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Abstract:

Recent studies in the tradition of Schmookler have re-emphasised the potential role of demand in stimulating innovation. Here, we reconsider the role of 'home' and 'export' market demand in stimulating manufacturing innovation using comparable panel data for two small open economies – Ireland and Switzerland. Our analysis is based on the estimation of reduced form innovation production functions using panel data estimators over the sample period 1994 to 2005. For a range of innovation indicators, however, we find little evidence of any significant market demand effects, with innovation performance instead determined largely by firm-level capability effects and characteristics. In policy and strategy terms this suggests the continued value of measures to improve innovation capability regardless of market demand conditions. In more methodological terms our results suggest the validity of the usual assumption implicit in modelling innovation outputs that supply-side factors predominate.

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Keywords: Innovation, demand, Ireland, Switzerland

JEL Codes: O3, O5, P5

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1.Introduction

Recent studies have re-emphasised the potential role of demand in stimulating innovation in the tradition of Schmookler (1966). Piva and Vivarelli (2007), for example, consider the role of sales growth in stimulating R&D investments and innovation among Italian firms, while Edler and Georghiou (2007) consider the potential role of public procurement in stimulating innovation. Other studies have investigated the cyclicality of research and development expenditures and found either pro-cyclical firm behaviour (see Barlevy, 2007), or no effects of demand shocks on R&D investments (see Rafferty and Funk, 2004). A third group of studies has, more specifically, considered the relationship between innovation and export market demand and generally finds a positive linkage (Wakelin, 1998; Sterlacchini, 1999; Bleaney and Wakelin, 2002; Roper and Love, 2002; Lachenmaier and Wobmann, 2006). Blind and Jungmittag (2004), for example, examine the effect of exporting on innovation among 2,019 German service firms and find evidence that being an exporter is strongly correlated with the probability of being both a product and process innovator.

Here, we reconsider the role of ‘home’ and ‘export’ market demand in stimulating manufacturing innovation using comparable panel data for two small open economies – Ireland and Switzerland. Our separate identification of home and export market demand follows Piva and Vivarelli (2007) who find that, among Italian firms, export demand has a stronger influence on innovation expenditures than domestic sales. In addition, as we are using rich panel datasets we are able to control for a range of factors – firm size, ownership, internal resources, industrial sector – which have been shown in earlier studies to influence firms’ innovation outputs (see, for example, Love and Roper, 2001). We are also able to explore alternative time lags between firms’ innovation activity and market demand, counteracting the potential for endogeneity (e.g. Kleinknecht and Verspagen, 1990). In this sense our study follows Hall et al. (1999), who demonstrated positive demand effects on R&D growth in France, Japan and the US, although here we focus on innovation outputs rather than the R&D input to the innovation process.

The comparison between Ireland and Switzerland is interesting both because we are able to use panel data to overcome some of the causal issues which arise in cross-sectional studies, a point highlighted in Piva and Virarelli (2007), but also because of the very different economic development, innovation performance and export performance of the two areas over recent years[1]. The Republic of Ireland – the so called 'Celtic Tiger' – achieved economic growth rates averaging around 9.7 per cent between 1995 and 2004 (Northern Ireland 3.0 per cent) compared to an average of 1.4 per cent GDP growth in Switzerland[2]. Similarly, export growth averaged 9.9 per cent pa in the Republic of Ireland over the same period compared to an average of 1.9 per cent in Switzerland between 1995 and 2004. Conversely, over the period covered by our study (1994 to 2005) business R&D spending in Switzerland increased steadily reaching 2.1 per cent of GDP in 2004, with public R&D spending accounting for about 0.8 per cent of GDP. In the Republic of Ireland, R&D spending accounted for 1.25 per cent of GDP in 2004 (1.48 per cent of GNP) with public R&D spending accounting for around 0.55 per cent of GDP (see Table 1) [3].

These very different patterns of domestic growth, together with the two countries' common international market environment, might be expected to lead to very different patterns of demand effects on innovation. In fact, we find marked commonalities between the two countries, with our analysis emphasising the role of supply-side rather than demand-side effects. The rest of the paper is organised as follows. Section 2 outlines our conceptual model which adopts a behavioural approach, linking innovation outcomes to the anticipated effects of market demand on post-innovation returns. Section 3 describes our data and analytical approach and Section 4 outlines our main empirical results. Section 5 highlights the key empirical conclusions and draws out implications for methodology and policy.

2. Conceptual Approach

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[1] Here we use the term Republic of Ireland to refer to the Irish nation state and Ireland to refer to the whole island of Ireland including both the Republic of Ireland and the UK region of Northern Ireland.
[2] For the Swiss data see KOF-Analysen (2007)
[3] Irish GDP and exports data from www.cso.ie. R&D data from Research and Development Statistics in Ireland, 2006, Forfas, Dublin. GDP figures for Northern Ireland from UK National Statistics.

Our conceptual approach is based around the notion of an innovation or knowledge production function which models the knowledge transformation process by which knowledge inputs from R&D are translated into innovation outputs (Roper et al., 2008). Firms' investments in R&D will occur when the results of these investments (i.e. innovations) are expected to earn positive post-innovation returns. Moreover, the scale of firms' investments in R&D are likely to vary positively with expected post-innovation returns. Decision-theoretic models of the choice of research intensity by firms (e.g. Levin and Reiss, 1984), for example, suggest first order conditions which relate firms' investments in R&D positively to expected post innovation price-cost margins[4]. Firms' expectations of post-innovation returns, however, are likely to reflect their experience of growth in their home (HMG_i) and export (XMG_i) markets as well as the market position of the firm itself, and other firm and industry specific factors[5]. That is firms R&D intensity (RD_{it}) will be given by:

$$RD_{it} = \alpha_0 + \alpha_1 XMG_{it-j} + \alpha_2 HMG_{it-j} + \alpha_3 K_{it} + \alpha_4 RI_{it} + \alpha_5 IND_i + \eta_{it} \qquad (1)$$

Where, K_{it} represents the availability of other external knowledge, RI_{it} is a series of indicators of the strength of firms' internal resource and IND_{it} is an indication of potential industry resources which might affect post innovation returns.

Innovation outputs will then be determined by the innovation production function (Geroski 1990; Harris and Trainor 1995), reflecting firms' R&D investments, other knowledge sources and any additional factors which may influence the effectiveness of firms' knowledge transformation activities. If I_{it} is an innovation output indicator we can write this:

$$I_{it} = \beta_0 + \beta_1 RD_{it} + \beta_3 K_{it} + \beta_4 RI_{it} + \beta_5 IND_i + \delta_{it} \qquad (2)$$

Substituting for RD_{it} from (1) then suggests the reduced form innovation production function:

[4] See the references cited in Geroski (1990), p 588, for a discussion of the basis for this type of relationship but in particular Dasgupta (1986) and Kamien and Schwartz (1982).
[5] 'Conditioning variables' which have previously been used as part of the vector Z_k include (Geroski, 1990); industry size and growth, capital intensity, export intensity and a proxies for the extent of unionisation.

$$I_{it} = \phi_0 + \phi_1 XMG_{it-j} + \phi_2 HMG_{it-j} + \phi_3 K_{it} + \phi_4 RI_{it} + \phi_5 IND_i + \phi_6 TDUM_t + v_i + \varepsilon_{it} \qquad (3)$$

Here, the coefficients φ_1 and φ_2 will capture the impact of export and home market growth on the scale of firms' R&D investments and hence innovation. As we expect R&D investments to be positively related to expected post innovation returns, and innovation to be positively related to R&D inputs we anticipate both will have positive signs. In fact, we consider two forms of this model in our empirical analysis reflecting first the growth of firms' home and export markets and secondly the change in the growth of firms' home and export markets. We consider the second of these to reflect the possibility that innovation responds to market acceleration and deceleration rather than market growth per se.

The coefficient φ_3 on K_{it} will reflect both the indirect effect of K_{it} on RD_{it} (i.e.α_3) as well as the direct impact of other knowledge sources on innovation outputs (i.e. β_3) The former of these – the sign of α_3 in equation (1) - will reflect the complementarity or substitute nature of R&D and other external knowledge sources, and may therefore in theory take either sign. Recent empirical studies, however, have emphasised the complementarity between internal and external knowledge sources for innovation, suggesting α_3 is likely to be positive (Roper et al., 2008). The latter – the sign of β_3 in equation (2) reflects the impact of external knowledge sources on innovation. This should also be positive as external knowledge resources, like customers, suppliers, and universities should increases the likelihood of knowledge spillovers and innovation (Cassiman and Veugelers, 2002). Our expectation is therefore that φ_3 will itself be positive (Table 2).

Similarly, parameter φ_4 will reflect the indirect effect of firms' resource base on R&D investments (equation (1)) as well as the direct effect on innovation (equation (2)), and here we include a range of variables drawing on previous innovation production function studies. First, we include a variable to reflect firm size which we interpret in the Schumpeterian tradition as a resource indicator, and would anticipate following this tradition that firm size would have a positive direct effect on R&D investments. Evidence on the direct impact of firm size on innovation measures is more equivocal, however. Based on CIS data, for example, Raymond et al. (2004) found in the Dutch case (three waves of the Dutch Community Innovation Survey, i.e. CIS 2, 2.5, 3) a negative size effect in the innovation production function. This is in line with the findings of Janz et al. (2003) for Germany. In contrast (Crepon et al., 1998) do not detected any size effect and Mairesse and Mohnen (2001) found a positive size effect. In sum, we have no strong a priori sign expectations for the coefficient on firm size in the reduced form innovation production function. An essentially similar position exists for external-owned firms, particularly when we control for firm size, sector and other characteristics (e.g. Love et al., 2007). We expect more clarity in terms of firms' skill base where we expect a positive relationship between skill levels and R&D investments and between skill levels and innovation (Freel, 2005). In part this expectation reflects the notion of absorptive capacity (Cohen and Levinthal, 1989; Cohen and Levinthal, 1990) which is likely to be greater the stronger is firms' skill base. In the models we include three skills variables; an indicator of the level of graduate skills in the firm; an indicator of the proportion of the workforce with no qualifications and a subjective indicator in which firms report whether skills were a barrier to their innovation activity. This is regularly observed in innovation studies to be a significant determinant of firms' innovation activity (see Arvanitis et al., 2007). Finally, we also include a dummy variable reflecting firms' subjective assessment of whether they faced financial barriers to engaging in successful innovation. On both this and the skill barrier variable we expect negative signs reflecting anticipated negative direct and indirect effects (see Table 2).

In addition to these firm-level variables we also include a set of sector controls at the 2- digit level and we also include three time dummies to pick up any secular differences between waves of the Irish and Swiss panel datasets[6]. For Switzerland we expect the time dummies to take a generally negative sign as the innovation performance of Swiss firms has deteriorated somewhat since 1996 (see Figure 1). For Ireland, any sign expectations are less straightforward although we expect a negative sign on the time dummy relating to the 2000 to 2002 wave reflecting the impact on innovation of the high-tech downturn over this period (Figure 2).

[6] For both countries we use the food, drink and tobacco sector as the reference sector and the first wave of the panels 1994-1996 as the reference time period.

3. **Data and Methods**

Our empirical analysis is based on data from four sources: the Irish Innovation Panel (IIP) which provides information on the innovation activities of Irish firms; the Swiss innovation panel (SIP) which provides information on the activities of Swiss firms; value added data in OECD countries from the STAN Database; and, value added data for Switzerland from KOF (the Swiss Economic Institute). The later two sources provide information on the growth of firms' home and export markets. We briefly describe each in turn.

The Irish Innovation Panel provides information on manufacturing plants' technology adoption, networking and performance over the period 1991-2005. More specifically, the IIP comprises five surveys or waves conducted using similar survey methodologies and questionnaires with common questions (Roper et al., 1996; Roper and Hewitt-Dundas, 1998; Roper and Anderson, 2000; Roper et al., 2003). Each of the five surveys covers the innovation activities of manufacturing establishments with 10 or more employees over a three year period. For manufacturing each of the five surveys was undertaken by post using a sampling frame provided by the economic development agencies in Ireland and Northern Ireland[7]. The IIP is a highly unbalanced panel reflecting non-response but also the closure and opening of manufacturing units over the 15 year period covered by the panel. The panel itself contains 4525 observations from 2564 establishments and representing an overall response rate of 33.2 per cent (Northern Ireland, 39.1 per cent; Ireland 30.5 per cent).

Innovation in the IIP is represented by three main variables. First, the proportion of firms' total sales (at the end of each three year period) derived from products newly introduced during the previous three years. This variable – "innovation success" - reflects not only firms' ability to introduce new products to the market but also their short-term commercial success. On average, 15.1 per cent of firms' sales were derived

[7] The initial survey, undertaken between October 1994 and February 1995, related to plants' innovation activity over the 1991-93 period, and achieved a response rate of 38.2 per cent (Roper et al., 1996; Roper and Hewitt-Dundas, 1998, Table A1.3). The second survey was conducted between November 1996 and March 1997, covered plants' innovation activity during the 1994-96 period, and had a response rate of 32.9 per cent (Roper and Hewitt-Dundas, 1998). The third survey covering the 1997-99, period was undertaken between October 1999 and January 2000 and achieved an overall response rate of 32.8 per cent (Roper and Anderson, 2000). The fourth survey was undertaken between November 2002 and May 2003 and achieved an overall response rate of 34.1 per cent. The IIP5, conducted between January and June 2006, had an overall response rate of 28.7 per cent.

from new products across the IIP (Table 3). The second innovation output measure is a binary indicator of product innovation which reflects the extent of product innovation within the target population. The third innovation output measure is a similar binary indicator of process innovation, an indication of the extent of process innovation within the target population[8]. Over the whole sample, 62.5 per cent of firms were product innovators while 59.2 per cent were process innovators (Table 3). Notably, however, the overlap between the group of product and process innovators was not complete: around 70.2 per cent of product innovators were also process innovators, with 75.3 per cent of process innovators also being product innovators.

Swiss innovation data provides information on manufacturing firms' innovation performance, innovation input, R&D cooperation, external knowledge sources, IPR, innovation obstacles, technological potential, and public innovation promotion over the period 1990 – 2005 (triennial). However the questionnaires in 1990 and 1993 were much less comprehensive than the later ones. The surveys are conducted based on a stratified random sample from the Swiss business census on firms with more than 5 employees (firm panel) covering the manufacturing, construction, and service sectors. For the international comparison at hand we refer to firms with 10 or more employees. Only data from the manufacturing sector and only data from the surveys 1996, 1999, 2002, and 2005 are used in this investigation. The SIP contains around 3000 manufacturing firms and the response rates are 33.5 per cent, 33.8 per cent, 44.6 per cent, and 41.6 per cent for the years 1996, 1999, 2002, and 2005 respectively. Like the IIP, the Swiss innovation panel is a highly unbalanced panel, reflecting' non-response[9].

Looking at the three innovation output measure we use, we find that in the SIP the proportion of new (innovative) products on total sales averages around 17 per cent slightly above the 15 per cent in Irish firms (see Table 3)[10]. The second innovation indicator we use is the proportion of firms undertaking product innovations. In Switzerland, this share decreased from 72 per cent in 1996 to 55 per cent in 2005, an

[8] For this variable a product (process) innovator was defined as an establishment which had introduced any new or improved product (process) during the previous three years.
[9] For a detailed discussion of methodology, questionnaires, and descriptive results for the SIP see Arvanitis et al. (1998, 2001, 2004, and 2007).
[10] The figures for the respective years include also non-response weights, while the overall average is only firm-weighted.

average of around 68 per cent compared to 63 per cent in Ireland (Table 3). The third innovation indicator is the proportion of firms undertaking process innovation. Here, the Swiss share also decreased over the years from 71 per cent in 1996 to 45 per cent 2005, averaging 58 per cent (Ireland, 59.2 per cent).

Market growth data for each 2-digit manufacturing sector in real terms were calculated from the OECD STAN database (see Annex 1)[11]. The aggregated growth rate for firms' international markets consists of value added figures from the EU15 countries, Japan and USA for the years 1991 to 2003. Home market growth industrial output price deflators were derived from Swiss, Irish and UK national sources to derive output volume indicators[12]. Due to missing values for Switzerland we assumed that the value added for the wood industry, the pulp/paper/printing industry, and other non-metallic minerals did not change between the years 2002 and 2003. Thus we assumed a growth rate of zero. For Swiss firms home market growth therefore reflects the real growth of the Swiss domestic market, with real export market growth proxied by growth in the US, Japanese and EU15. For Irish firms – some of which are in Ireland and some in the UK region of Northern Ireland - the UK and Ireland are treated as the home market with real export market growth again proxied by growth in the US, Japanese and EU15 markets (excluding Ireland and the UK).

Our econometric approach is dictated largely by the fact that we are using firm level data from two highly unbalanced panels and that our dependent variables – the innovation output indicators – are not continuous[13]. We therefore make use of the GEE (population-average) estimator which provides perhaps the best econometric

[11] Sectors are: food, textile/clothing, wood, pulp/paper/printing, chemical/rubber/plastics, other non-metallic minerals, basic metal/fabricated metal, machinery and equipment (nes.), and electrical and optical equipment. For deflation procedures please refer to the accompanying note of the STAN database, i.e. the OECD STAN database for Industrial Analysis, February 2005. (see http://www.oecd.org/document/15/0,2340,en_2649_201185_1895503_1_1_1_1,00.html and go to full documentation)

[12] For Ireland, industrial price indices by industry were available from CSO. Prior to 1993 no sectoral price deflators are available so an aggregate manufacturing deflator is used.

[13] One might think in applying GLS or GMM estimators. The problem is that our panel is very unbalanced and most of the alternative estimation procedures "balance" the panel if you take into account heteroscedasticity and/or autocorrelation. This results in a tremendous loss of observations (more than one third in the case of Switzerland).

approach[14]. It enables us to specify the binary character of our variables for process and product innovations, the Gaussian distributed and metric innovation sales variable (innovative firms) and the very right skewed (Poisson) distribution of the innovation sales variable (all firms). Furthermore all standard errors are heteroscedasticity robust and we also could model the residuals of our estimations although for the moment we assume them to be unstructured[15].

4. **Estimation results**

Our main focus here is on the effect of home and export market demand on innovation outputs in the context of the contrasting development trajectories of Ireland and Switzerland. During the 1990s, and post-2002, the innovation indicators for Ireland suggest improving performance (Figure 2). In contrast, the innovation indicators suggest a downward trend for Switzerland over the same period (Figure 1). Concurrently, overall economic performance in Switzerland deteriorated with declining growth rates while the Irish economy grew rapidly. These contrasting situations provide an ideal context in which to compare the influence of macro-economic demand effects with that of firm-level factors on the innovation performance of firms in the two countries. For each country, we estimate a set of identical empirical models over the same period (1994-2005) applying essentially the same set of variables (see Table 4) and using the same estimation methods. In each model we include an export market growth indicator and a home market growth indicator with illustrative models given for Ireland and Switzerland in Table 4. Table 10 gives a symbolic summary of the entire set of estimation results for home and export market demand.

Perhaps the key result which emerges from the estimation is the dominance of firm-level factors and the relative weakness of home and export market demand effects in explaining innovation performance. For Ireland, we find no evidence of the anticipated positive and significant home or export market growth effects on any of

[14] We use STATA software (xtgee). Stata implementation follows that of Liang and Zeger (1986). For the minimal differences between random effects and population average estimators see Sribney (2007), Neuhaus et al. (1991).

[15] We also conducted a “weak” test on endogeneity of especially suspicious variables, i.e. the R&D variable and the “knowledge” variable. We lagged them and in fact the knowledge variable looses some explanatory power. There is no problem with the R&D variable. Since the knowledge variable is of minor importance to the investigation at hand we do not further investigate this issue.

the innovation indicators, and also no positive and significant effects from any of the market acceleration variables (Table 5). For Switzerland the same general pattern is evident although we see some evidence of positive and significant export market effects on both the extent and success of firms' innovation activity (Table 5). Predominantly, however, for Switzerland as for Ireland we see little consistent evidence of the expected positive market demand effects on innovation.

What explains the differences between the two countries, particularly given the much more rapid growth of Ireland over the period of our study? In part this may be a result of the different circumstances of the two economies at the start of the study period. For Switzerland, which had an established export market position in many sectors, some dominated by multi-national firms, intensifying international competition in both home and export markets may have reduced the significance of market growth effects as other competitors emerged. In some major Swiss industries like mechanical engineering, for example, the revaluation of the Swiss currency, and the further integration of the EU and trade advantages for competing countries, like Austria and the Scandinavian countries, are likely to have reduced Swiss firms' ability to benefit from market growth. Ireland by contrast experienced massive inward investment during our study period by strongly export oriented multi-national firms. Growth and innovation in the Irish economy over this period was not therefore driven by changes in export demand but rather by investment-led growth as multinational firms sought to gain market share in Europe and Middle-Eastern markets. This emphasises the importance of supply-side factors rather than market demand measures in shaping Irish innovation performance over this period.

As a result, plant-level and sectoral factors prove more important in shaping innovation than our demand-side indicators, and highlight a range of similarities between the determinants of innovation performance in the two countries (Tables 4). Against the background of little market demand effects, this result shows that plant-level factors, many of which can be shaped by the strategic decisions of firms, can contribute to increase the innovativeness of a firm. Such firms are likely to gain market shares based on their innovative products and prosper independently of market fluctuations. Furthermore their innovative behaviour increases market flexibility and allows for positive economic development.

In comparing the results for Ireland and Switzerland we see marked similarities between most of the effects of explanatory variables (see highlighted fields in Table 4) and relatively few divergences. This points at the robustness of the results. Looking at the results in greater detail we see first and in both countries, a positive size effect on the probability of the firm being a product and process innovator but no size effect on innovation performance (see also Roper et al. 2008). Second, in both countries we see the anticipated strong positive effects from graduate employment in the firm on the sales of innovative products (Freel 2005) but significant negative effects on the probability that firms will undertake process change. This latter result is interesting and may reflect the fact that more process oriented firms – which may be more likely to make process innovations – tend to have a larger unskilled workforce. Third, both in-house R&D activities and external knowledge sourcing are, as expected, both positively associated with an increased probability of innovating and innovative sales in both countries (Table 4). Plant vintage (age), however, is negatively associated with innovation in both countries.

Marked differences emerge between the two countries, however, in terms of the pattern of coefficients on the time dummies, for which the reference period is 1993 to 1996. In Ireland, these are largely insignificant suggesting little change in innovation performance over the period of our study. Only the proportion of product innovators in the 2002 to 2005 period is significantly different from the reference period ceteris paribus (Table 4). For Switzerland, however, we see a series of significant negative time dummy effects with a clear tendency for these to increase in absolute size in more recent years (Table 4). Sales of innovative products by innovative firms, for example, were 7.1 pp below the reference level in 2003 to 2005 compared to -5.6 pp in 2000 to 2002 and -3.9 pp in 1997 to 1999. Some more positive signs are evident here too, however, with the proportion of product innovators in Switzerland actually increasing in the 2002 to 2005 period relative to the reference period (Table 4).

5. Conclusions

Our main conclusion is that in terms of the probability of innovating, and in terms of the proportion of innovative sales, market demand matters much less than individual firms' innovation capability. In particular, our results suggest that both for Irish and Swiss firms the anticipated effects of market demand changes on post-innovation returns have a weaker impact on R&D investments and hence innovation than other capability or supply-side effects. Where we do find positive demand effects on innovation for Switzerland these are stronger for the growth in export market demand, reflecting the findings of (Piva and Vivarelli, 2007) for Italian firms.

From both a policy and strategy perspective the relative strength of firm-level capability effects – or supply-side effects - is reassuring suggesting that measures to improve firms' innovation capability can generate improvements in innovation performance regardless of market conditions. From a strategy standpoint, this suggests that firm innovation outputs are largely strategically determined with, for example, training for innovation and external knowledge sourcing proving important innovation determinants for both Swiss and Irish firms. From a policy perspective these results emphasise the potential benefits for innovation outputs of measures to develop firms' internal knowledge absorption or transformation capabilities. Interestingly, we find little evidence in either country to support claims that financial barriers are having any significant negative effect on innovation outputs.

For Ireland, the finding that supply-side or capability factors are the primary determinants of innovation rather than market demand is perhaps unsurprising given the extent of inward investment and reinvestment over the study period. Indeed other studies have attributed similar importance to supply-side developments in Ireland with Daveri (2001) finding Ireland to be one of few EU countries to have derived both TFP and labour productivity gains from ICT investment[16]. What is not clear from our

[16] Daveri (2001), for example, shows that ICT spending in Ireland as a percentage of GDP was around the EU average in 1992 (5.38 per cent compared to 5.26 per cent), and 1998 (5.88 per cent compared to 5.93 per cent), but had fallen behind the EU average by 2001 (6.21 per cent compared to 8.20 per cent). Using a growth accounting methodology Daveri decomposes the capital accumulation component of TFP into ICT related and 'other' categories. Based on ICT investment data he then estimates the contribution of ICT stimulated productivity changes to national GDP growth. In terms of labour productivity growth, he concludes that for Ireland, ICT capital added 0.35 pp to the growth in GDP per man hour through the later 1990s in addition to adding 0.59 pp to TFP growth. Only three EU countries (Ireland, Portugal and Greece) experienced positive growth effects from ICT through both effects.

modelling here, however, is whether these capability effects for Ireland were operating primarily through their indirect effects on anticipated post innovation returns and hence innovation, or directly on firms' knowledge transformation capabilities. For Switzerland, the situation is rather different, however, as levels of both R&D investment and innovation have fallen over the study period. The fall in R&D investment, in particular, in Switzerland suggests a decline in anticipated post-innovation returns due either to changing market conditions or capability factors rather than any particular decline in firms' knowledge transformation capabilities. Here, therefore we would argue that changing international market conditions – linked to revaluation and EU integration – have reduced Swiss firms' ability to benefit from market growth.

In addition to these policy and strategy implications, our results also provide some reassurance in terms of standard approaches to modelling firms' innovation performance using innovation production functions. These standardly relate firms' innovation outputs to factor or knowledge inputs and other variables relating to firms' knowledge transformation capability and make an implicit assumption of the weakness of potential demand effects (Roper et al., 2008). Here we do consider these effects but find they are relatively weak, suggesting that the supply-side dominated approach of most innovation production function studies may indeed be capturing most of the factors which drive innovation performance at the level of the individual firm.

Having said this it is clear that our market demand variables – albeit adjusted for each firm's exposure to home and export markets – are relatively crude proxies for firms' actual market growth. For example, we make no allowance for the segment of each sectoral market in which firms are operating, a factor which might significantly alter anticipated post-innovation returns. Limitations in our data also mean that we are unable to identify which specific export markets to which firms are exposed, and we are therefore forced to us a more generalised indicator of export market growth. On the innovation and capabilities side of our modelling we are more confident, and the similarity of the Irish and Swiss results here is particularly reassuring here. In the light of the weakness of the demand effects observed here, probing these supply-side effects in future comparisons seems an obvious extension.

Table 1: Comparative Data

	Republic of Ireland	Northern Ireland	Ireland	Switzerland
A. Land Area and Population				
Land area (km^2 x 1000)	81519	13602	95121	41285
Population (x million, 2006)	4.239	1.741	5.98	7.5
Population density (per km^2, 2006)	52	128	62	182
B. Labour Market				
Working age employment rate (per cent, 2006)	57.6	69.4	60.4	81.2
Unemployment rate (per cent, 2006)	4.4	3.2	4.1	3.3
C. Openness				
Total exports (per cent of GDP)	81.6			52.5
Total imports (per cent of GDP)	69.3			44.9
C. Composition of GDP (2006)				
Primary (agriculture, fishing, mining)	2.5	3.2	2.6	1.1
Manufacturing (incl. construction for CH)	25.4	16.1	23.7	25.9
Construction	9.4	7.7	9.1	
Services (for CH)				67.0
Distribution, transport and comms	15.0	23.0	16.5	
public admin and defence	3.5	11.1	4.9	
other services	44.1	38.9	43.2	
D. R&D Spending (% GNP, Ireland 2006, % GDP, Switzerland 2004))				
R&D Spending	1.6	1.3	1.5	2.9
- Industry	1.1	0.6	1.0	2.1
- Higher education	0.4	0.6	0.4	0.7
- Other	0.1	0.1	0.1	0.1

Notes: Land area and population: population estimates relate to 2006, Sources: Northern Ireland Annual Abstract of Statistics (NIAAS), NISRA, Belfast and CSO. Labour Market: Employment rate as per cent of working age population (in Switzerland between 15 and 64 years), unemployment rate ILO unified rate, Sources: Annual Abstract of Statistics, CSO Dublin and NIAAS, Statistic Switzerland. Openness: No figures are available for Northern Ireland; for Ireland Source: CSO, Dublin. Total Exports and Imports as a proportion of current prices GDP 2006. Composition of GDP 2006: Source: Annual Abstract of Statistics, CSO Dublin. R&D Spending: For Ireland, R&D Spending: Ireland as per cent of GNP, 2006; Source: Research and Development Statistics in Ireland, 2006, Forfás, Dublin. For Northern Ireland, Northern Ireland R&D Statistics 2006, Department of Trade, Enterprise and Investment, Belfast. Estimated as a proportion of 2004 GDP allowing for growth at 3.0 per cent pa during 2005 and 2006. For Switzerland all information are from Swiss Statistics (www.bfs.admin.ch).

Table 2: Determinants of firms' innovation performance – Independent variables

Independent Variables	Description	Expected sign
Innovation Output Indicators		
Product innovation	Binary variable; 1 for product innovation, 0 for no product innovation for the periods under investigation, i.e. 1994-1996, 1997-1999, 2000-2002, 2003-2005	
Process innovation	Binary variable; 1 for process innovation, 0 for no process innovation	
Sales of new products (innovative firms)	Share of sales of new products. Basis: innovative firms only	
Sales of new products (all firms)	Share of sales of new products. Basis: all firms	
Weighted market growth variables		
XMG	Growth rate of the sum of value added (STAN data base, deflated) of manufacturing industries of Austria, Belgium, Denmark, Finland, France, Germany, Greece, (Ireland for Swiss calculations), Italy, Japan, Luxembourg, Nederland, Portugal, Spain, Sweden, (Switzerland for Irish calculations), United Kingdom (only for Swiss calculations), United States. The growth rates of the respective industries are weighted by the export share of each firm. Where a firm is not exporting this variable is zero. The industrial breakdown is that reported in Tables 4 to 6.	+
HMG	Growth rate of the value added (deflated) for manufacturing industries for Ireland (and UK) and for Switzerland. The selected industries correspond with the industries of the XMG variable for Switzerland and Ireland respectively. The growth rates of the respective industries are weighted by share of home market sales of each firm (1 – share of export).	+
Plant characteristics		
SIZE	Logarithm of the number of employees in full time equivalents	
FOREIGN	Firm owned by a foreign company (0/1)	
EDUC (human capital)	Share of employees with tertiary-level vocational education (universities, universities of applied sciences, other business and technical schools at tertiary level)	+
NOEDUC (human capital)	Share of semi-skilled and unskilled workers	+
RD	Research and development activities of a firm (0/1)	+
KNOWLEDGE	Importance of external knowledge sources; at least one of the external knowledge sources (suppliers, concern internal, consultants, customers, fairs, exhibitions, patents, universities)	
FINANCE	Finance barrier to innovation; value 4 or 5 on a five-point likert scale (0/1)	-
SKILLS	Skills barrier to innovation; value 4 or 5 on a five-point likert scale (0/1)	-
AGE	2005 minus the year of firm foundation	+/-
Sectoral dummies		
SECDUM	Ireland: Food products/beverages and tobacco (reference), Textiles, textile products, leather and footwear, Wood and products of wood and cork, Pulp/paper/ paper products/ printing, Chemical/rubber/ plastics and fuel products, Other non-metallic mineral products, Basic metals and fabricated metal products, Machinery and equipment nec, Electrical and optical equipment, Transport equipment, Manufacturing nec; Switzerland: food (reference), textiles and clothing, wood and wood products, paper and printing, chemicals, non-metallic	+/-

	mineral products, metals and metal fabrication, mechanical engineering, electrical and optical equipment.	
Time dummies TDUM	Period dummy 1994-1996 (reference), period dummy 1997-1999, period dummy 2000-2002, period dummy 2003-2005	+

Table 3: Descriptive data

	Ireland			Switzerland		
	Obs	Mean	Std. Dev.	Obs	Mean	Std. Dev.
Innovation Indicators						
Product innovation (0/1)	3453	0.639	0.480	3912	0.689	0.463
Process innovation (0/1)	3445	0.582	0.493	3912	0.588	0.492
Percentage of new products (innovators)	1828	26.741	24.188	2610	17.414	19.623
Percentage of new products (all firms)	3230	15.134	22.511	3496	13.001	18.572
Market Growth						
Home market growth (3 year MA, -2)	3242	92.677	182.303	3819	65.476	242.420
Home market growth (3 year MA, -3)	3242	116.724	191.691	3819	57.596	262.149
Export market growth (3 year MA, -2)	3242	58.287	155.559	3819	57.701	144.628
Export market growth (3 year MA, -3)	3242	29.411	160.972	3819	93.780	230.184
Plant Characteristics						
Plant size (log(employment)	3460	3.876	1.117	3911	4.317	1.262
Externally Owned	3530	0.309	0.462	3854	0.156	0.363
Workforce with degree (per cent)	3310	9.696	13.102	3912	12.401	11.346
Workforce no qualifications (per cent)	3281	45.129	32.487	3912	36.047	25.095
R&D in the plant	3460	0.484	0.500	3640	0.685	0.465
External knowledge sourcing	3530	0.422	0.494	3695	0.480	0.500
Finance barrier to innovation	3530	0.478	0.500	3912	0.330	0.470
Skills barrier to innovation	3530	0.426	0.495	3912	0.370	0.470
Plant age (years)	3400	28.259	29.686	3817	63.222	43.045
Time Dummies						
Period dummy 1997-1999	3530	0.299	0.458	3912	0.221	0.415
Period dummy 2000-2002	3530	0.261	0.439	3912	0.288	0.453
Period dummy 2003-2005	3530	0.227	0.419	3912	0.287	0.452

Source: Irish Innovation Panel (Waves 2 to 5). Swiss Innovation Panel (Waves 3 to 6). See text for derivation of variables.

Table 4: Illustrative Model for Ireland (IRL)and Switzerland (CH)

	Product Innovation		Process Innovation		Sales of new products (Innovators Only)		Sales of new products (All	
	Random Effects Probit		Random Effects Probit		Random Effects Regression (OLS type)		Random Effects Tobit	
	IRL	CH	IRL	CH	IRL	CH	IRL	CH
	dy/dx	dy/dx	dy/dx	dy/dx	dy/dx	dy/dx	dy/dx	dy/dx
Demand Growth								
XMG (3 year MA, -2)	0.000	0.000**	0.000	0.000*	0.002	0.006	0.001	0.004*
	(-0.12)	(2.06)	(-0.08)	(1.66)	(0.41)	(1.50)	(0.24)	(1.89)
HMG (3 year MA, -2)	0.000	0.000	0.000	-0.000	-0.003	-0.003	-0.002	-0.002
	(0.99)	(1.55)	(0.82)	(-0.23)	(-0.8)	(-1.50)	(-0.75)	(-1.33)
Plant Characteristics								
Size	0.051***	0.014*	0.092***	0.041***	-0.692	-0.271	0.708	-0.039
	(4.48)	(1.91)	(8.14)	(4.73)	(-0.86)	(-0.64)	(1.48)	(-0.14)
Foreign	0.041*	0.014	0.032	-0.049*	1.813	0.582	1.218	0.318
	(1.66)	(0.63)	(1.29)	(-1.84)	(1.1)	(0.47)	(1.23)	(0.42)
Educ	0.003***	0.001	-0.002***	-0.002*	0.210***	0.114**	0.098***	0.059**
	(2.26)	(0.94)	(-2.39)	(-1.76)	(3.28)	(2.38)	(3.5)	(2.34)
Noeduc	0.000	-0.001**	0.000	0.000	-0.027	-0.035*	-0.007	-0.026*
	(1.1)	(-2.01)	(0.46)	(0.29)	(-1.38)	(-1.67)	(-0.55)	(-1.76)
Rd	0.328***	0.584***	0.193***	0.440***	-0.175	2.891***	7.044***	11.542***
	(17.84)	(29.41)	(9.46)	(21.17)	(-0.13)	(2.59)	(7.78)	(17.78)
Knowledge	0.179***	0.002	0.178***	0.061***	3.165***	1.633**	4.787***	1.069*
	(9.52)	(0.10)	(8.78)	(3.17)	(2.62)	(2.09)	(5.64)	(1.95)
Finance	-0.014	-0.028*	-0.033	-0.026	2.022	-0.07	0.849	-0.292
	(-0.66)	(-1.78)	(-1.54)	(1.27)	(1.58)	(-0.08)	(1.09)	(-0.50)
Skills	-0.042**	0.011	-0.005	-0.022	-0.005	0.094	-0.768	-0.411
	(-1.95)	(0.72)	(-0.21)	(-1.15)	(0.00)	(0.12)	(-0.96)	(-0.76)
Age	0.000	0.000	-0.001***	0.000	-0.106***	-0.024**	-0.099***	-0.018**
	(-0.69)	(-0.56)	(-2.24)	(0.06)	(-4.83)	(-2.05)	(-4.23)	(-1.98)
Observations	2818	3272	2803	3272	1553	2407	2660	2939
Groups	1912	1920	1901	1920	1179	1508	1833	1787
Wald $\chi^2(23)$	586.5***	1032.23***	384.17***	621.97***	121.67***	212.09***	327.47***	427.44***

Notes: (d) for discrete change of dummy variable from 0 to 1. * p<0.1, ** p<0.05, *** p<0.01
All estimated models include a constant term, sector dummies and time dummies. Omitted sector is Food, Drink and Tobacco. Omitted time dummy is 1994-1996. Time dummies (1997-1999; 2003-2005) are significant negative for all models and for Switzerland and for Ireland time dummies are with one exception (process innovation 1997-1999 is significant positive) insignificant.
T-statistics in brackets.

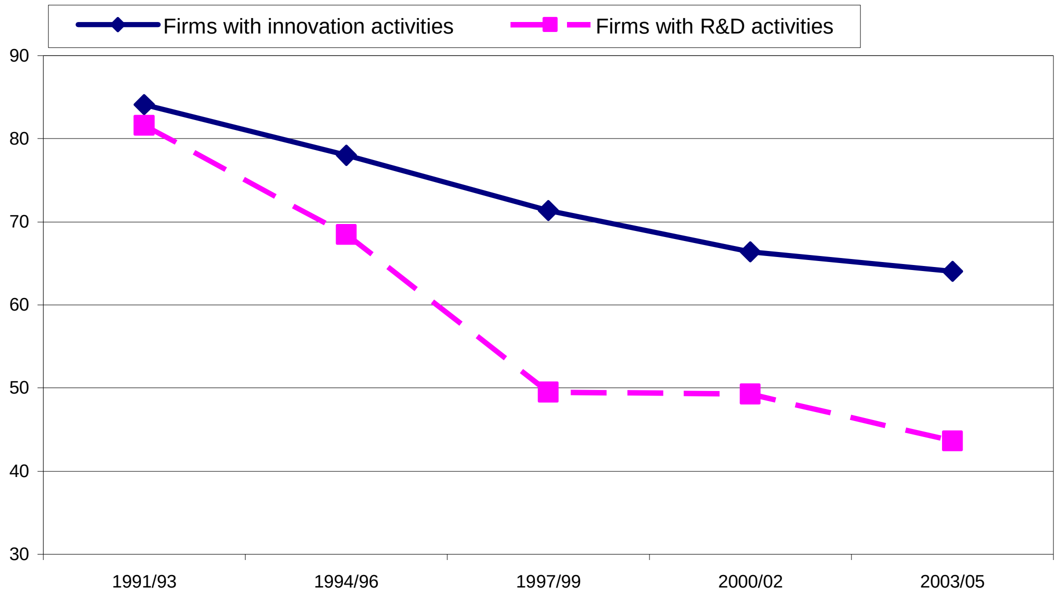
Table 5: Symbolic Summary of Estimation Results

	Ireland				Switzerland			
	Product Innovation	Process Innovation	Sales of new products (Innovators Only)	Sales of new products (All firms)	Product Innovation	Process Innovation	Sales of new products (Innovators Only)	Sales of new products (All firms)
A. By Variable Type								
Home market growth (3 year	(+)	(+)	(-)	(-)	(+)	(+)	(-)	(-)
Export market growth (3 year	(+)	(-)	(+)	(+)	+	+	(+)	+
Home market growth (3 year	(+)	(+)	-	-	(+)	(-)	(-)	(-)
Export market growth (3 year	(-)	(-)	(-)	(-)	+	(+)	(-)	(+)
Change in home market	(+)	(+)	(-)	(+)	(-)	(+)	(+)	(+)
Change in export market	(-)	(-)	(+)	(+)	+	(-)	+	+
Change in home market	-	(-)	+	(-)	(-)	(-)	(+)	(+)
Change in export market	-	(+)	-	-	(+)	(+)	(+)	(+)
Change in home market	(+)	(+)	(+)	(+)	(+)	(-)	(-)	(-)
Change in export market	(+)	(-)	(+)	(+)	-	(+)	(-)	(-)

Notes: ‘(+)’ denotes positive but insignificant effect; ‘+’ denotes positive and significant (at 10 per cent) effect; ‘-‘ denotes negative and significant effect; ‘(-)’ denotes negative but insignificant effect.

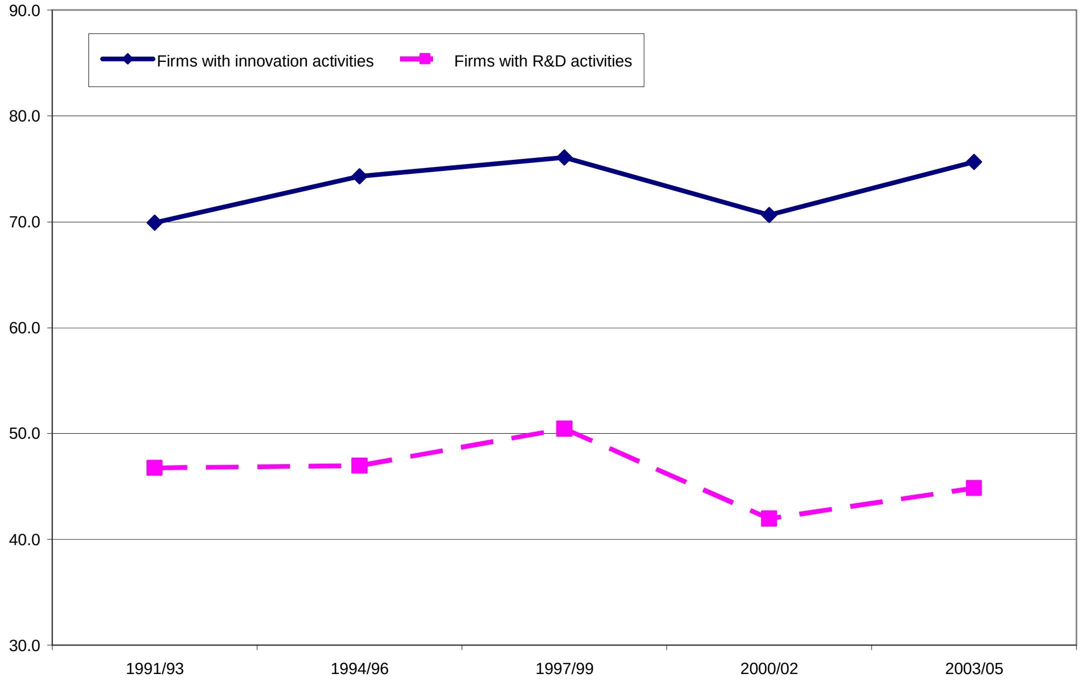
Figure 1: Time Series for Innovation Indicators

(a) Switzerland



Source: Swiss Innovation Panel

(b) Ireland



Notes: Firms with innovation activities reflects firms with either product or process innovation activities. Firms with R&D are those firms with R&D based in the firm.
Sources: Irish Innovation Panel

Annex: Home and Export Market Growth Data

Data for home and export market growth is taken primarily from the OECD STAN database. International market growth – as defined in the text is given in Table A1, part A. Some missing values for individual countries are dealt with as follows. For manufacturing industries in Greece we used the aggregated growth rates for the manufacturing sector. The missing values for the machinery and equipment (nec) industry and the electrical and optical equipment industry in Spain we used the data from basic metal and fabricated metal products. Germany shows some missing values for the industries in 2003; we used the overall manufacturing growth rates. The same procedure was applies for Sweden for the year 1990. For France we also had to use overall manufacturing growth rates for some industries in the years 1990 and 2003.

Table A1, parts B and C give the home market growth rates for Irish firms and Swiss firms respectively. For the Irish home market – covering the UK and Ireland - UK data are taken from the STAN database. Irish industry value added in nominal terms is taken from the STAN database and deflated using industrial producer price indices from CSO, Dublin. Prior to 1993 for Ireland producer prices are based on an aggregate manufacturing deflator as individual sectoral deflators are not available. For Switzerland, home market growth data is taken from Arvanitis et al. (2005). Due to missing values for wood, pulp/paper/printing, and other non-metallic mineral products, we assumed that value added have not changed between 2002 and 2003. Thus the respective growth rate is zero.

Table A1: Compounded growth rate data of international markets

	90/91	91/92	92/93	93/94	94/95	95/96	96/97	97/98	98/99	99/00	00/01	01/02	02/03
Part A: Export Market Growth													
TOTAL MANUFACTURING	-1.2	0.5	-0.5	6.8	4.5	1.6	5.4	4.6	3.6	5.5	-2.6	1.2	2.6
Food products, beverages and tobacco	0.5	0.0	4.5	4.9	6.7	-3.9	-0.9	-1.1	0.9	0.6	-0.3	0.6	2.0
Textiles, textile products, leather and footwear	-0.2	0.8	-1.7	1.4	-1.1	-3.8	-0.5	-2.2	-5.0	2.3	-6.9	-1.6	1.1
Wood and products of wood and cork	-4.2	-3.2	-2.6	8.1	4.9	0.4	1.8	2.8	2.5	4.4	-0.8	-0.6	0.9
Pulp, paper, paper products, printing and publishing	-1.1	3.8	7.8	5.0	-2.6	3.0	5.0	2.3	6.0	-1.0	-4.3	-0.2	3.4
Chemical, rubber, plastics and fuel products	0.0	2.5	3.6	6.7	0.8	3.2	6.3	2.4	2.6	2.7	-0.9	6.0	1.2
Other non-metallic mineral products	-4.9	3.7	1.1	8.1	1.9	-1.9	5.9	0.9	3.1	3.1	-1.0	-1.8	2.1
Basic metals and fabricated metal products	-2.6	0.7	2.1	8.2	4.0	-0.2	3.6	0.9	1.0	4.7	-4.0	-1.0	0.2
Machinery and equipment, n.e.c.	-5.6	-3.3	-2.3	6.4	8.5	-2.8	2.3	5.3	-5.3	5.0	-0.9	-2.1	0.6
Electrical and optical equipment	0.9	-3.8	-11.2	10.3	11.0	11.2	14.8	16.2	16.2	24.5	-3.8	4.3	10.8
Part B: UK and Ireland Home Market Growth													
Food products, beverages and tobacco	0.00	2.70	0.35	2.81	-0.65	2.32	2.05	0.80	0.75	-2.19	5.70	2.58	0.80
Textiles, textile products, leather and footwear	-9.99	0.18	-0.11	1.97	-3.33	-1.65	-1.57	-6.44	-7.65	-3.99	-9.90	-7.75	-1.61
Wood and products of wood and cork	-10.62	-0.70	1.71	7.92	-7.00	-1.06	-1.04	-0.70	-2.61	2.06	1.38	4.25	0.62
Pulp, paper, paper products, printing …	-4.36	1.99	3.07	2.73	2.36	-0.68	2.46	1.72	4.32	1.72	-1.18	1.79	-1.15
Chemical, rubber, plastics and fuel products	2.60	5.41	3.28	7.66	6.41	1.80	9.12	10.22	3.42	4.02	3.91	10.17	2.69
Other non-metallic mineral products	-9.17	-4.27	4.44	3.82	-1.99	-2.91	4.17	-0.33	0.48	2.15	0.82	-2.89	5.24
Basic metals and fabricated metal products	-9.12	-4.85	-0.99	2.53	3.20	0.44	2.58	-0.42	-1.55	2.31	-1.92	-4.12	-1.74
....Machinery and equipment, n.e.c.	-10.41	-3.77	-0.31	5.79	0.65	-1.65	-0.37	0.46	-6.12	-0.43	2.20	-5.25	2.36
....Electrical and optical equipment	-2.89	0.83	5.28	12.25	13.85	3.70	7.68	5.55	17.51	14.55	-3.42	-14.59	1.51
Transport equipment	-6.54	-1.63	-2.02	2.78	0.11	6.78	4.67	5.07	2.47	-3.04	-2.36	-3.35	5.49
Manufacturing nec	-11.76	-0.20	1.26	2.96	-1.32	2.38	2.68	2.10	1.08	0.29	-2.51	1.12	0.19
Part C: Switzerland Home Market Growth													
Food products, beverages and tobacco	6.4	-1.3	-2.8	2.1	4.3	-1.0	-2.3	-1.2	6.8	-9.1	-2.2	-0.4	28.8
Textiles, textile products, leather and footwear	-5.0	1.9	-7.4	-0.8	-6.0	-4.7	-6.7	-6.9	-15.1	-4.0	-3.4	-0.9	66.2
Wood and products of wood and cork	-1.6	-5.3	-6.4	5.0	0.2	-10.7	11.3	0.7	1.9	3.8	-3.5	-4.9	0.0
Pulp, paper, paper products, printing and publishing	5.6	5.3	-1.9	5.0	-0.7	0.8	5.4	8.6	6.8	-2.3	-0.9	0.2	0.0

Chemical, rubber, plastics and fuel products	2.8	2.5	4.5	4.2	3.3	7.7	12.0	-3.8	3.6	-2.3	7.3	16.7	2.6
Other non-metallic mineral products	-6.3	-9.5	-7.0	5.7	-9.7	-14.5	8.4	2.6	4.4	6.8	-5.0	-1.3	0.0
Basic metals and fabricated metal products	2.9	-1.8	-1.6	3.0	6.5	0.1	-2.1	-2.2	5.1	0.9	-0.1	-6.4	1.5
Machinery and equipment, n.e.c.	0.8	-0.7	0.5	-9.6	4.9	0.4	8.7	1.9	1.8	4.7	-9.2	-2.1	-1.5
Electrical and optical equipment	-3.0	-2.3	8.5	1.7	-1.8	-2.8	1.2	-1.9	7.4	11.1	1.0	-0.1	4.1

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