 (0.04)
MP	0.2 (0.4)	0.1 (0.3)	0.2 (0.4)	0.2 (0.4)	0.1 (0.3)	0.1 (0.3)	0.2 (0.4)	0.1 (0.4)	0.1 (0.3)	0.1 (0.3)

Output variable: *Q* firm sales. Input variables: *C* capital, *L* labour and *M* materials, innovation expenditures: *RD* R&D expenditures, *TI* expenditures on technology imports

Control variables: *Age* firm age in 1992, *ET* firm exports technology (dummy variable) and *MP* multi-plant firm (dummy variable)

Output, inputs and innovation expenditures are in thousands of constant New Taiwan Dollar

Standard errors in parentheses

Note that no firm exports technology in industry (18) ‘Paper, pulp and paper products’ (ET = 0 in that industry)

Table 3 Summary statistics, panel 2 (1997–2003)

	(8)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18) + (19)	(20)
Q	145.5 (782.6)	212.3 (920.6)	89.5 (222.0)	164.4 (612.4)	32.2 (90.6)	52.0 (160.3)	122.6 (473.9)	33.4 (120.6)	952.8 (3152.7)	364.7 (4384.6)	88.1 (302.2)
C	104.2 (438.9)	215.1 (1197.8)	34.7 (220.6)	49.8 (153.9)	19.6 (140.3)	27.4 (110.3)	107.8 (549.3)	34.6 (200.6)	1014.5 (3811.8)	382.0 (5785.1)	65.8 (271.0)
L	32.1 (115.1)	61.2 (197.3)	46.3 (100.8)	46.9 (145.5)	14.5 (25.7)	24.0 (60.2)	31.8 (70.3)	18.5 (50.8)	90.7 (262.3)	36.7 (124.3)	37.8 (96.7)
E	82.1 (435.5)	115.8 (530.8)	43.6 (109.8)	106.7 (400.3)	19.6 (55.6)	27.7 (85.5)	73.4 (296.9)	16.7 (61.4)	582.5 (1914.7)	252.0 (3328.7)	41.6 (147.6)
M	2.4 (13.7)	9.1 (43.4)	0.6 (1.6)	1.4 (4.3)	0.5 (1.5)	0.5 (1.6)	4.2 (24.9)	0.5 (1.5)	33.7 (127.4)	4.0 (43.5)	1.9 (7.2)
RD	0.5 (6.3)	1.1 (10.5)	0.3 (3.3)	2.4 (24.8)	0.0 (0.2)	0.4 (3.4)	0.3 (2.8)	0.1 (2.4)	6.2 (27.2)	1.9 (9.7)	0.8 (5.0)
TI	0.1 (2.9)	0.1 (2.3)	0.1 (1.3)	0.0 (0.6)	0.0 (1.2)	0.0 (0.3)	0.2 (6.0)	0.0 (0.0)	1.9 (16.6)	0.3 (3.6)	0.2 (1.6)
Age	17.3 (8.9)	14.6 (8.6)	13.0 (7.6)	14.1 (7.9)	18.1 (7.6)	12.5 (7.2)	13.7 (7.4)	11.8 (7.8)	15.8 (8.6)	16.7 (8.5)	14.3 (7.7)
ET	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.1)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.1)	0.0 (0.1)	0.0 (0.1)
MP	0.1 (0.3)	0.1 (0.3)	0.1 (0.3)	0.1 (0.3)	0.0 (0.2)	0.1 (0.3)	0.1 (0.3)	0.1 (0.2)	0.2 (0.4)	0.1 (0.3)	0.1 (0.3)

Table 3 continued

	(21)	(22)	(23)	(24)	(25)	(26)	(27)	(28)	(29)	(30)	(31)
Q	49.6 (448.3)	112.2 (365.2)	392.7 (3297.8)	47.9 (175.4)	41.6 (188.7)	542.4 (2146.2)	593.8 (3344.8)	186.4 (912.4)	266.9 (2224.7)	77.2 (352.3)	62.7 (216.4)
C	34.0 (392.8)	136.8 (674.1)	489.8 (8838.1)	27.2 (132.5)	20.6 (85.0)	93.7 (293.9)	388.5 (2517.4)	95.1 (505.8)	107.6 (733.0)	27.2 (73.9)	27.2 (99.4)
L	19.0 (72.6)	35.7 (80.5)	46.9 (320.9)	19.0 (36.7)	16.3 (34.8)	80.6 (196.9)	128.9 (389.0)	46.6 (148.1)	51.6 (187.5)	35.0 (99.3)	25.2 (59.0)
E	28.4 (268.9)	57.2 (152.8)	242.6 (1690.4)	23.8 (94.4)	21.0 (91.1)	359.6 (1592.7)	325.1 (2443.8)	106.8 (518.5)	153.9 (1350.8)	42.8 (231.9)	33.3 (119.7)
M	1.5 (15.6)	5.1 (27.7)	12.9 (110.9)	0.9 (3.3)	0.4 (2.0)	1.7 (6.8)	9.0 (39.1)	2.2 (10.2)	1.9 (9.2)	0.9 (3.2)	0.9 (4.6)
RD	0.3 (6.1)	0.5 (4.7)	1.2 (25.0)	0.1 (1.4)	0.3 (4.6)	15.1 (71.9)	18.3 (147.1)	2.3 (20.7)	4.2 (60.5)	1.1 (8.8)	0.6 (4.6)
TI	0.1 (7.1)	0.1 (2.1)	0.5 (17.0)	0.0 (0.7)	0.0 (0.7)	1.8 (17.0)	9.1 (99.9)	0.6 (11.2)	2.9 (47.1)	0.0 (0.7)	0.1 (2.5)
Age	12.9 (7.1)	15.9 (8.5)	13.5 (7.7)	11.6 (6.9)	11.3 (6.9)	9.6 (6.7)	10.2 (6.7)	12.1 (7.3)	13.2 (7.5)	12.6 (6.9)	13.7 (7.9)
ET	0.0 (0.0)	0.0 (0.0)	0.0 (0.1)	0.0 (0.0)	0.0 (0.0)	0.0 (0.1)	0.0 (0.1)	0.0 (0.1)	0.0 (0.1)	0.0 (0.1)	0.0 (0.0)
MP	0.1 (0.3)	0.1 (0.3)	0.1 (0.3)	0.1 (0.2)	0.1 (0.2)	0.1 (0.3)	0.1 (0.3)	0.1 (0.3)	0.1 (0.3)	0.1 (0.3)	0.1 (0.2)

Output variable: *Q* firm sales. Input variables: *C* capital, *L* labour and *M* materials, innovation expenditures: *RD* R&D expenditures, *TI* expenditures on technology imports
Control variables: *Age* firm age in 1992, *ET* firm exports technology (dummy variable) and *MP* multi-plant firm (dummy variable)
Output, inputs and innovation expenditures are in thousands of constant New Taiwan Dollar
Standard errors in parentheses
Note that no firm exports technology in industry (18) ‘Paper, pulp and paper products’ (ET = 0 in that industry)

3 Econometric analysis

3.1 Econometric model

Our analysis derives from a production function approach, linking firm output Q to input vector X (with $X_1 = \text{capital}$, $X_2 = \text{labour}$, $X_3 = \text{energy}$ and $X_4 = \text{materials}$) and knowledge K, assuming that knowledge and inputs have distinct effects. As in Basant and Fikkert (1996), we assume an exponential link between output and knowledge. For firm i operating at time t in a given 2-digit industry, we write:

$$Q_{it} = F(X_{it}) \exp(K_{it}) \exp(\varepsilon_{it}), \tag{1}$$

where F is an unspecified functional form and ε_{it} a random error term.

In order to estimate Eq. 1, we need to specify F, and to specify how knowledge K relates to innovation expenditures. Since we want to keep F as general as possible, we assume a translog specification, usually considered as a reasonable second-order approximation of an arbitrary production function (see for instance Berndt and Christensen 1973; Chan and Moutain 1983; Beason and Weinstein 1996). We may then rewrite (1) as:

$$\ln Q_{it} = \beta_0 + \Sigma_j \beta_j \cdot \ln X_{jit} + \frac{1}{2} \left[\Sigma_j \Sigma_k \beta_{jk} (\ln X_{jit})(\ln X_{kit})\right] + K_{it} + \varepsilon_{it}. \tag{2}$$

3.2 Measurement of the stocks of R&D capital and technology imports

As in Basant and Fikkert (1996), we assume that the stock of knowledge has a Generalized Leontief functional form of the type:

$$K_{it} = \alpha_0 \, (\text{KO}_{it})^{1/2} + \alpha_1 \, (\text{KP}_{it})^{1/2} + \alpha_2 \, (\text{KO}_{it} \times \text{KP}_{it})^{1/2} \tag{3}$$

where KO represents a firm's own knowledge (i.e., its stock of R&D capital) and KP a firm's purchased knowledge (i.e., its stock of imported technology). As stated in Basant and Fikkert (1996), the specification of Eq. 3 allows KO and KP to be complements or substitutes to one another. It also avoids the problem of taking the logarithm of the knowledge inputs, which are frequently equal to zero.

The stocks of R&D capital and technology imports are measured using the perpetual inventory method (Griliches 1979; Hall and Mairesse 1995); i.e., if δ denote the depreciation rate of knowledge, we have:

$$\text{KO}_t = (1-\delta)\text{KO}_{t-1} + \text{RD}_{t-1}, \quad \text{where RD is the value of R\&D expenditures} \tag{4a}$$

$$\text{KP}_t = (1-\delta)\text{KP}_{t-1} + \text{TI}_{t-1}, \quad \text{where TI is the value of technology imports.} \tag{4b}$$

This method normally requires the use of a long history of R&D (technology imports), so that knowledge stocks may be computed pre-sample. However, no such historical series are available at the firm level in our case, for, as was stated in Sect. 1, the history of innovation in Taiwan before 1991 is way too short. Therefore, initial values KO_1 and KP_1 had to be calculated on the basis of our panels, taking the first year of each panel as year 1. For this calculation, we used Hall and Mairesse (1995) Eq. (5), p 270, which states:

$$\mathrm{KO}_1 = \mathrm{RD}_1/(g+\delta) \tag{5a}$$

$$\mathrm{KP}_1 = \mathrm{TI}_1/(g+\delta) \tag{5b}$$

where g denotes the growth rate of R&D and technology imports expenditures.

Following Basant and Fikkert (1996), we assume that both g and δ are the same for TI and RD. As usual, it is very difficult to assign a value to those parameters. The most frequently used assumptions in the literature are a depreciation rate of 15% and a growth rate of 5%. After conducting a sensitivity analysis (taking, for instance, values of 20–25% for the depreciation rate and of 10% for the growth rate), we have decided to follow this set of assumption in our econometric modelling.

3.3 Estimation procedure

The econometric model to be estimated in each 2-digit industry is finally written as:

$$\begin{aligned} q_{it} = {} & \beta_0 + \Sigma_j \beta_j \cdot x_{jit} + \frac{1}{2}\left[\Sigma_j \Sigma_k \beta_{jk} \left(x_{jit}\right)\left(x_{kit}\right)\right] + \alpha_0 \cdot \mathrm{ko}_{it} + \alpha_1 \cdot \mathrm{kp}_{it} \\ & + \alpha_2 \cdot \mathrm{ko}_{it} \times \mathrm{kp}_{it} + \varepsilon_{it}, \end{aligned} \tag{6}$$

where q and x_j denote the natural logarithms of Q and X_j respectively, and where ko and kp denote the square roots of KO and KP, respectively. We estimated Eq. (6) using a Stochastic Frontier Estimation (SFE) approach (Kumbhakar and Lovell 2000). SFE provides an econometric framework which explicitly models technical inefficiencies (arising from unobserved factors such as managerial abilities) in the production process. We feel that this approach is particularly well suited to the case of Taiwan in the period we study. As explained in Sect. 1, this period corresponds to a context of technological upgrading, in which many firms are likely to operate at a distance from their production frontier.

We estimated two alternative specifications of a stochastic frontier model. The first one is derived from the single-equation model proposed by Battese and Coelli (1992). We decompose ε_{it}, the error term from Eq. 6, into three components: a time effect λ_t, a one-sided error term u_{it}, which represents technical inefficiencies, and a symmetric (noise) error term v_{it}. This yields the following model:

$$\begin{aligned} q_{it} = {} & \beta_0 + \Sigma_j \beta_j \cdot x_{jit} + \frac{1}{2}\left[\Sigma_j \Sigma_k \beta_{jk} \left(x_{jit}\right)\left(x_{kit}\right)\right] + \alpha_0 \cdot \mathrm{ko}_{it} + \alpha_1 \cdot \mathrm{kp}_{it} + \alpha_2 \cdot \mathrm{ko}_{it} \\ & \times \mathrm{kp}_{it} + \lambda_t + v_{it} - u_{it} \end{aligned} \tag{7}$$

where v_{it} is assumed to be i.i.d. $N(0, \sigma_v^2)$ and independently distributed of u_{it}. The technical inefficiency effect u_{it} is written as

$$u_{it} = u_i \cdot \exp(-\eta(t - T)) \tag{8}$$

where u_i is an i.i.d. non-negative random term, the distribution of which is the truncation at zero of the normal distribution $N(\mu, \sigma_u^2)$, η is a parameter to be estimated, and T is the total number of time periods in the panel.

The second specification is derived from the two-equation stochastic frontier model proposed by Battese and Coelli (1995). In this specification, ε_{it} is decomposed as above, but we now assume the technical inefficiency effect u_{it} to be a function of a set of explanatory variables z_{it} and a vector of parameters δ (to be estimated). We can then rewrite Eq. 6 into a stochastic frontier model *à la* (Battese and Coelli 1995):

$$\begin{aligned} q_{it} &= \beta_0 + \Sigma_j \beta_j \cdot x_{jit} + \frac{1}{2}[\Sigma_j \Sigma_k \beta_{jk} \left(x_{jit}\right)(x_{kit})] + \alpha_0 \cdot \mathrm{ko}_{it} + \alpha_1 \cdot \mathrm{kp}_{it} + \alpha_2 \cdot \mathrm{ko}_{it} \\ &\quad \times \mathrm{kp}_{it} + \lambda_t + v_{it} - u_{it} \qquad \text{(9a)} \\ u_{it} &= \delta z_{it} + \omega_{it}, \qquad \text{(9b)} \end{aligned}$$

where the ω_{it} random variable is defined by the truncation of $N(0, \sigma_u^2)$, so that $\omega_{it} \geq -\delta z_{it}$. This is consistent with specifying the distribution of u_{it} as the truncation at zero of the normal distribution $N(\delta z_{it}, \sigma_u^2)$.

Both specifications were estimated using the Frontier 4.1 programme (Coelli 1996). This allowed us, amongst other things, to estimate Eqs. 9a and 9b simultaneously by Maximum Likelihood (ML), as in Battese and Coelli (1995). In both specifications, the likelihood function is expressed in terms of the variance parameters, with $\sigma^2 = \sigma_v^2 + \sigma_u^2$ and $\gamma = \sigma_u^2/\sigma^2$. In the first specification, where u_{it} is not defined in terms of observed variables, two additional ancillary parameters, μ and η, defined in Eq. 8, have to be estimated.

3.4 Specification of the technical inefficiency equation

The main advantage of our second SFE specification *à la* (Battese and Coelli 1995) is that the technical inefficiency term, u_{it}, is explicitly modelled as a function of observed firm characteristics, denoted by z_{it} in Eq. 9b. This allows researchers to identify potential firm-level determinants of technical efficiency, and to explain inter-firm differences in efficiency. Our z_{it} vector includes the following variables: firm age at the beginning of the period, a dummy variable indicating whether a firm exports technology, a dummy variable indicating whether a firm is a single- or multi-plant producer, and a set of 4-digit industry dummy variables. We explain and justify this choice in the following paragraphs.

A theoretical justification for including firm age in the efficiency equation can be found in the model of firm selection proposed by Jovanovic (1982). In this model, efficient firms survive, whereas inefficient ones decline and close down. Firms discover their efficiency as they operate in an industry. Since this process of discovery takes time, more efficient firms are older than less efficient ones. Thus, Jovanovic's (1982) model postulates a positive relationship between firm age and efficiency. This theoretical prediction has found little empirical support, however.

For instance, Lundvall and Battese (2000) investigate the determinants of technical efficiency by applying SFE to a panel of 235 Kenyan manufacturing firms. They do not find any systematic relationship between age and efficiency in their sample. They claim, however, that this conclusion does not completely invalidate Jovanovic's (1982) model. It may simply indicate that the positive effect expected from firms' selection is counterbalanced by negative effects not accounted for in the theoretical model (e.g., the depreciation of the capital stock). Lundvall and Battese (2000)'s conclusion has been comforted by subsequent studies (e.g., Söderbom and Teal 2002; Niringiye et al. 2010). In the light of the above discussion, including age in the technical efficiency equation is relevant, if only to check whether our findings are in accordance with the empirical literature.

We included the 'technology exports' dummy variable in the inefficiency equation because: (1) this variable qualifies a firm as an exporter of goods or services (even though of a specific nature) and (2) it may indicate that a firm's knowledge-generating ability is above average (since the firm is not only able to generate knowledge, but also to export it).[3] The link between exports and efficiency (broadly defined) is empirically well documented, and has some theoretical foundations. The international economics literature (Bernard and Wagner 1997; Clerides et al. 1998; Bernard and Jensen 1999; Bleaney and Wakelin 2002) has found a positive association between exports and efficiency in both developed and developing economies, and has provided a theoretical rationale for it.[4] By contrast, we lack both empirical evidence and theoretical guidelines as to why a higher knowledge-generating ability should increase or reduce inefficiency.

In Taiwan, Chen and Tang (1987), using a sample of electronics firms, have found that export-oriented firms are 6–11% closer to the production frontier than other firms. Since the electronics industry is the foremost high-technology industry in Taiwan, export-oriented firms in this industry are likely to export not only goods, but also technology. Based on these reasoning and empirical evidence, we may expect technology exports to be associated with a higher technical efficiency, at least in some high-technology industries. This is far from certain, however, as Aw and Batra (1998) provide contradictory evidence. Using SFE on a cross-sectional sample of Taiwanese manufacturing firms, they find that, amongst high-technology firms, technical efficiency does not significantly differ between exporters and non-exporters. By contrast, amongst low-technology firms, exporters are significantly closer to the production frontier than non-exporters. In any case, these contradictory empirical findings suggest that it is important to include technology exports in the efficiency equation.

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[3] Unfortunately, the MOEA data did not provide us with a more general measure of exports, which we could have contrasted with our indicator of technology exports.

[4] For instance, Clerides et al. (1998) explain the positive association between exporting and efficiency by a self-selection of more efficient firms into the export market, whilst Roberts and Tybout (1997) develop a similar argument in terms of sunk costs of exporting, which less efficient firms cannot afford to pay.

Although the literature offers little theoretical guidance, we include a ‘multi-plant’ indicator because subsidiaries may have to follow ‘best practices’ imposed by or transferred from their parent company. This may make them more efficient than single-plant producers. For instance, a subsidiary using a ‘just-in-time’ mode of production may be more efficient than a firm using older, more traditional modes of production. Empirical evidence regarding the impact of the organizational structure of a firm on its technical efficiency is scarce. Existing investigations focus mostly on the impact of being part of a foreign group, and provide mixed evidence. In the US banking sector, Chang et al. (1998) find that foreign-owned multinational banks are significantly less efficient than their US-owned counterparts. By contrast, applying a SFE approach to a cross-sectional sample of Nepalese manufacturing firms, Oczkowski and Sharma (2005) find no effect of foreign participation on technical efficiency. Similarly, Söderbom and Teal (2002) find no effect of foreign ownership on technical efficiency in their sample of African manufacturing firms.

Finally, we include 4-digit industry dummy variables to control for inter-industry differences in efficiency that may appear, at this more disaggregated level, within a 2-digit industry. Badunenko et al. (2008) find industry effects to be the main driver of productive efficiency in a large sample of German firms, whilst Söderbom and Teal (2002) find that technical efficiency varies significantly across industries in their sample of African manufacturing firms.

4 Results and discussion

Table 4 presents our estimation results for both specifications of the stochastic frontier model (the single-equation model *à la* Battese and Coelli 1992, and the two-equation model *à la* Battese and Coelli 1995). To make comparisons and interpretations easier, we present the marginal effects of the Translog production function, computed at the sample mean (detailed tables of results are available upon requests from the authors). Note that, since the 2-digit industry codes have changed from one panel to the next (as explained in Sect. 2), we only refer to the 2-digit industries by their full names. This makes the various tables of results easier to read, and facilitates the comparison of panels 1 and 2.

A cursory look at Table 4 shows that the marginal effects of the main inputs (capital, labour and materials in panel 1; capital, labour, energy and materials in panel 2) are similar in both models, in terms of sign and significance. Reassuringly, these marginal effects are overall significant and positive, which is consistent with the theoretical framework of a production function. The magnitude of the effects is often quite close in both models as well. We also find evidence that the law of diminishing returns holds in both panels and with both specifications: as can be seen in Appendix, Table A, the second derivatives of the output with respect to the main inputs (computed at the sample mean) are overall significantly negative. This finding, which is consistent with the usual conceptions of microeconomic theory, brings additional support to the reliability of our estimation results.

Table 4 also reports, for both panels and both models, the estimates of the marginal effects of the knowledge inputs (i.e., the stocks of R&D capital and technology

Table 4 Stochastic frontier estimates of the marginal effects of input

2-Digit industry	Marginal effects	Panel 1 (1992–1995)		Panel 2 (1997–2003)	
		B and C (1992)	B and C (1995)	B and C (1992)	B and C (1995)
Food manufacturing	$\mathrm{d}q/\mathrm{d}c$	0.11 (0.01)[b]	0.06 (0.00)[b]	0.01 (0.00)[b]	0.01 (0.00)[b]
	$\mathrm{d}q/\mathrm{d}l$	0.62 (0.01)[b]	0.44 (0.01)[b]	0.26 (0.00)[b]	0.24 (0.00)[b]
	$\mathrm{d}q/\mathrm{d}e$			0.10 (0.00)[b]	0.10 (0.00)[b]
	$\mathrm{d}q/\mathrm{d}m$	0.33 (0.01)[b]	0.49 (0.00)[b]	0.65 (0.00)[b]	0.68 (0.00)[b]
	$\mathrm{d}q/\mathrm{dko}$	0.04 (0.01)[b]	0.01 (0.01)	0.02 (0.00)[b]	0.02 (0.00)[b]
	$\mathrm{d}q/\mathrm{dkp}$	0.06 (0.03)[a]	0.02 (0.02)	0.01 (0.01)[a]	0.01 (0.00)[b]
Textile mill products	$\mathrm{d}q/\mathrm{d}c$	0.11 (0.01)[b]	0.06 (0.00)[b]	0.01 (0.00)[b]	0.01 (0.00)[b]
	$\mathrm{d}q/\mathrm{d}l$	0.62 (0.01)[b]	0.46 (0.01)[b]	0.32 (0.01)[b]	0.24 (0.01)[b]
	$\mathrm{d}q/\mathrm{d}e$			0.14 (0.01)[b]	0.08 (0.00)[b]
	$\mathrm{d}q/\mathrm{d}m$	0.28 (0.01)[b]	0.48 (0.00)[b]	0.54 (0.01)[b]	0.68 (0.00)[b]
	$\mathrm{d}q/\mathrm{dko}$	0.02 (0.01)[b]	0.01 (0.00)[b]	0.01 (0.00)[b]	0.01 (0.00)[b]
	$\mathrm{d}q/\mathrm{dkp}$	0.01 (0.02)	0.01 (0.01)	0.06 (0.02)[b]	0.03 (0.01)[a]
Wearing apparel and accessories	$\mathrm{d}q/\mathrm{d}c$	0.04 (0.01)[b]	0.04 (0.01)[b]	0.01 (0.00)[b]	0.01 (0.00)[b]
	$\mathrm{d}q/\mathrm{d}l$	0.70 (0.02)[b]	0.51 (0.04)[b]	0.27 (0.01)[b]	0.26 (0.01)[b]
	$\mathrm{d}q/\mathrm{d}e$			0.06 (0.00)[b]	0.05 (0.01)[b]
	$\mathrm{d}q/\mathrm{d}m$	0.25 (0.01)[b]	0.46 (0.01)[b]	0.69 (0.00)[b]	0.71 (0.01)[b]
	$\mathrm{d}q/\mathrm{dko}$	0.02 (0.01)	0.01 (0.01)	0.01 (0.01)[b]	0.01 (0.00)[b]
	$\mathrm{d}q/\mathrm{dkp}$	0.00 (0.09)	0.07 (0.05)	0.03 (0.01)[a]	0.04 (0.01)[b]
Leather and fur products	$\mathrm{d}q/\mathrm{d}c$	0.14 (0.02)[b]	0.03 (0.01)[b]	0.01 (0.00)[a]	0.01 (0.00)[b]
	$\mathrm{d}q/\mathrm{d}l$	0.54 (0.03)[b]	0.37 (0.02)[b]	0.21 (0.01)[b]	0.20 (0.01)[b]
	$\mathrm{d}q/\mathrm{d}e$			0.05 (0.00)[b]	0.04 (0.00)[b]
	$\mathrm{d}q/\mathrm{d}m$	0.34 (0.02)[b]	0.59 (0.01)[b]	0.74 (0.01)[b]	0.75 (0.00)[b]
	$\mathrm{d}q/\mathrm{dko}$	0.01 (0.01)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
	$\mathrm{d}q/\mathrm{dkp}$	−0.02 (0.04)	0.00 (0.02)	−0.68 (0.70)	−0.10 (0.68)
Wood and bamboo products	$\mathrm{d}q/\mathrm{d}c$	0.07 (0.01)[b]	0.04 (0.01)[b]	0.00 (0.00)[b]	0.00 (0.00)[b]
	$\mathrm{d}q/\mathrm{d}l$	0.65 (0.01)[b]	0.43 (0.01)[b]	0.22 (0.01)[b]	0.23 (0.01)[b]
	$\mathrm{d}q/\mathrm{d}e$			0.06 (0.00)[b]	0.05 (0.00)[b]
	$\mathrm{d}q/\mathrm{d}m$	0.33 (0.01)[b]	0.52 (0.01)[b]	0.70 (0.00)[b]	0.71 (0.00)[b]
	$\mathrm{d}q/\mathrm{dko}$	−0.03 (0.06)	−0.02 (0.03)	0.03 (0.02)[a]	0.03 (0.01)[b]
	$\mathrm{d}q/\mathrm{dkp}$	0.10 (0.07)	0.00 (0.04)	0.03 (0.02)	0.03 (0.02)
Furniture and fixtures	$\mathrm{d}q/\mathrm{d}c$	0.06 (0.01)[b]	0.03 (0.00)[b]	0.00 (0.00)[b]	0.01 (0.00)[b]
	$\mathrm{d}q/\mathrm{d}l$	0.72 (0.01)[b]	0.50 (0.01)[b]	0.22 (0.01)[b]	0.22 (0.01)[b]
	$\mathrm{d}q/\mathrm{d}e$			0.05 (0.00)[b]	0.05 (0.03)
	$\mathrm{d}q/\mathrm{d}m$	0.25 (0.01)[b]	0.49 (0.01)[b]	0.73 (0.01)[b]	0.74 (0.01)[b]

Table 4 continued

2-Digit industry	Marginal effects	Panel 1 (1992–1995)		Panel 2 (1997–2003)	
		B and C (1992)	B and C (1995)	B and C (1992)	B and C (1995)
	dq/dko	0.04 (0.01)[b]	0.02 (0.01)[a]	0.01 (0.01)[a]	0.01 (0.01)
	dq/dkp	−0.03 (0.04)	0.00 (0.03)	0.02 (0.02)	0.01 (0.05)
Pulp, paper and paper products	dq/dc	0.13 (0.01)[b]	0.08 (0.01)[b]	0.01 (0.00)[b]	0.01 (0.00)[b]
	dq/dl	0.64 (0.01)[b]	0.42 (0.01)[b]	0.21 (0.01)[b]	0.21 (0.01)[b]
	dq/de			0.05 (0.00)[b]	0.05 (0.00)[b]
	dq/dm	0.28 (0.01)[b]	0.51 (0.01)[b]	0.72 (0.00)[b]	0.74 (0.00)[b]
	dq/dko	0.02 (0.01)[a]	0.00 (0.01)	0.02 (0.00)[b]	0.02 (0.00)[b]
	dq/dkp	0.03 (0.02)	0.01 (0.01)	0.02 (0.01)[b]	0.00 (0.00)
Printing processing	dq/dc	0.07 (0.01)[b]	0.04 (0.01)[b]	0.01 (0.00)[b]	0.01 (0.00)[b]
	dq/dl	0.68 (0.01)[b]	0.54 (0.01)[b]	0.32 (0.01)[b]	0.31 (0.00)[b]
	dq/de			0.08 (0.00)[b]	0.08 (0.02)[b]
	dq/dm	0.24 (0.01)[b]	0.43 (0.01)[b]	0.61 (0.00)[b]	0.64 (0.00)[b]
	dq/dko	0.07 (0.02)[b]	0.02 (0.01)[a]	0.03 (0.01)[b]	0.02 (0.00)[b]
	dq/dkp	0.00 (0.03)	0.00 (0.01)	0.19 (0.14)	0.13 (0.12)
Basic chemical matter manufacturing	dq/dc	0.16 (0.01)[b]	0.15 (0.01)[b]	0.02 (0.00)[b]	0.01 (0.00)[b]
	dq/dl	0.55 (0.02)[b]	0.45 (0.02)[b]	0.17 (0.01)[b]	0.16 (0.01)[b]
	dq/de			0.08 (0.00)[b]	0.07 (0.00)[b]
	dq/dm	0.34 (0.01)[b]	0.43 (0.01)[b]	0.73 (0.01)[b]	0.77 (0.01)[b]
	dq/dko	0.02 (0.01)[a]	0.01 (0.00)	0.01 (0.00)[b]	0.01 (0.00)[b]
	dq/dkp	0.02 (0.01)	0.01 (0.01)	0.01 (0.00)[b]	0.01 (0.00)[a]
Chemical, petroleum and coal products	dq/dc	0.09 (0.01)[b]	0.05 (0.01)[b]	0.01 (0.00)[b]	0.01 (0.00)[b]
	dq/dl	0.65 (0.01)[b]	0.47 (0.01)[b]	0.22 (0.01)[b]	0.21 (0.00)[b]
	dq/de			0.06 (0.00)[b]	0.06 (0.00)[b]
	dq/dm	0.34 (0.01)[b]	0.51 (0.01)[b]	0.72 (0.00)[b]	0.75 (0.00)[b]
	dq/dko	0.00 (0.00)	0.00 (0.00)	0.02 (0.00)[b]	0.02 (0.00)[b]
	dq/dkp	0.05 (0.01)[b]	0.01 (0.01)	0.02 (0.01)[b]	0.02 (0.00)[b]
Rubber products manufacturing	dq/dc	0.07 (0.01)[b]	0.05 (0.01)[b]	0.01 (0.00)[b]	0.01 (0.00)[b]
	dq/dl	0.70 (0.02)[b]	0.49 (0.02)[b]	0.27 (0.01)[b]	0.25 (0.01)[b]
	dq/de			0.09 (0.00)[b]	0.08 (0.00)[b]
	dq/dm	0.23 (0.01)[b]	0.46 (0.01)[b]	0.65 (0.01)[b]	0.68 (0.00)[b]
	dq/dko	0.03 (0.01)[a]	0.01 (0.01)	0.01 (0.00)[b]	0.01 (0.00)[b]
	dq/dkp	0.07 (0.04)	0.03 (0.02)	0.05 (0.01)[b]	0.05 (0.01)[b]

Table 4 continued

2-Digit industry	Marginal effects	Panel 1 (1992–1995)		Panel 2 (1997–2003)	
		B and C (1992)	B and C (1995)	B and C (1992)	B and C (1995)
Plastic products manufacturing	dq/dc	0.09 (0.01)[b]	0.06 (0.00)[b]	0.01 (0.00)[b]	0.01 (0.00)[b]
	dq/dl	0.68 (0.01)[b]	0.48 (0.01)[b]	0.23 (0.00)[b]	0.24 (0.00)[b]
	dq/de			0.09 (0.00)[b]	0.08 (0.00)[b]
	$dq/d\mathrm{ko}$	0.03 (0.01)[b]	0.01 (0.01)[a]	0.02 (0.00)[b]	0.01 (0.00)[b]
	$dq/d\mathrm{kp}$	0.08 (0.02)[b]	0.04 (0.01)[b]	0.01 (0.01)[a]	0.02 (0.01)[b]
Non-metallic mineral products	dq/dc	0.14 (0.01)[b]	0.08 (0.01)[b]	0.01 (0.00)[b]	0.01 (0.00)[b]
	dq/dl	0.68 (0.01)[b]	0.51 (0.01)[b]	0.25 (0.00)[b]	0.26 (0.00)[b]
	dq/de			0.09 (0.00)[b]	0.08 (0.00)[b]
	dq/dm	0.26 (0.01)[b]	0.43 (0.01)[b]	0.67 (0.00)[b]	0.68 (0.00)[b]
	$dq/d\mathrm{ko}$	0.01 (0.01)	0.02 (0.01)[b]	0.02 (0.00)[b]	0.01 (0.00)[b]
	$dq/d\mathrm{kp}$	0.00 (0.02)	0.01 (0.01)	0.03 (0.01)[b]	0.02 (0.00)[b]
Basic metal industries	dq/dc	0.15 (0.01)[b]	0.06 (0.01)[b]	0.01 (0.00)[b]	0.01 (0.00)[b]
	dq/dl	0.54 (0.01)[b]	0.42 (0.01)[b]	0.18 (0.01)[b]	0.18 (0.00)[b]
	dq/de			0.06 (0.00)[b]	0.06 (0.00)[b]
	dq/dm	0.40 (0.01)[b]	0.56 (0.03)[b]	0.76 (0.00)[b]	0.78 (0.00)[b]
	$dq/d\mathrm{ko}$	−0.02 (0.01)	0.00 (0.01)	0.01 (0.00)[b]	0.00 (0.00)
	$dq/d\mathrm{kp}$	0.00 (0.03)	0.01 (0.02)	−0.02 (0.01)	−0.02 (0.01)[a]
Fabricated metal products	dq/dc	0.10 (0.00)[b]	0.06 (0.00)[b]	0.01 (0.00)[b]	0.01 (0.00)[b]
	dq/dl	0.66 (0.01)[b]	0.52 (0.00)[b]	0.25 (0.00)[b]	0.25 (0.00)[b]
	dq/de			0.06 (0.00)[b]	0.06 (0.00)[b]
	dq/dm	0.27 (0.00)[b]	0.44 (0.00)[b]	0.68 (0.00)[b]	0.70 (0.00)[b]
	$dq/d\mathrm{ko}$	0.03 (0.01)[b]	0.01 (0.00)[b]	0.01 (0.00)[b]	0.01 (0.00)[b]
	$dq/d\mathrm{kp}$	0.05 (0.02)[b]	0.00 (0.01)	0.02 (0.01)[b]	0.02 (0.01)[b]
Machinery and equipment	dq/dc	0.07 (0.01)[b]	0.04 (0.00)[b]	0.01 (0.00)[b]	0.01 (0.02)
	dq/dl	0.67 (0.01)[b]	0.48 (0.01)[b]	0.26 (0.00)[b]	0.26 (0.10)[b]
	dq/de			0.06 (0.00)[b]	0.06 (0.03)
	dq/dm	0.27 (0.01)[b]	0.48 (0.00)[b]	0.68 (0.00)[b]	0.69 (1.03)
	$dq/d\mathrm{ko}$	0.04 (0.01)[b]	0.02 (0.00)[b]	0.02 (0.00)[b]	0.01 (0.05)
	$dq/d\mathrm{kp}$	0.04 (0.02)[a]	0.02 (0.01)	0.03 (0.01)[b]	0.02 (0.98)

imports), which are the main focus of our analysis. As pointed out in Coelli (1996), the two stochastic frontier specifications we have implemented are non-nested, and no set of restrictions can be defined to test one specification versus the other. Fortunately, in our application, both specifications yield extremely convergent results, and show significant effects of the knowledge inputs in the same 2-digit industries. Whenever ko

Table 4 continued

2-Digit industry		Marginal effects	Panel 1 (1992–1995)		Panel 2 (1997–2003)	
			B and C (1992)	B and C (1995)	B and C (1992)	B and C (1995)
Panel 1, 1992–1995	Panel2, 1997–2003					
Electrical and electronic machinery	Audio and video products	dq/dc	0.10 (0.01)^{b}	0.07 (0.00)^{b}	0.01 (0.00)^{b}	0.01 (0.00)^{b}
	dq/dl	0.65 (0.01)^{b}	0.44 (0.01)^{b}	0.27 (0.01)^{b}	0.25 (0.01)^{b}	
	dq/de			0.04 (0.01)^{b}	0.04 (0.01)^{b}	
	dq/dm	0.29 (0.01)^{b}	0.50 (0.00)^{b}	0.67 (0.01)^{b}	0.71 (0.01)^{b}	
	dq/dko	0.02 (0.00)^{b}	0.01 (0.00)^{b}	0.01 (0.00)^{b}	0.01 (0.00)^{b}	
	dq/dkp	0.02 (0.00)^{b}	0.01 (0.00)^{b}	0.00 (0.01)	0.00 (0.01)	
	Electronic parts and components	dq/dc			0.02 (0.00)^{b}	0.01 (0.00)^{b}
	dq/dl			0.26 (0.01)^{b}	0.24 (0.01)^{b}	
	dq/de			0.10 (0.00)^{b}	0.10 (0.00)^{b}	
	dq/dm			0.64 (0.01)^{b}	0.67 (0.00)^{b}	
	dq/dko			0.01 (0.00)^{b}	0.01 (0.00)^{b}	
	dq/dkp			0.00 (0.00)	0.00 (0.00)^{a}	
	Electric machinery and parts	dq/dc			0.00 (0.00)^{b}	0.00 (0.00)
	dq/dl			0.22 (0.00)^{b}	0.23 (0.04)^{b}	
	dq/de			0.05 (0.00)^{b}	0.05 (0.02)^{a}	
	dq/dm			0.73 (0.00)^{b}	0.75 (0.03)^{b}	
	dq/dko			0.01 (0.00)^{b}	0.01 (0.01)	
	dq/dkp			0.00 (0.00)	0.00 (0.03)	
Transportation industry		dq/dc	0.10 (0.01)^{b}	0.06 (0.00)^{b}	0.01 (0.00)^{b}	0.01 (0.00)^{b}
		dq/dl	0.69 (0.01)^{b}	0.47 (0.01)^{b}	0.25 (0.00)^{b}	0.25 (0.00)^{b}
		dq/de			0.06 (0.00)^{b}	0.06 (0.00)^{b}
		dq/dm	0.27 (0.01)^{b}	0.47 (0.00)^{b}	0.69 (0.00)^{b}	0.71 (0.00)^{b}
		dq/dko	0.01 (0.00)^{b}	0.01 (0.00)^{b}	0.00 (0.00)^{b}	0.00 (0.00)^{a}
		dq/dkp	0.01 (0.01)^{a}	0.00 (0.00)	0.01 (0.00)^{b}	0.00 (0.00)^{a}
Precision instruments		dq/dc	0.08 (0.01)^{b}	0.04 (0.05)	0.00 (0.00)	0.01 (0.00)^{b}
		dq/dl	0.65 (0.02)^{b}	0.50 (0.01)^{b}	0.28 (0.01)^{b}	0.27 (0.01)^{b}
		dq/de			0.06 (0.00)^{b}	0.06 (0.00)^{b}
		dq/dm	0.27 (0.01)^{b}	0.47 (0.05)^{b}	0.68 (0.01)^{b}	0.70 (0.00)^{b}
		dq/dko	0.03 (0.01)^{b}	0.01 (0.01)	0.02 (0.00)^{b}	0.01 (0.00)^{b}
		dq/dkp	0.04 (0.04)	0.03 (0.02)	0.06 (0.02)^{a}	0.05 (0.01)^{b}

Table 4 continued

2-Digit industry	Marginal effects	Panel 1 (1992–1995)		Panel 2 (1997–2003)	
		B and C (1992)	B and C (1995)	B and C (1992)	B and C (1995)
Miscellaneous industrial products	dq/dc	0.05 (0.01)[b]	0.06 (0.01)[b]	0.01 (0.00)[b]	0.01 (0.00)[b]
	dq/dl	0.73 (0.01)[b]	0.57 (0.01)[b]	0.27 (0.00)[b]	0.26 (0.00)[b]
	dq/de			0.07 (0.00)[b]	0.08 (0.00)[b]
	dq/dm	0.22 (0.01)[b]	0.36 (0.01)[b]	0.66 (0.00)[b]	0.68 (0.00)[b]
	dq/dko	0.05 (0.01)[b]	0.02 (0.01)[a]	0.02 (0.00)[b]	0.01 (0.00)[b]
	dq/dkp	0.13 (0.05)[a]	0.06 (0.04)	0.02 (0.01)[a]	0.02 (0.01)[b]

Notations: $q = \ln Q, c = \ln C, l = \ln L, e = \ln E, m = \ln M, \mathrm{ko} = (\mathrm{KO})^{1/2}, \mathrm{kp} = (\mathrm{KP})^{1/2}$

[a] Significant at the 5% level

[b] significant at the 1% level

B and C (1992): Battese and Coelli (1992)'s single-equation stochastic frontier model

B and C (1995): Battese and Coelli (1995)'s two-equation stochastic frontier model

Marginal effects computed at sample mean. Calculations of the standard errors are based on the delta method

Standard errors in parentheses

All models include a time effect (year dummies)

Goodness-of-fit for Battese and Coelli (1995)'s stochastic frontier model: the null hypothesis H_0: '$\beta = 0$' was rejected by a LR test at the 1% level in all industries in both panels

Goodness-of-fit for Battese and Coelli (1995)'s stochastic frontier model: the null hypothesis H_0: '$\beta = \delta = 0$' was rejected by a LR test at the 1% level in all industries and in both panels (β and δ are the vectors of coefficients of the production function and inefficiency equations respectively)

and/or kp are significant, they have a positive effect on firm output.[5] In order to give the reader a more complete view of the effects of the knowledge inputs, we present the estimate of their interaction in Table 5. When significant, this term is negative, although very close to zero in absolute value. This suggests that the knowledge inputs are, to some extent, substitutes rather than complements.

Overall, we find that, in panel 2, innovation impacts firm performance in a much larger number of industries than in panel 1. Both models show that the marginal effects of ko and kp are significantly different from zero (and positive) in 17 industries out of 22 in panel 2, whereas this is the case in only 9 industries out of 20 in panel 1. Moreover, the interaction term is mainly significant in panel 2. Taken together, these results suggest that the gradual implementation of the SUI in Taiwan really started to pay-off from the mid-1990s onwards. In what follows, we discuss these results in more details for two groups of industries: the textile and traditional industries on the one hand, and the electronics and high-tech industries on the other.

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[5] The only exception is 'Basic Metal Industries' in panel 2, where Battese and Coelli (1995)'s specification shows that kp has a negative effect on firm output. This result suggests difficulties in catching up with the technology frontier in that industry (which has never played a leading role in Taiwan's economic development).

Table 5 Estimate of interaction term dq/d(ko × kp)

2-Digit industry		Panel 1 (1992–1995)		Panel 2 (1997–2003)	
		B and C (1992)	B and C (1995)	B and C (1992)	B and C (1995)
Food manufacturing		−0.01 (0.01)	−0.00 (0.00)	−0.00 (0.00)	−0.00 (0.00)
Textile mill products		−0.00 (0.00)	−0.00 (0.00)	−0.00 (0.00)[b]	−0.00 (0.00)[a]
Wearing apparel and accessories		0.07 (0.15)	0.10 (0.08)	−0.02 (0.01)[a]	−0.02 (0.01)[b]
Leather and fur products		0.00 (0.00)	0.00 (0.00)	−0.95 (1.06)	−0.04 (1.03)
Wood and bamboo products		0.01 (0.04)	0.02 (0.02)	0.02 (0.02)	0.02 (0.02)
Furniture and fixtures		0.00 (0.00)	−0.00 (0.00)	−0.00 (0.00)	−0.01 (0.01)
Pulp, paper and paper products		−0.01 (0.01)	−0.00 (0.00)	−0.00 (0.00)	−0.00 (0.00)
Printing processing		0.01 (0.04)	0.01 (0.02)	–	–
Basic chemical matter manufacturing		−0.00 (0.00)	−0.00 (0.00)	−0.00 (0.00)[b]	−0.00 (0.00)[a]
Chemical, petroleum and coal products		−0.00 (0.00)	−0.00 (0.00)	−0.00 (0.00)[b]	−0.00 (0.00)[b]
Rubber products manufacturing		−0.00 (0.00)	−0.00 (0.00)	−0.00 (0.00)[b]	−0.00 (0.00)[b]
Plastic products manufacturing		−0.01 (0.00)[b]	−0.00 (0.00)[b]	−0.00 (0.00)[a]	−0.00 (0.00)[b]
Non-metallic mineral products		−0.00 (0.00)	−0.00 (0.00)	−0.00 (0.00)[b]	−0.00 (0.00)[b]
Basic metal industries		0.00 (0.00)	0.00 (0.00)	−0.00 (0.00)	0.00 (0.00)
Fabricated metal products		−0.00 (0.00)[a]	−0.00 (0.00)	−0.00 (0.00)[b]	−0.00 (0.00)[b]
Machinery and equipment		−0.00 (0.00)[a]	−0.00 (0.00)	−0.00 (0.00)[b]	−0.00 (0.06)
Panel 1, 1992–1995	Panel 2, 1997–2003				
Electrical and electronic	Audio and video products	−0.00 (0.00)[b]	−0.00 (0.00)	−0.00 (0.00)[a]	−0.00 (0.00)
Machinery	Electronic parts and components			−0.00 (0.00)[a]	−0.00 (0.00)[a]
	Electric machinery and parts			−0.00 (0.00)[b]	−0.00 (0.00)
Transportation industry		−0.00 (0.00)	−0.00 (0.00)	−0.00 (0.00)[b]	−0.00 (0.00)
Precision instruments		0.00 (0.00)	−0.00 (0.00)	−0.01 (0.00)[b]	−0.01 (0.00)[b]
Miscellaneous		−0.01 (0.01)	−0.01 (0.00)	−0.00 (0.00)[a]	−0.00 (0.00)[b]

[a] Significant at the 5% level

[b] Significant at the 1% level

B and C (1992): Battese and Coelli (1992)'s single-equation stochastic frontier model

B and C (1995): Battese and Coelli (1995)'s two-equation stochastic frontier model

Standard errors in parentheses

In panel 2, in the 'Printing Processing' industry, there are not enough firms both doing R&D and importing technology to estimate an interaction term

4.1 Textile and other traditional industries

We start our discussion with the textile industry (‘Textile Mill Products’). In this industry, both models show a positive effect of the stock of R&D capital in the first panel (1992–1995), and positive effects of both R&D and technology imports in the second panel (1997–2003). These results make perfect sense when one considers the recent history of the textile industry in Taiwan. In the 1980s, Taiwan was specialized in labour-intensive textile and clothing, but this position became increasingly contested by other East-Asian countries. To preserve their competitiveness, many firms operating in this industry outsourced their production towards mainland China and Thailand. Those remaining in Taiwan abandoned traditional textile in favour of high-technology man-made fibres and other knowledge-intensive textile (Guerrieri and Pietrobelli 2006). Our results shed additional light on this recent history. They suggest that, in the early 1990s, Taiwanese textile firms conducted mostly adaptive R&D (in the sense of Cohen and Levinthal 1989, 1990). After this early phase where only R&D mattered, these firms were able to reach for the global frontier by purchasing foreign patents and licences, whilst keeping a significant amount of in-house R&D. In this second phase, R&D needs not remain purely adaptive, but may be used to generate new knowledge. This interpretation is consistent with the fact that both ko and kp are significantly positive in 1997–2003, whilst their interaction effect (negative but very close to zero) hints at a mild substitutability.

Other traditional industries, such as ‘Non-Metallic Mineral Products’ and ‘Fabricated Metal Products’, may have followed a similar path of development. In these industries, R&D capital appears as the primary source of knowledge in the early 1990s, whereas we find consistently positive effects of both R&D and technology imports from the late 1990s onward. As before, their interaction is significantly negative but very close to zero, which suggests that the two types of knowledge inputs where mild substitutes in this second period.

In other traditional industries, such as ‘Wood and Bamboo Products’, a similar pattern of development may be occurring with a lag: the stock of R&D capital is the only significant knowledge input, and it is significant only from the late 1990s onward. Taiwan’s wood industry has actually experienced in the 1990s the same difficulties that the textile industry faced in the 1980s. Since its early days, Taiwan has been a major producer of quality hardwoods, an abundant natural resource in the island. However, in the 1990s, the wood industry faced both the depletion of quality commercial timber, and an increased competition from neighbouring economies with large wooded areas and a cheaper labour force (such as Malaysia and Thailand). Again, Taiwanese firms answered these problems either by outsourcing the production, or by improving their production process through R&D (sometimes with the help of foreign experts).

On the contrary, in the ‘Plastic Products Manufacturing’ industry, the aforementioned pattern of development may have occurred earlier than in the textile industry. Indeed, both specifications of the model show a positive effect of R&D capital and technology imports in both periods, together with a (small) negative interaction effect in both periods as well. These results suggest that the transition from labour-intensive to knowledge-intensive products may have occurred in this industry from the early 1990s onwards.

4.2 Electronics and high-technology industries

To proceed with the discussion of our results, we now consider the electronics industry. The fact that there is a single 2-digit industry in panel 1 (‘Electrical and electronic machinery’), versus three in panel 2 (‘Audio and video products’, ‘Electronic parts and components’ and ‘Electric machinery and parts’) is in itself a testimony to the rapid growth of the electrical and electronic industries in Taiwan over the period of interest.

In the 1990s, Taiwan’s manufacturing industry actually experienced a rapid structural transformation in which the leadership shifted from labour-intensive industries such as textile to high-technology industries such as electronics. As Guerrieri and Pietrobelli (2006) explain, the development of the electronics industry in Taiwan relied on a flow of FDI which granted an immediate access to foreign technology. Taiwan’s innovation policy largely contributed to making access to foreign technology easier: as was said in Sect. 1, several measures in the SUI were specifically designed to accelerate the inflow of both disembodied and embodied knowledge.[6]

Our findings are easy to reconcile with this type of development: in the early 1990s, we observe, in the ‘Electrical and Electronic machinery’, significantly positive effects of both R&D and technology imports. The splitting of this industry into three new industries after 1996 allows us to give a more detailed account of the development of electronics in Taiwan in the late 1990s. Over the 1997–2003 period, the effect of knowledge inputs is located in two industries: in the ‘Audio and Video Products’ industry, we observe a positive effect of the stock of R&D capital on firm output; in the ‘Electronic Parts and Components’ industry, both R&D and technology imports have a significantly positive effect. Overall, in the electronics and other high-technology industries, R&D appears to be the privileged knowledge source to increase firm performance in the late 1990s. The impact of technology imports is then either less significant or not significant.

These results are consistent with the historical evidence of an economic growth primarily driven by the industry of electronic components[7] over the 1990s. What the history of electronics in Taiwan relates is not merely the upgrading of a labour-intensive industry, but the emergence of a fully fledged knowledge-intensive industry. Therefore, and contrary to what was observed in the textile and other traditional industries, R&D in the electronic industries is unlikely to be purely adaptive. It is rather a mean for these high-tech, knowledge-intensive industries to remain close to the global technology frontier. Anecdotal evidence illustrate this point: in the early 1990s, there was little or no emphasis on product differentiation in the electronic industries. This proved vital for the development of this sector, as it allowed small firms to be created with very low up-front investment. There was no need for advertising or reputation

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[6] As an illustration, Saxenian and Hsu (2001) relate how the strong ties between the Hsinchu science park in Taiwan and the Silicon Valley in the US contributed to increase the bilateral flow of skills and know-how.

[7] Hobday (1995) and Levy and Kuo (1991) explain that the output of Taiwan’s electronic industry in the 1990s consisted primarily in the production of small unbranded components by SMEs. These components were sold to large multinational firms and used for the production of their branded products (e.g., computers).

building through brand names (Aw 2002; Hobday 1995; Levy and Kuo 1991). However, things have changed from the late 1990s onwards. Building on their experience in the production of quality electronic components, Taiwanese brands (such as the Acer computer brand) have appeared on the international market.

4.3 Efficiency analysis

Before concluding, we give additional elements concerning the technical efficiency equation of the stochastic frontier model. First of all, we verify that the variance parameters σ^2 and γ, which are common to both specifications of the model (see Sect. 3.3) are well identified. Table 6 shows that, in panels 1 and 2, σ^2 and γ are significantly different from zero in all 2-digit industries and (almost all the time) with both specifications. According to these results, we can reject the hypothesis that the inefficiency effects are not stochastic. In the single-equation specification *à la* Battese and Coelli (1992), μ, the estimated mean value of the inefficiency effect, is always significantly different from zero. The η parameter, which identifies the time-variation of this inefficiency effect, is significantly different from zero in most industries.[8]

Table 7 gives the parameter estimates for the main determinants of the inefficiency equation from the Battese and Coelli (1995) model. These determinants are convergent across industries and across both panels. We first find that multi-plant firms are generally less inefficient (i.e., more efficient) than single-plant firms. As we mentioned in Sect. 3.4, this may be because multi-plant firms adopt 'best practices' from their parent company. Firms that export technology also tend to be less inefficient (i.e., more efficient), although this trend is not as prevalent as the previous one. In particular, the effect of technology exports is not significant in any of the electronics industries of either panels 1 or 2. If we refer to the literature mentioned in Sect. 3.4, this finding is consistent with those of Aw and Batra (1998) rather than with those of Chen and Tang (1987).

The effect of firm age is more frequently significant in our samples than it is generally found to be in the literature. Moreover, this effect is always positive when significant, which means that older firms are more inefficient (i.e., less efficient). If we follow the argument developed in Lundvall and Battese (2000), this may be because the positive effect associated with firms' survival (as theorized in Jovanovic 1982) is outweighed by negative effects caused, for instance, by the depreciation of the capital stock. Finally, we find that inefficiencies may also result from industry-specific factors, which is in accordance with the literature reviewed in Sect. 3.4. In several 2-digit industries, LR tests show a significant global effect of 4-digit industry dummy variables in the inefficiency equation.

Table 8 displays the mean technical efficiency by 2-digit industry for both panels. Both specifications of the econometric model show an increase in the mean efficiency over time. In panel 1, it is within the 0.45–0.75 range in most industries, whereas in panel 2, it is rather within the 0.70–0.95 range. Interestingly, the estimated mean

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[8] We tested for a restriction of this model to a model with a time-invariant inefficiency term (i.e., with η constrained to zero), but all LR tests favoured the full Battese and Coelli (1992) specification.

Table 6 Ancillary parameters estimates for both stochastic frontier models

2-Digit industry	Parameter	Panel 1 (1992–1995)		Panel 2 (1997–2003)	
		B and C (1992)	B and C (1995)	B and C (1992)	B and C (1995)
Food manufacturing	σ^2	0.55 (0.02)[b]	0.98 (0.01)[b]	0.26 (0.01)[b]	0.06 (0.00)[b]
	γ	0.29 (0.02)[b]	0.91 (0.00)[b]	0.82 (0.01)[b]	0.03 (0.00)[b]
	μ	0.80 (0.09)[b]		−0.93 (0.06)[b]	
	η	−0.02 (0.01)		−0.06 (0.01)[b]	
Textile mill products	σ^2	0.37 (0.01)[b]	0.55 (0.01)[b]	0.16 (0.01)[b]	0.52 (0.01)[b]
	γ	0.43 (0.02)[b]	0.87 (0.00)[b]	0.52 (0.03)[b]	0.94 (0.00)[b]
	μ	0.79 (0.05)[b]		0.58 (0.04)[b]	
	η	−0.07 (0.01)[b]		−0.13 (0.01)[b]	
Wearing apparel and accessories	σ^2	0.28 (0.02)[b]	0.45 (0.02)[b]	0.07 (0.00)[b]	0.06 (0.00)[b]
	γ	0.42 (0.04)[b]	0.88 (0.01)[b]	0.42 (0.02)[b]	0.3 (0.06)[b]
	μ	0.69 (0.09)[b]		0.33 (0.03)[b]	
	η	0.01 (0.03)		−0.14 (0.02)[b]	
Leather and fur products	σ^2	1.51 (0.24)[b]	0.8 (0.05)[b]	0.05 (0.00)[b]	0.06 (0.00)[b]
	γ	0.79 (0.03)[b]	0.96 (0.01)[b]	0.45 (0.04)[b]	0.55 (0.04)[b]
	μ	−2.19 (0.76)[a]		0.30 (0.12)[b]	
	η	−0.09 (0.04)[a]		−0.21 (0.04)[b]	
Wood and bamboo products	σ^2	0.47 (0.03)[b]	0.87 (0.02)[b]	0.22 (0.03)[b]	0.23 (0.01)[b]
	γ	0.31 (0.03)[b]	0.94 (0.00)[b]	0.87 (0.02)[b]	0.89 (0.01)[b]
	μ	0.76 (0.05)[b]		−0.87 (0.15)[b]	
	η	−0.07 (0.03)[a]		−0.18 (0.02)[b]	
Furniture and fixtures	σ^2	0.31 (0.01)[b]	0.55 (0.01)[b]	0.05 (0.00)[b]	0.04 (0.00)[b]
	γ	0.35 (0.03)[b]	0.92 (0.00)[b]	0.43 (0.02)[b]	0.00 (0.00)
	μ	0.66 (0.06)[b]		0.29 (0.03)[b]	
	η	−0.03 (0.02)		−0.15 (0.03)[b]	
Pulp, paper and paper products	σ^2	0.85 (0.14)[b]	0.63 (0.02)[b]	0.05 (0.00)[b]	0.11 (0.00)[b]
	γ	0.75 (0.04)[b]	0.95 (0.00)[b]	0.59 (0.02)[b]	0.80 (0.01)[b]
	μ	−1.60 (0.50)[b]		0.33 (0.03)[b]	
	η	−0.02 (0.02)		−0.17 (0.01)[b]	
Printing processing	σ^2	0.28 (0.01)[b]	0.56 (0.02)	0.07 (0.00)[b]	0.07 (0.00)[b]
	γ	0.32 (0.03)[b]	0.93 (0.01)	0.58 (0.02)[b]	0.48 (0.02)[b]
	μ	0.60 (0.07)[b]		0.41 (0.02)[b]	
	η	−0.02 (0.02)		−0.13 (0.01)[b]	

Table 6 continued

2-Digit industry	Parameter	Panel 1 (1992–1995)		Panel 2 (1997–2003)	
		B and C (1992)	B and C (1995)	B and C (1992)	B and C (1995)
Basic chemical matter manufacturing	σ^2	1.07 (0.08)^{b}	3.85 (0.26)^{b}	0.07 (0.00)^{b}	0.04 (0.00)^{b}
	γ	0.67 (0.03)^{b}	0.96 (0.00)^{b}	0.59 (0.02)^{b}	0.26 (0.02)^{b}
	μ	−1.69 (0.26)^{b}		0.40 (0.03)^{b}	
	η	0.11 (0.03)^{b}		−0.18 (0.02)^{b}	
Chemical, petroleum and coal products	σ^2	0.78 (0.08)^{b}	0.76 (0.02)^{b}	0.05 (0.00)^{b}	0.04 (0.00)^{b}
	γ	0.59 (0.05)^{b}	0.94 (0.00)^{b}	0.38 (0.03)^{b}	0.05 (0.00)^{b}
	μ	−1.36 (0.32)^{b}		0.28 (0.04)^{b}	
	η	0.17 (0.02)^{b}		−0.08 (0.02)^{b}	
Rubber products manufacturing	σ^2	0.30 (0.02)^{b}	0.60 (0.03)^{b}	0.03 (0.00)^{b}	0.03 (0.00)^{b}
	γ	0.32 (0.05)^{b}	0.94 (0.01)^{b}	0.27 (0.04)^{b}	0.06 (0.01)^{b}
	μ	0.61 (0.13)^{b}		0.18 (0.02)^{b}	
	η	−0.07 (0.04)		0.02 (0.02)	
Plastic products manufacturing	σ^2	0.33 (0.01)^{b}	0.65 (0.01)^{b}	0.04 (0.00)^{b}	0.03 (0.00)^{b}
	γ	0.31 (0.02)^{b}	0.92 (0.00)^{b}	0.44 (0.01)^{b}	0.01 (0.00)
	μ	0.64 (0.06)^{b}		0.26 (0.01)^{b}	
	η	−0.02 (0.01)		−0.07 (0.01)^{b}	
Non-metallic mineral products	σ^2	0.97 (0.09)^{b}	0.71 (0.02)^{b}	0.06 (0.00)^{b}	0.14 (0.00)^{b}
	γ	0.67 (0.03)^{b}	0.89 (0.00)^{b}	0.44 (0.02)^{b}	0.77 (0.01)^{b}
	μ	−1.62 (0.33)^{b}		0.33 (0.02)^{b}	
	η	0.04 (0.02)^{a}		−0.14 (0.01)^{b}	
Basic metal industries	σ^2	1.40 (0.08)^{b}	1.05 (0.02)^{b}	0.04 (0.00)^{b}	0.03 (0.00)^{b}
	γ	0.68 (0.02)^{b}	0.93 (0.00)^{b}	0.41 (0.03)^{b}	0.02 (0.00)^{b}
	μ	−1.95 (0.26)^{b}		0.24 (0.02)^{b}	
	η	0.06 (0.02)^{b}		−0.04 (0.01)^{b}	
Fabricated metal products	σ^2	0.32 (0.01)^{b}	0.57 (0.01)^{b}	0.06 (0.00)^{b}	0.04 (0.00)^{b}
	γ	0.34 (0.01)^{b}	0.90 (0.00)^{b}	0.54 (0.01)^{b}	0.06 (0.01)^{b}
	μ	0.66 (0.03)^{b}		0.35 (0.01)^{b}	
	η	−0.06 (0.01)^{b}		−0.11 (0.01)^{b}	
Machinery and equipment	σ^2	0.34 (0.01)^{b}	0.62 (0.01)^{b}	0.04 (0.00)^{b}	0.04 (0.01)^{b}
	γ	0.32 (0.02)^{b}	0.91 (0.00)^{b}	0.37 (0.01)^{b}	0.00 (0.43)
	μ	0.66 (0.04)^{b}		1.80 (0.67)^{b}	
	η	−0.05 (0.01)^{b}		−0.03 (0.01)^{b}	

Table 6 continued

2-Digit industry		Parameter	Panel 1 (1992–1995)		Panel 2 (1997–2003)	
			B and C (1992)	B and C (1995)	B and C (1992)	B and C (1995)
Panel 1, 1992–1995	Panel 2, 1997–2003					
Electrical and electronic machinery	Audio and video products	σ^2	0.34 (0.01)^{b}	0.60 (0.01)^{b}	0.08 (0.00)^{b}	0.07 (0.00)^{b}
		γ	0.35 (0.02)^{b}	0.90 (0.00)^{b}	0.17 (0.04)^{b}	0.14 (0.01)^{b}
		μ	0.68 (0.05)^{b}		0.22 (0.05)^{b}	
		η	0.00 (0.01)		0.05 (0.05)	
	Electronic parts and components	σ^2			0.08 (0.00)^{b}	0.06 (0.00)^{b}
		γ			0.50 (0.02)^{b}	0.34 (0.04)^{b}
		μ			0.40 (0.03)^{b}	
		η			−0.14 (0.02)^{b}	
	Electric machinery and parts	σ^2			0.04 (0.00)^{b}	0.03 (0.02)^{a}
		γ			0.38 (0.02)^{b}	0.01 (0.62)
		μ			0.23 (0.01)^{b}	
		η			−0.03 (0.01)^{a}	
Transportation industry		σ^2	0.99 (0.10)^{b}	0.72 (0.01)^{b}	0.05 (0.00)^{b}	0.13 (0.00)^{b}
		γ	0.72 (0.03)^{b}	0.95 (0.00)^{b}	0.50 (0.02)^{b}	0.77 (0.01)^{b}
		μ	−1.69 (0.37)^{b}		0.31 (0.02)^{b}	
		η	0.03 (0.01)^{a}		−0.11 (0.01)^{b}	
Precision instruments		σ^2	0.27 (0.02)^{b}	0.49 (0.02)^{b}	0.05 (0.00)^{b}	0.04 (0.00)^{b}
		γ	0.31 (0.04)^{b}	0.91 (0.01)^{b}	0.40 (0.03)^{b}	0.07 (0.02)^{b}
		μ	0.58 (0.09)^{b}		0.28 (0.03)^{b}	
		η	0.00 (0.03)		−0.07 (0.03)^{a}	
Miscellaneous		σ^2	0.45 (0.02)^{b}	0.60 (0.02)^{b}	0.06 (0.00)^{b}	0.11 (0.00)^{b}
		γ	0.44 (0.02)^{b}	0.82 (0.01)^{b}	0.42 (0.02)^{b}	0.68 (0.01)^{b}
		μ	0.89 (0.06)^{b}		0.32 (0.01)^{b}	
		η	−0.04 (0.02)^{a}		−0.07 (0.01)^{b}	

[a] Significant at the 5% level
[b] Significant at the 1% level
B and C (1992): Battese and Coelli (1992)'s single-equation stochastic frontier model
B and C (1995): Battese and Coelli (1995)'s two-equation stochastic frontier model
Standard errors in parentheses

efficiency is not systematically higher in innovation-intensive industries. To understand this result, one must keep in mind that implementing an innovation can sometimes generate unforeseen inefficiencies, as the innovation process is costly and based on trial-and-error.

Table 7 Inefficiency equation estimates—Battese and Coelli (1995)'s stochastic frontier model

2-Digit industry		Panel 1 (1992–1995) Coeff. S.E	Panel 2 (1997–2003) Coeff. S.E
Food manufacturing	Constant	−7.67 (0.08)[b]	−0.19 (0.02)[b]
	Multiplant	−0.02 (0.03)	−0.05 (0.01)[b]
	Exports tech.	0.08 (0.14)	0.03 (0.17)
	Age	0.00 (0.00)	0.00 (0.00)[b]
	4-Digit ind.	0.048	0.000
Textile mill products	Constant	−5.65 (0.07)[b]	−5.39 (0.19)[b]
	Multiplant	−0.08 (0.03)[a]	0.00 (0.03)
	Exports tech.	0.05 (0.20)	0.07 (0.41)
	Age	0.00 (0.00)	0.01 (0.00)[b]
	4-Digit ind.	0.000	0.000
Wearing apparel and accessories	Constant	−2.17 (0.25)[b]	−0.62 (0.09)[b]
	Multiplant	0.00 (0.08)	−0.01 (0.01)
	Exports tech.	−1.00 (0.50)[a]	0.19 (0.22)
	Age	0.00 (0.00)	0.00 (0.00)
	4-Digit ind.	0.014	0.000
Leather and fur products	Constant	−6.98 (0.28)[b]	−1.35 (0.36)[b]
	Multiplant	−0.23 (0.12)	−0.08 (0.05)
	Exports tech.	−0.17 (0.14)	−0.04 (0.10)
	Age	0.00 (0.00)	0.00 (0.00)
	4-Digit ind.	0.000	0.000
Wood and bamboo products	Constant	−7.28 (0.13)[b]	−2.56 (0.15)[b]
	Multiplant	0.09 (0.09)	0.00 (0.03)
	Exports tech.	−0.05 (1.00)	0.00 (1.00)
	Age	0.00 (0.00)	0.01 (0.00)[b]
	4-Digit ind.	0.000	0.011
Furniture and fixtures	Constant	−5.83 (0.06)[b]	−0.02 (0.18)
	Multiplant	0.01 (0.03)	0.06 (0.02)[b]
	Exports tech.	4.99 (1.00)[b]	0.06 (0.42)
	Age	0.00 (0.00)	0.00 (0.00)[a]
	4-Digit ind.	0.000	0.057
Pulp, paper and paper products	Constant	−6.18 (0.14)[b]	−2.14 (0.05)[b]
	Multiplant	−0.06 (0.06)	−0.09 (0.01)[b]
	Exports tech.	0.00 (1.00)	−0.16 (0.03)[b]
	Age	0.00 (0.00)	0.02 (0.00)[b]
	4-Digit ind.	0.001	0.000

Table 7 continued

2-Digit industry		Panel 1 (1992–1995) Coeff. S.E	Panel 2 (1997–2003) Coeff. S.E
Printing processing	Constant	−5.78 (0.14)[b]	−0.86 (0.02)[b]
	Multiplant	−0.17 (0.09)	−0.03 (0.03)
	Exports tech.	0.46 (0.99)	0.00 (1.00)
	Age	0.00 (0.00)	0.00 (0.00)[b]
	4-digit ind.	0.000	0.105
Basic chemical matter manufacturing	Constant	−14.27 (1.25)[b]	0.26 (0.03)[b]
	Multiplant	0.48 (0.11)[b]	−0.01 (0.02)
	Exports tech.	−0.89 (0.58)	0.00 (0.01)
	Age	0.02 (0.01)[b]	0.00 (0.00)
	4-digit ind.	0.000	0.000
Chemical products	Constant	−3.27 (0.13)[b]	0.20 (0.02)[b]
	Multiplant	−0.03 (0.02)	0.00 (0.00)
	Exports tech.	−0.31 (0.44)	0.12 (0.08)
	Age	0.00 (0.00)	0.00 (0.00)
	4-Digit ind.	0.000	0.000
Rubber products manufacturing	Constant	−6.12 (0.19)[b]	−0.06 (0.02)[a]
	Multiplant	−0.11 (0.10)	−0.04 (0.02)[a]
	Exports tech.	−0.23 (0.16)	0.21 (0.06)[b]
	Age	0.00 (0.01)	0.00 (0.00)[b]
	4-Digit ind.	0.000	0.000
Plastic products manufacturing	Constant	−6.22 (0.10)[b]	0.02 (0.01)
	Multiplant	−0.07 (0.04)	−0.04 (0.01)[b]
	Exports tech.	−0.06 (0.15)	−0.09 (0.04)[a]
	Age	0.00 (0.00)	0.00 (0.00)[b]
	4-Digit ind.	0.000	0.000
Non-metallic mineral products	Constant	−5.43 (0.11)[b]	−1.37 (0.05)[b]
	Multiplant	−0.02 (0.02)	−0.01 (0.01)
	Exports tech.	−0.29 (0.58)	0.44 (0.20)[a]
	Age	0.01 (0.00)	0.00 (0.00)
	4-Digit ind.	0.000	0.000
Basic metal industries	Constant	−7.79 (0.14)[b]	0.22 (0.02)[b]
	Multiplant	−0.31 (0.05)[b]	−0.04 (0.01)[b]
	Exports tech.	−0.73 (0.97)	−0.08 (0.05)
	Age	0.01 (0.00)[b]	0.00 (0.00)[b]
	4-Digit ind.	0.000	0.000

Table 7 continued

2-Digit industry			Panel 1 (1992–1995) Coeff. S.E	Panel 2 (1997–2003) Coeff. S.E
Fabricated metal products		Constant	−5.68 (0.06)^{b}	0.00 (0.01)
		Multiplant	−0.02 (0.02)	−0.06 (0.01)^{b}
		Exports tech.	0.22 (0.13)	−0.19 (0.01)^{b}
		Age	0.01 (0.00)^{b}	0.00 (0.00)^{b}
		4-Digit ind.	0.000	0.000
Machinery and equipment		Constant	−5.85 (0.07)^{b}	−0.01 (0.80)
		Multiplant	0.00 (0.02)	−0.04 (0.76)
		Exports tech.	0.03 (0.10)	0.00 (1.00)
		Age	0.00 (0.00)	0.00 (0.03)
		4-Digit ind.	0.000	0.996
Panel 1, 1992–1995	Panel 2, 1997–2003			
Electrical and electronic machinery	Audio and video products	Constant	−5.81 (0.09)^{b}	−0.19 (0.05)^{b}
		Multiplant	−0.15 (0.04)^{b}	0.01 (0.04)
		Exports tech.	−0.08 (0.06)	−0.04 (0.26)
		Age	0.00 (0.00)^{a}	0.00 (0.01)
		4-Digit industries	0.000	0.000
	Electronic parts and components	Constant		1.26 (0.16)^{b}
		Multiplant		0.02 (0.02)
		Exports tech.		−0.03 (0.02)
		Age		0.00 (0.00)
		4-Digit industries		0.000
	Electric machinery and parts	Constant		0.05 (0.27)
		Multiplant		−0.02 (0.77)
		Exports tech.		−0.01 (1.00)
		Age		0.00 (0.01)
		4-Digit industries		0.000
Transportation industry		Constant	−6.64 (0.08)^{b}	−1.48 (0.10)^{b}
		Multiplant	−0.02 (0.02)	−0.59 (0.02)^{b}
		Exports tech.	0.17 (0.12)	−0.20 (0.05)^{b}
		Age	0.00 (0.00)	0.02 (0.00)^{b}
		4-Digit ind.	0.000	0.000

Table 7 continued

2-Digit industry		Panel 1 (1992–1995) Coeff. S.E	Panel 2 (1997–2003) Coeff. S.E
Precision instruments	Constant	−5.47 (0.13)[b]	0.15 (0.04)[b]
	Multiplant	−0.02 (0.04)	−0.04 (0.03)
	Exports tech.	−0.05 (0.11)	−0.09 (0.03)[b]
	Age	0.01 (0.00)	0.01 (0.00)[b]
	4-Digit ind.	0.000	0.000
Miscellaneous industrial products	Constant	−2.60 (0.30)[b]	−0.51 (0.04)[b]
	Multiplant	0.05 (0.06)	−0.88 (0.04)[b]
	Exports tech.	−0.07 (0.50)	−1.45 (0.04)[b]
	Age	0.01 (0.00)[b]	0.01 (0.00)[b]
	4-Digit ind.	0.000	0.738

[a] Significant at the 5% level

[b] Significant at the 1% level

For the sake of concision, we do not report parameter estimates for the 4-digit industry dummy variables. Instead, we show the *P* value of a LR test of global significance of the 4-digit industry dummies within a given 2-digit industry

5 Conclusion

We estimated the impact of R&D and technology imports on firm performance in Taiwan in the 1990s, in a policy context of industrial upgrading. To do so, we estimated a Translog production function on two panels of Taiwanese firms (1992–1995 and 1997–2003), using the Stochastic Frontier models proposed by Battese and Coelli (1992, 1995). We find that the effects of the knowledge inputs become significant in a larger number of industries in the second panel. These results suggest that the policies encouraging innovation, implemented from 1991 onwards, actually paid off in the second half of the 1990s. Innovation then became a key factor to boost firm sales. The impact of innovation can nevertheless be interpreted differently across industries.

In traditional industries like 'Textile mill products', 'Non-metallic mineral products' and 'Fabricated metal products', it can be interpreted as an effort to catch up with the global technology frontier. Firms operating in these industries conducted mostly adaptive R&D in the early 1990s, to build up their knowledge absorption capacity. In the late 1990s, they relied on technology imports, whilst reorienting their R&D capacity towards the generation of new knowledge. This pattern seems to have occurred earlier in the 'Plastic products manufacturing' industry, and later in the "Wood and bamboo products' industry.

In the electronics and associated high-tech industries, R&D appears as the preferred knowledge source to increase firm performance in the late 1990s. The impact of technology imports is less significant, or not at all. In these industries, therefore, R&D cannot be seen as purely adaptive. Its positive impact on firm performance rather testifies of the emergence of knowledge-intensive industries as a new domain

Table 8 Estimate of mean technical efficiency by industry

2-Digit industry		Panel 1 (1992–1995)		Panel 2 (1997–2003)	
		B and C (1992)	B and C (1995)	B and C (1992)	B and C (1995)
Food manufacturing		0.48	0.46	0.87	0.94
Textile mill products		0.50	0.47	0.64	0.77
Wearing apparel and accessories		0.51	0.49	0.79	0.88
Leather and fur products		0.73	0.48	0.83	0.80
Wood and bamboo products		0.52	0.48	0.90	0.92
Furniture and fixtures		0.54	0.48	0.81	0.98
Pulp, paper and paper products		0.77	0.51	0.80	0.94
Printing processing		0.57	0.48	0.74	0.68
Basic chemical matter manufacturing		0.73	0.67	0.76	0.79
Chemical, petroleum and coal products		0.75	0.44	0.79	0.93
Rubber products manufacturing		0.58	0.56	0.82	0.95
Plastic products manufacturing		0.55	0.47	0.80	0.96
Non-metallic mineral products		0.75	0.45	0.79	0.93
Basic metal industries		0.71	0.48	0.80	0.87
Fabricated metal products		0.55	0.47	0.76	0.94
Machinery and equipment		0.55	0.48	0.88	0.97
Panel 1, 1992–1995	Panel 2, 1997–2003				
Electrical and electronic machinery	Audio and video products	0.52	0.46	0.78	0.95
	Electronic parts and components			0.75	0.38
	Electric machinery and parts			0.80	0.97
Transportation industry		0.75	0.46	0.78	0.93
Precision instruments		0.57	0.49	0.78	0.96
Miscellaneous industrial products		0.45	0.46	0.76	0.92

B and C (1992): Battese and Coelli (1992)'s single-equation stochastic frontier model
B and C (1995): Battese and Coelli (1995)'s two-equation stochastic frontier model

of specialization for Taiwan—which was largely encouraged by the aforementioned innovation policies.

Appendix

See Table A.

Table A Estimates of the second derivatives of output with respect to each input, by industry

2-Digit industry	Input	Panel 1 (1992–1995)		Panel 2 (1997–2003)	
		B and C (1992)	B and C (1995)	B and C (1992)	B and C (1995)
Food manufacturing	$d^2 Q/dC^2$	$-9.4 \times 10^{-08} (3.2 \times 10^{-08})^{b}$	$-4.3 \times 10^{-08} (2.8 \times 10^{-08})$	$-7.6 \times 10^{-23} (7.1 \times 10^{-24})^{b}$	$-7.7 \times 10^{-23} (7.1 \times 10^{-24})^{b}$
	$d^2 Q/dL^2$	$-2.4 \times 10^{-05} (1.3 \times 10^{-06})^{b}$	$-1.5 \times 10^{-05} (1.3 \times 10^{-06})^{b}$	$-1.1 \times 10^{-02} (5.5 \times 10^{-04})^{b}$	$-1.1 \times 10^{-02} (5.0 \times 10^{-04})^{b}$
	$d^2 Q/dE^2$			$-4.6 \times 10^{-03} (2.6 \times 10^{-04})^{b}$	$-4.0 \times 10^{-03} (2.5 \times 10^{-04})^{b}$
	$d^2 Q/dM^2$	$-7.6 \times 10^{-07} (3.6 \times 10^{-08})^{b}$	$-1.1 \times 10^{-06} (2.9 \times 10^{-08})^{b}$	$-3.6 \times 10^{-05} (2.8 \times 10^{-07})^{b}$	$-3.9 \times 10^{-05} (2.8 \times 10^{-07})^{b}$
Textile mill products	$d^2 Q/dC^2$	$-2.7 \times 10^{-08} (1.0 \times 10^{-08})^{b}$	$-1.4 \times 10^{-08} (9.6 \times 10^{-09})$	$-9.7 \times 10^{-19} (3.3 \times 10^{-20})^{b}$	$-2.3 \times 10^{-21} (3.1 \times 10^{-22})^{b}$
	$d^2 Q/dL^2$	$-1.1 \times 10^{-05} (1.0 \times 10^{-06})^{b}$	$-7.9 \times 10^{-06} (1.1 \times 10^{-06})^{b}$	$-7.6 \times 10^{-02} (2.9 \times 10^{-03})^{b}$	$-6.4 \times 10^{-03} (5.2 \times 10^{-04})^{b}$
	$d^2 Q/dE^2$			$-7.4 \times 10^{-02} (3.9 \times 10^{-03})^{b}$	$-5.2 \times 10^{-04} (4.3 \times 10^{-05})^{b}$
	$d^2 Q/dM^2$	$-4.2 \times 10^{-07} (2.9 \times 10^{-08})^{b}$	$-6.9 \times 10^{-07} (2.2 \times 10^{-08})^{b}$	$-4.0 \times 10^{-04} (1.9 \times 10^{-05})^{b}$	$-3.9 \times 10^{-05} (2.4 \times 10^{-07})^{b}$
Wearing apparel and accessories	$d^2 Q/dC^2$	$-8.8 \times 10^{-07} (2.4 \times 10^{-06})$	$-6.2 \times 10^{-07} (1.6 \times 10^{-06})$	$-3.6 \times 10^{-24} (1.8 \times 10^{-25})^{b}$	$-1.5 \times 10^{-26} (2.4 \times 10^{-27})^{b}$
	$d^2 Q/dL^2$	$-3.0 \times 10^{-05} (6.8 \times 10^{-06})^{b}$	$-1.9 \times 10^{-05} (5.6 \times 10^{-06})^{b}$	$-3.8 \times 10^{-02} (2.4 \times 10^{-03})^{b}$	$-1.1 \times 10^{-02} (6.7 \times 10^{-04})^{b}$
	$d^2 Q/dE^2$			$-8.5(0.86)^{b}$	$-1.1 \times 10^{-01} (4.3 \times 10^{-02})^{b}$
	$d^2 Q/dM^2$	$-2.9 \times 10^{-06} (4.4 \times 10^{-07})^{b}$	$-5.2 \times 10^{-06} (3.8 \times 10^{-07})^{b}$	$-2.5 \times 10^{-03} (1.4 \times 10^{-04})^{b}$	$-3.5 \times 10^{-04} (5.7 \times 10^{-06})^{b}$
Leather and fur products	$d^2 Q/dC^2$	$-7.9 \times 10^{-07} (1.1 \times 10^{-06})$	$-2.9 \times 10^{-07} (7.0 \times 10^{-07})$	$-1.2 \times 10^{-20} (1.1 \times 10^{-21})^{b}$	$-2.4 \times 10^{-23} (9.7 \times 10^{-24})^{a}$
	$d^2 Q/dL^2$	$-1.6 \times 10^{-05} (6.9 \times 10^{-06})^{a}$	$-1.0 \times 10^{-05} (5.6 \times 10^{-06})$	$-2.3 \times 10^{-02} (3.9 \times 10^{-03})^{b}$	$-4.6 \times 10^{-03} (1.1 \times 10^{-03})^{b}$
	$d^2 Q/dE^2$			$-1.9(8.7 \times 10^{-01})^{a}$	$-2.1 \times 10^{-02} (4.5 \times 10^{-03})^{b}$
	$d^2 Q/dM^2$	$-1.1 \times 10^{-06} (2.1 \times 10^{-07})^{b}$	$-1.9 \times 10^{-06} (1.7 \times 10^{-07})^{b}$	$-4.1 \times 10^{-04} (3.7 \times 10^{-05})^{b}$	$-6.0 \times 10^{-05} (6.6 \times 10^{-07})^{b}$
Wood and bamboo products	$d^2 Q/dC^2$	$-5.1 \times 10^{-07} (4.8 \times 10^{-07})$	$-1.4 \times 10^{-07} (3.6 \times 10^{-07})$	$-1.9 \times 10^{-27} (6.7 \times 10^{-29})^{b}$	$-2.1 \times 10^{-30} (6.5 \times 10^{-31})^{b}$
	$d^2 Q/dL^2$	$-9.6 \times 10^{-05} (9.0 \times 10^{-06})^{b}$	$-5.7 \times 10^{-05} (9.0 \times 10^{-06})^{b}$	$-6.5 \times 10^{-01} (9.9 \times 10^{-02})^{b}$	$-2.7 \times 10^{-02} (3.8 \times 10^{-03})^{b}$
	$d^2 Q/dE^2$			$9.3(1.6)^{b}$	$-2.9 \times 10^{-02} (5.4 \times 10^{-03})^{b}$
	$d^2 Q/dM^2$	$-3.0 \times 10^{-06} (2.9 \times 10^{-07})^{b}$	$-4.7 \times 10^{-06} (2.0 \times 10^{-07})^{b}$	$-6.7 \times 10^{-03} (1.6 \times 10^{-04})^{b}$	$-5.3 \times 10^{-04} (5.3 \times 10^{-06})^{b}$

Table A continued

2-Digit industry	Input	Panel 1 (1992–1995)		Panel 2 (1997–2003)	
		B and C (1992)	B and C (1995)	B and C (1992)	B and C (1995)
Furniture and fixtures	d^2Q/dC^2	$-2.8 \times 10^{-07}(3.3 \times 10^{-07})$	$-8.9 \times 10^{-08}(2.5 \times 10^{-07})$	$-1.3 \times 10^{-23}(6.1 \times 10^{-25})^b$	$-3.6 \times 10^{-26}(1.3 \times 10^{-26})^b$
	d^2Q/dL^2	$-3.0 \times 10^{-05}(3.1 \times 10^{-06})^b$	$-1.8 \times 10^{-05}(3.1 \times 10^{-06})^b$	$-5.8 \times 10^{-02}(3.3 \times 10^{-03})^b$	$-1.2 \times 10^{-02}(1.6 \times 10^{-03})^b$
	d^2Q/dE^2			$-4.3(5.5 \times 10^{-01})^b$	$-6.5 \times 10^{-02}(6.3 \times 10^{-02})$
	d^2Q/dM^2	$-4.1 \times 10^{-06}(4.2 \times 10^{-07})^b$	$-7.8 \times 10^{-06}(3.4 \times 10^{-07})^b$	$-2.5 \times 10^{-03}(1.3 \times 10^{-04})^b$	$-3.8 \times 10^{-04}(2.0 \times 10^{-05})^b$
Pulp, paper and paper products	d^2Q/dC^2	$-2.6 \times 10^{-08}(1.4 \times 10^{-08})$	$-1.5 \times 10^{-08}(1.0 \times 10^{-08})$	$-1.8 \times 10^{-15}(4.3 \times 10^{-17})^b$	$-3.5 \times 10^{-18}(6.9 \times 10^{-19})^b$
	d^2Q/dL^2	$-1.8 \times 10^{-05}(2.1 \times 10^{-06})^b$	$-1.1 \times 10^{-05}(1.9 \times 10^{-06})^b$	$-9.7 \times 10^{-02}(4.3 \times 10^{-03})^b$	$-9.8 \times 10^{-03}(2.2 \times 10^{-03})^b$
	d^2Q/dE^2			$-5.5 \times 10^{-02}(5.3 \times 10^{-03})^b$	$-6.0 \times 10^{-04}(6.5 \times 10^{-05})^b$
	d^2Q/dM^2	$-6.5 \times 10^{-07}(6.9 \times 10^{-08})^b$	$-1.2 \times 10^{-06}(5.3 \times 10^{-08})^b$	$-7.5 \times 10^{-04}(2.1 \times 10^{-05})^b$	$-7.7 \times 10^{-05}(6.8 \times 10^{-07})^b$
Printing processing	d^2Q/dC^2	$-1.2 \times 10^{-07}(1.0 \times 10^{-07})$	$-6.3 \times 10^{-08}(6.9 \times 10^{-08})$	$-6.9 \times 10^{-20}(1.7 \times 10^{-21})^b$	$-3.4 \times 10^{-22}(2.7 \times 10^{-23})^b$
	d^2Q/dL^2	$-1.1 \times 10^{-05}(1.1 \times 10^{-06})^b$	$-8.0 \times 10^{-06}(1.1 \times 10^{-06})^b$	$-6.4 \times 10^{-01}(1.6 \times 10^{-02})^b$	$-2.0 \times 10^{-02}(1.1 \times 10^{-03})^b$
	d^2Q/dE^2			$7.9 \times 10^{-01}(1.4 \times 10^{-01})^b$	$-5.9 \times 10^{-02}(2.8 \times 10^{-02})^a$
	d^2Q/dM^2	$-4.9 \times 10^{-06}(6.0 \times 10^{-07})^b$	$-8.3 \times 10^{-06}(5.7 \times 10^{-07})^b$	$-3.1 \times 10^{-03}(1.4 \times 10^{-04})^b$	$-3.9 \times 10^{-04}(4.8 \times 10^{-06})^b$
Basic Chemical matter manufacturing	d^2Q/dC^2	$-1.5 \times 10^{-08}(9.9 \times 10^{-09})$	$-1.1 \times 10^{-08}(1.1 \times 10^{-08})$	$-2.5 \times 10^{-14}(8.3 \times 10^{-16})^b$	$-5.6 \times 10^{-17}(1.1 \times 10^{-17})^b$
	d^2Q/dL^2	$-7.8 \times 10^{-06}(2.4 \times 10^{-06})^b$	$-5.5 \times 10^{-06}(2.5 \times 10^{-06})^a$	$-5.1 \times 10^{-02}(6.6 \times 10^{-03})^b$	$-3.9 \times 10^{-03}(2.2 \times 10^{-03})$
	d^2Q/dE^2			$-2.2 \times 10^{-02}(1.9 \times 10^{-03})^b$	$-1.5 \times 10^{-04}(2.7 \times 10^{-05})^b$
	d^2Q/dM^2	$-2.1 \times 10^{-07}(2.4 \times 10^{-08})^b$	$-2.6 \times 10^{-07}(2.0 \times 10^{-08})^b$	$-1.6 \times 10^{-04}(6.1 \times 10^{-06})^b$	$-1.4 \times 10^{-05}(1.5 \times 10^{-07})^b$

Table A continued

2-Digit industry	Input	Panel 1 (1992–1995)		Panel 2 (1997–2003)	
		B and C (1992)	B and C (1995)	B and C (1992)	B and C (1995)
Chemical, petroleum, and coal products	d^2Q/dC^2	$-1.1 \times 10^{-08}(6.5 \times 10^{-09})$	$-5.7 \times 10^{-09}(5.1 \times 10^{-09})$	$-3.0 \times 10^{-21}(1.8 \times 10^{-22})^b$	$-1.1 \times 10^{-23}(1.5 \times 10^{-24})^b$
	d^2Q/dL^2	$-2.2 \times 10^{-05}(2.6 \times 10^{-06})^b$	$-1.5 \times 10^{-05}(2.7 \times 10^{-06})^b$	$-1.0 \times 10^{-01}(7.6 \times 10^{-03})^b$	$-1.8 \times 10^{-02}(2.2 \times 10^{-03})^b$
	d^2Q/dE^2			$-4.9 \times 10^{-02}(6.5 \times 10^{-03})^b$	$-5.7 \times 10^{-04}(7.4 \times 10^{-05})^b$
	d^2Q/dM^2	$-1.8 \times 10^{-07}(1.6 \times 10^{-08})^b$	$-2.7 \times 10^{-07}(1.2 \times 10^{-08})^b$	$-1.2 \times 10^{-05}(8.8 \times 10^{-07})^b$	$-2.0 \times 10^{-06}(1.7 \times 10^{-08})^b$
Rubber products manufacturing	d^2Q/dC^2	$-1.6 \times 10^{-08}(9.7 \times 10^{-08})$	$-1.4 \times 10^{-08}(7.0 \times 10^{-08})$	$-3.3 \times 10^{-16}(3.7 \times 10^{-17})^b$	$-1.6 \times 10^{-18}(3.4 \times 10^{-19})^b$
	d^2Q/dL^2	$-9.4 \times 10^{-06}(1.7 \times 10^{-06})^b$	$-6.0 \times 10^{-06}(1.7 \times 10^{-06})^b$	$-1.6 \times 10^{-02}(1.4 \times 10^{-03})^b$	$-1.1 \times 10^{-02}(9.5 \times 10^{-04})^b$
	d^2Q/dE^2			$-2.5 \times 10^{-01}(3.4 \times 10^{-02})^b$	$-8.8 \times 10^{-03}(8.0 \times 10^{-04})^b$
	d^2Q/dM^2	$-9.8 \times 10^{-07}(1.9 \times 10^{-07})^b$	$-1.9 \times 10^{-06}(1.5 \times 10^{-07})^b$	$-9.1 \times 10^{-04}(1.3 \times 10^{-04})^b$	$-2.0 \times 10^{-04}(3.7 \times 10^{-06})^b$
Plastic products manufacturing	d^2Q/dC^2	$-5.2 \times 10^{-08}(2.8 \times 10^{-08})$	$-2.9 \times 10^{-08}(1.9 \times 10^{-08})$	$-1.3 \times 10^{-16}(3.3 \times 10^{-18})^b$	$-3.4 \times 10^{-19}(3.4 \times 10^{-20})^b$
	d^2Q/dL^2	$-1.9 \times 10^{-05}(1.3 \times 10^{-06})^b$	$-1.3 \times 10^{-05}(1.4 \times 10^{-06})^b$	$-3.4 \times 10^{-02}(1.0 \times 10^{-03})^b$	$-8.4 \times 10^{-03}(3.8 \times 10^{-04})^b$
	d^2Q/dE^2			$-4.5 \times 10^{-02}(2.2 \times 10^{-03})^b$	$-8.7 \times 10^{-04}(3.2 \times 10^{-05})^b$
	d^2Q/dM^2	$-3.8 \times 10^{-07}(2.5 \times 10^{-08})^b$	$-6.6 \times 10^{-07}(2.1 \times 10^{-08})^b$	$-2.7 \times 10^{-04}(8.5 \times 10^{-06})^b$	$-3.7 \times 10^{-05}(1.8 \times 10^{-07})^b$
Non-metallic mineral products	d^2Q/dC^2	$-3.5 \times 10^{-08}(1.9 \times 10^{-08})$	$-1.7 \times 10^{-08}(1.7 \times 10^{-08})$	$-1.2 \times 10^{-16}(3.8 \times 10^{-18})^b$	$-4.7 \times 10^{-19}(4.7 \times 10^{-20})^b$
	d^2Q/dL^2	$-3.9 \times 10^{-05}(3.9 \times 10^{-06})^b$	$-2.9 \times 10^{-05}(4.0 \times 10^{-06})^b$	$-7.3 \times 10^{-02}(3.5 \times 10^{-03})^b$	$-1.7 \times 10^{-02}(1.0 \times 10^{-03})^b$
	d^2Q/dE^2			$-4.3 \times 10^{-02}(2.9 \times 10^{-03})^b$	$-6.3 \times 10^{-04}(4.2 \times 10^{-05})^b$
	d^2Q/dM^2	$-1.7 \times 10^{-06}(1.4 \times 10^{-07})^b$	$-2.8 \times 10^{-06}(1.2 \times 10^{-07})^b$	$-1.9 \times 10^{-03}(7.3 \times 10^{-05})^b$	$-2.3 \times 10^{-04}(2.0 \times 10^{-06})^b$

Table A continued

2-Digit industry		Input	Panel 1 (1992–1995)		Panel 2 (1997–2003)	
			B and C (1992)	B and C (1995)	B and C (1992)	B and C (1995)
Basic metal industries		d^2Q/dC^2	$-7.5 \times 10^{-08} (3.9 \times 10^{-08})$	$-4.2 \times 10^{-08} (2.4 \times 10^{-08})$	$-2.7 \times 10^{-21} (1.4 \times 10^{-22})^{b}$	$-5.7 \times 10^{-24} (1.1 \times 10^{-24})^{b}$
		d^2Q/dL^2	$-5.6 \times 10^{-05} (8.8 \times 10^{-06})^{b}$	$-4.0 \times 10^{-05} (8.3 \times 10^{-06})^{b}$	$-1.2 \times 10^{-02} (1.1 \times 10^{-03})^{b}$	$-2.5 \times 10^{-03} (3.6 \times 10^{-04})^{b}$
		d^2Q/dE^2			$-7.4 \times 10^{-03} (5.7 \times 10^{-04})^{b}$	$-1.1 \times 10^{-04} (9.5 \times 10^{-06})^{b}$
		d^2Q/dM^2	$-5.9 \times 10^{-07} (3.7 \times 10^{-08})^{b}$	$-8.2 \times 10^{-07} (6.9 \times 10^{-08})^{b}$	$-5.5 \times 10^{-05} (3.6 \times 10^{-06})^{b}$	$-8.8 \times 10^{-06} (5.7 \times 10^{-08})^{b}$
Fabricated metal products		d^2Q/dC^2	$-2.2 \times 10^{-07} (8.7 \times 10^{-08})^{a}$	$-1.2 \times 10^{-07} (7.7 \times 10^{-08})$	$-3.3 \times 10^{-20} (5.2 \times 10^{-22})^{b}$	$-1.1 \times 10^{-22} (6.9 \times 10^{-24})^{b}$
		d^2Q/dL^2	$-5.3 \times 10^{-05} (3.1 \times 10^{-06})^{b}$	$-4.0 \times 10^{-05} (3.3 \times 10^{-06})^{b}$	$-1.5 \times 10^{-01} (4.2 \times 10^{-03})^{b}$	$-2.7 \times 10^{-02} (1.1 \times 10^{-03})^{b}$
		d^2Q/dE^2			$-1.2 (4.6 \times 10^{-02})^{b}$	$-1.6 \times 10^{-02} (7.1 \times 10^{-04})^{b}$
		d^2Q/dM^2	$-1.9 \times 10^{-06} (1.0 \times 10^{-07})^{b}$	$-3.0 \times 10^{-06} (8.1 \times 10^{-08})^{b}$	$-2.5 \times 10^{-03} (4.6 \times 10^{-05})^{b}$	$-2.7 \times 10^{-04} (1.1 \times 10^{-06})^{b}$
Machinery and equipment		d^2Q/dC^2	$-2.9 \times 10^{-07} (1.8 \times 10^{-07})$	$-1.5 \times 10^{-07} (1.5 \times 10^{-07})$	$-2.7 \times 10^{-29} (1.7 \times 10^{-30})^{b}$	$-3.5 \times 10^{-29} (1.1 \times 10^{-28})$
		d^2Q/dL^2	$-4.9 \times 10^{-05} (3.3 \times 10^{-06})^{b}$	$-3.3 \times 10^{-05} (3.5 \times 10^{-06})^{b}$	$-2.6 \times 10^{-02} (1.1 \times 10^{-03})^{b}$	$-2.7 \times 10^{-02} (2.2 \times 10^{-01})$
		d^2Q/dE^2			$-3.9 \times 10^{-02} (1.5 \times 10^{-03})^{b}$	$-4.2 \times 10^{-02} (6.0 \times 10^{-02})$
		d^2Q/dM^2	$-1.6 \times 10^{-06} (9.8 \times 10^{-08})^{b}$	$-2.7 \times 10^{-06} (8.3 \times 10^{-08})^{b}$	$-2.4 \times 10^{-04} (1.1 \times 10^{-06})^{b}$	$-2.5 \times 10^{-04} (4.2 \times 10^{-04})$
Panel 1, 1992–1995	Panel 2, 1997–2003					
Electrical and electronic	Audio and video products	d^2Q/dC^2	$-3.8 \times 10^{-08} (1.4 \times 10^{-08})^{b}$	$-2.3 \times 10^{-08} (1.1 \times 10^{-08})^{a}$	$-4.9 \times 10^{-19} (8.6 \times 10^{-20})^{b}$	$-4.3 \times 10^{-21} (7.9 \times 10^{-22})^{b}$
Machinery		d^2Q/dL^2	$-9.9 \times 10^{-06} (7.7 \times 10^{-07})^{b}$	$-6.0 \times 10^{-06} (7.9 \times 10^{-07})^{b}$	$-9.9 \times 10^{-02} (1.0 \times 10^{-02})^{b}$	$-9.9 \times 10^{-03} (1.9 \times 10^{-03})^{b}$
		d^2Q/dE^2			$-2.6 (6.1 \times 10^{-01})^{b}$	$-2.1 \times 10^{-02} (9.6 \times 10^{-03})^{a}$
		d^2Q/dM^2	$-1.0 \times 10^{-07} (6.6 \times 10^{-09})^{b}$	$-1.7 \times 10^{-07} (5.7 \times 10^{-09})^{b}$	$-3.4 \times 10^{-05} (8.9 \times 10^{-06})^{b}$	$-1.1 \times 10^{-05} (1.4 \times 10^{-07})^{b}$

Table A continued

2-Digit industry	Input	Panel 1 (1992–1995)		Panel 2 (1997–2003)	
		B and C (1992)	B and C (1995)	B and C (1992)	B and C (1995)
Electronic parts and components	d^2Q/dC^2			$-3.0 \times 10^{-13}(1.1 \times 10^{-14})^b$	$-1.0 \times 10^{-15}(1.5 \times 10^{-16})^b$
	d^2Q/dL^2			$-2.8 \times 10^{-02}(2.3 \times 10^{-03})^b$	$-5.0 \times 10^{-03}(4.7 \times 10^{-04})^b$
	d^2Q/dE^2			$-1.5 \times 10^{-01}(1.3 \times 10^{-02})^b$	$-2.5 \times 10^{-03}(1.7 \times 10^{-04})^b$
	d^2Q/dM^2			$-5.4 \times 10^{-05}(2.3 \times 10^{-06})^b$	$-5.0 \times 10^{-06}(4.5 \times 10^{-08})^b$
Electric machinery and parts	d^2Q/dC^2			$-7.7 \times 10^{-18}(3.1 \times 10^{-19})^b$	$-1.8 \times 10^{-20}(1.5 \times 10^{-20})$
	d^2Q/dL^2			$-3.0 \times 10^{-02}(1.4 \times 10^{-03})^b$	$-5.0 \times 10^{-03}(5.7 \times 10^{-03})$
	d^2Q/dE^2			$-3.7 \times 10^{-01}(2.1 \times 10^{-02})^b$	$-5.7 \times 10^{-03}(6.6 \times 10^{-03})$
	d^2Q/dM^2			$-2.4 \times 10^{-04}(1.1 \times 10^{-05})^b$	$-3.9 \times 10^{-05}(8.4 \times 10^{-06})^b$
Transportation industry	d^2Q/dC^2	$-5.0 \times 10^{-08}(3.7 \times 10^{-08})$	$-3.1 \times 10^{-08}(2.2 \times 10^{-08})$	$-1.0 \times 10^{-20}(3.1 \times 10^{-22})^b$	$-3.1 \times 10^{-23}(3.3 \times 10^{-24})^b$
	d^2Q/dL^2	$-8.1 \times 10^{-06}(6.8 \times 10^{-07})^b$	$-5.3 \times 10^{-06}(6.9 \times 10^{-07})^b$	$-2.9 \times 10^{-02}(1.5 \times 10^{-03})^b$	$-9.5 \times 10^{-03}(4.8 \times 10^{-04})^b$
	d^2Q/dE^2			$-8.2 \times 10^{-01}(6.0 \times 10^{-02})^b$	$-1.3 \times 10^{-02}(8.4 \times 10^{-04})^b$
	d^2Q/dM^2	$-7.1 \times 10^{-08}(5.2 \times 10^{-09})^b$	$-1.2 \times 10^{-07}(3.7 \times 10^{-09})^b$	$-6.9 \times 10^{-05}(2.4 \times 10^{-06})^b$	$-8.4 \times 10^{-06}(6.0 \times 10^{-08})^b$
Precision instruments	d^2Q/dC^2	$-7.0 \times 10^{-07}(6.3 \times 10^{-07})$	$-3.1 \times 10^{-07}(6.4 \times 10^{-07})$	$-2.6 \times 10^{-15}(1.9 \times 10^{-16})^b$	$-7.1 \times 10^{-18}(1.5 \times 10^{-18})^b$
	d^2Q/dL^2	$-1.9 \times 10^{-05}(2.9 \times 10^{-06})^b$	$-1.2 \times 10^{-05}(2.5 \times 10^{-06})^b$	$-2.5 \times 10^{-01}(1.9 \times 10^{-02})^b$	$-6.4 \times 10^{-03}(8.6 \times 10^{-04})^b$
	d^2Q/dE^2			$4.4 \times 10^{-01}(1.7 \times 10^{-01})^a$	$-2.9 \times 10^{-02}(3.8 \times 10^{-03})^b$
	d^2Q/dM^2	$-7.8 \times 10^{-07}(1.0 \times 10^{-07})^b$	$-1.3 \times 10^{-06}(2.1 \times 10^{-07})^b$	$-3.6 \times 10^{-04}(4.3 \times 10^{-05})^b$	$-7.4 \times 10^{-05}(9.3 \times 10^{-07})^b$

Table A continued

2-Digit industry	Input	Panel 1 (1992–1995)		Panel 2 (1997–2003)	
		B and C (1992)	B and C (1995)	B and C (1992)	B and C (1995)
Miscellaneous	d^2Q/dC^2	$-4.3 \times 10^{-07} (4.2 \times 10^{-07})$	$-4.2 \times 10^{-07} (3.6 \times 10^{-07})$	$-1.7 \times 10^{-19} (6.0 \times 10^{-21})^b$	$-6.8 \times 10^{-22} (9.2 \times 10^{-23})^b$
	d^2Q/dL^2	$-3.8 \times 10^{-05} (2.9 \times 10^{-06})^b$	$-2.8 \times 10^{-05} (3.3 \times 10^{-06})^b$	$-8.2 \times 10^{-02} (3.4 \times 10^{-03})^b$	$-1.9 \times 10^{-02} (1.3 \times 10^{-03})^b$
	d^2Q/dE^2			$-7.6 \times 10^{-01} (2.5 \times 10^{-02})^b$	$-1.0 \times 10^{-02} (6.4 \times 10^{-04})^b$
	d^2Q/dM^2	$-2.9 \times 10^{-06} (3.0 \times 10^{-07})^b$	$-4.5 \times 10^{-06} (3.0 \times 10^{-07})^b$	$-1.5 \times 10^{-03} (6.7 \times 10^{-05})^b$	$-2.1 \times 10^{-04} (1.7 \times 10^{-06})^b$

[a] Significant at the 5% level

[b] Significant at the 1% level

B and C (1992): Battese and Coelli (1992)'s single-equation stochastic frontier model

B and C (1995): Battese and Coelli (1995)'s two-equation stochastic frontier model

Standard errors in parentheses

Estimates computed at sample mean. Calculations of the standard errors are based on the delta method

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