INNOVATION AND COMPETITIVENESS: TRENDS IN UNIT PRICES IN GLOBAL TRADE

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SUMMARY

This paper seeks to build on theory, to develop new methods for understanding the nature and basis of sectoral and national competitive advantage, and to do so with a temporal perspective.

The neo-Schumpeterian and evolutionary economics perspectives developed in SPRU over the past four decades are in large part built around the concepts of barriers to entry and core competences. Unless these are established, individual firms, networks of firms and countries will be unable to generate sustained income growth. There is no one measure which adequately reflects these barriers to entry, and much of the research has been concerned to generate proxies, each of which is in itself partial, but which together provide for a comprehensive picture.

In an earlier period of SPRU's history, preliminary work was done on the unit price of UK trade as an indicator of relative technological competence. However, this approach has largely been neglected since then, receiving only sporadic attention in the US literature, and at high levels of product aggregation. This paper utilises this approach to try and reflect the dynamic process of shifting competitive advantage in the global economy. It comprises an analysis of the unit prices of the EU's imports of manufactures, over the period 1988-2002, at a 2-, 4- and 6-digit level of product disaggregation.

Unfortunately, problems with the data have meant that we are unable to report our full results at this Conference. Nevertheless, we believe that the preliminary results are of interest and that they provide an important test-bed for the methodology which we are developing.

1. Indicators of innovation

Schumpeter's model of innovation is founded on the role which barriers of entry provide in sustaining innovation rents. If barriers to entry are substantial, competition is limited, and price-competition is held at bay (and of course if the innovation is attractive to users), incomes are high and sustainable. Without innovation or if barriers to entry are low, price competition drives producers out of production or, at least, in a Malthusian race to the bottom in living standards.

How might we know if innovation is indeed being sustained? If we work at the plant- or firm-level, this is a matter for empirical investigation, examining production processes (reflected for example in factor productivity, quality, lead time and other indicators), products (for example, the introduction of new or differentiated products) and function (whether firms are involved in production, design, marketing or other links in the value chain).[1] However, once the focus moves beyond the plant and the firm, the measurement of innovation becomes more difficult.

Typically, in assessing rates of innovation in clusters, sectors or countries, innovative activity is reflected by the use of one or both of two indicators – an *input indicator* (for example, R&D expenditure, percentage of skills of different sorts in the labour force) or an *output indicator* (notably patents). Indeed Keith Pavitt was particularly influential in the development of patent statistics as a reflection of innovative activity, although of course he was cognisant of all the difficulties which are involved (not least that the effectiveness of patents as a barrier to entry varies across sectors). Clearly, none of these input or output indicators of innovation are ideal; we live in a world of the second-best (or perhaps the fourth- or fifth-best!). So, at best, we need to apply a range of innovation indicators, in each case interpreting the results with care.

A further indicator of innovation – and indeed one in which Keith played a primary role in promoting during the early 1980s – is the unit price of output. To the best of our knowledge, this indicator was first used in 1977 in a study by the then national Economic Development Office focusing on UK competitiveness (Stout, et al, 1977). Keith and his SPRU colleagues picked this up in their 1980 volume entitled *Technical Innovation in British Economic Performance*, and in his Introduction Keith concluded that "[c]ompared with Germany and other major competitors, Britain is producing unsophisticated machinery and consumer durable goods, requiring relatively few innovative activities, and *having relatively low unit values* and value to weight ratios" (emphasis added) (Pavitt, 1980: 7). This measure was used by SPRU colleagues to assess the competitiveness of the UK defence sector (Kaldor, 1980), textile machinery (Rothwell, 1980), and electrical power tools (Walker and Gardiner, 1980). In recent years there has been renewed interest in the use of unit prices as an indicator of trade specialisation in US imports (Schott, 2002), quality and product innovation in EU imports (Aiginger, 2000) and in analysing the impact of trade on employment in Italy (Celi and Smith, 2003). None of these studies – both in the 1980s and those of a more recent nature - looked in any systematic way at trends in unit prices.

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[1] Traditionally innovation has been thought of in relation to process and product. However, recent work on global value chains has thrown the spotlight on two other categories of innovation – functional upgrading (repositioning within the chain) and moving between chains. See the various contributions in Gereffi and Kaplinsky (eds.) (2001).

The rationale for using unit prices as an indicator of competitiveness is that it harks back to Schumpeter's discussion of innovation – low barriers to entry allow competitors into the market which has the effect of driving prices (and hence incomes and margins) down. This indicator suffers of course from the assumption that cost-reducing technical change is neutral across sectors, since if costs fall more than prices, than a fall in unit prices may not necessarily be associated with a decline in margins and incomes. Whilst this is notably a false assumption with regard to the electronics sector, there is no empirical basis for arguing the validity of this assumption across other sectors. One way around this is to link the discussion of unit-prices to that of market shares – that is, a combination of rising unit prices and rising market shares may indicate a virtuous path of innovation which provides the product rents to sustain growing incomes; and vice versa for falling prices and falling shares. This is a technique used in an embryonic form by Roy Rothwell in his study of textile machinery (op cit, 1980), and developed further by Jeff Readman and myself in a study of the global furniture industry (Kaplinsky and Readman, 2000).

However, in this paper our primary objective will be to focus on unit prices alone as an indicator of innovation and competitiveness. We will work with the hypothesis that there is a direct relationship between unit price performance and innovative capabilities – rising unit prices are said to reflect growing product innovation and/or margins protected by barriers to entry, and conversely, falling unit prices reflect the inability to erect barriers to entry and/or to augment products. In doing so we are fully aware of the dangers of using unit-prices as a measure of innovation, but we do so in the belief that used in conjunction with other innovation indicators, it does offer the possibility of enhancing our understanding of the outcome of innovation processes. This is, therefore, one arrow in a an arsenal targeting a fuller reflection of innovation processes, and the paper should be read with this health-warning in mind. Our secondary objective is to produce detailed sectoral taxonomies which others can use in sectoral analysis. Here we have been guided by the need to disaggregate data to the maximum extent, since our complementary work shows that the greater the degree of disaggregation, the greater the utility of the data; [2] these detailed taxonomies can be drawn down from the website we will be developing (see www.ids.ac.uk/global).

The dataset we use is the EUROSTAT COMEXT database, which provides monthly data at the eight-digit product level of European imports and exports in value and volume from 1988. In addition, we also bring two other databases to bear to the analysis, both drawn form the UK. The first is the Office of National Statistics Annual Business Survey covering 78,500 enterprises and conducted most recently to cover the years 1997-2001;[3] the second is a recent DTI firm-based survey of innovation conducted between 1998 and 200 and covering 8,173 manufacturing firms (DTI, Community Innovation Survey).

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[2] Briefly, the problem with much macro-economic analysis (for example, in the relationship between trade and employment and on the terms of trade) is conducted at a two-/three-digit level of disaggregation. Our data shows that it is necessary to go to a much higher degree of disaggregation if price and industry trends are to become visible. Similar conclusions are reached by Celi and Smith (2003) in their analysis of the employment effect of Italian imports from low-wage economies.

[3] For a discussion of the ABI, see Jones 1990

In determining the trend in unit prices we use the augmented Dickey-Fuller unit root tests (the ADF test) and the Kalman Filter methodology. The ADF test is based on a regression of the form: $\Delta y_t = \alpha + \phi y_{t-1} + \sum_{i=1}^{T} \Theta \Delta y_{t-i} + \delta t + \varepsilon_t$, where ε_t is a random error term, and α and t are a constant and time trend, respectively. The ADF test corresponds to the value of the t-ratio of the coefficient ϕ. The null hypothesis of the ADF test is that y_t is a non-stationary series, which is rejected when ϕ is significantly negative. Twelve lags, a constant, and a time trend were included in the ADF regressions of the levels of the variables. For the level variables, the sample is 1988-2001 monthly data. The ADF test determines whether price trends are indeed to be found. We then use a subsidiary t-test to determine the significance of the slope of these lines - a minus result indicates a falling trend in prices (the larger the magnitude the greater the fall in prices) and conversely for rising prices; these are characterised by various levels of statistical significance.

Unfortunately, the limitations imposed by our data base – only 13 years' data – diminish the likelihood of our finding statistically significant price trends over the whole period, and particularly in determining whether there have been breaks in trend (for example after the 1997 East Asian crisis). There is no way of getting around these data limitations and to the best of our knowledge there is no other statistical method which has the rigour to allow us to conclude whether price trends do exist over a 13 year period.[4]

2. Sectoral differentiation and unit price trends

How can we put this price data to use in illuminating the innovation content in global production and trade? One way is to examine the unit-price behaviour of products emanating from different countries and groups of countries – the function of this is to highlight the inter-country distributional impact of innovation and the robustness of national systems of innovation. But resources are more meaningfully allocated at the sectoral level and it is at this level that our analysis is pitched. Our question is: *to what extent do changes in unit prices reflect sectoral dynamics?* From this it may be possible to make judgements about the degree of innovation involved in different sectors and the extent to which, by erecting barriers to entry, this determines the distribution of returns from production.

How are we to distinguish which sectoral taxonomies should be used in this analysis? A first step is to draw on the taxonomies which have been identified by other researchers interested in these issues.[5] Figure 1 lists the characteristics of 23 studies

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[4] An alternative method which does not make use of statistical testing is to use a three-year moving average price for the first period, and a three-year moving price for the end-period, and then to compute the change in these composite prices.. This is the method which we have adopted in our analysis of price trends in the global furniture industry (Kaplinsky and Readman, 2000)..

[5] Peneder (undated) provides a helpful review of many sector taxonomies, including many of those included in Table 1. We agree with his observation that "in contrast to the prominent attention it is given in various sciences such as biology, psychology and sociology, the proper construction and use of classification has remained highly under-researched in the realm of economics. We still find little or no methodological debate and a striking lack of awareness for the different approaches pursued (p. 6).

which we were able to identify and which generated sectoral taxonomies. The elements of these various studies which we highlight (and use to select categories for sectoral price analysis) are:

- the purpose for which the taxonomy is constructed
- whether they focus on product or process characteristics
- whether they use ordinal or cardinal measures (this has an important bearing on statistical and econometric analysis)
- whether they use single criteria (for example, R&D intensity) or multiple criteria (for example, R&D and advertising intensity)
- the type of data which is involved (for example, trade data, industrial statistics, innovation data)
- the level of detail and the number of sectors involved
- the sectoral categories identified
- the basis for allocating individual sectors into these categories
- the time period of this data
- the source of this data

Table 1: Summary of Sector Taxonomy Studies

Study	**Purpose**	**Indicator** **Process/ product** **Type**	**Single or multiple criteria** **Ordinal or cardinal measurement**	**Type of data**	**Level detail**	**# sector categ-ories/ subsec-tors**	**Categories**	**Basis of allocation**	**Time period**	**Source of data**
Mayer, Butkevicius and Kadri (2002)	Identify sectors of dynamism in trade	Products Dynamic products	Multiple Cardinal	Trade data	3-digit	20/20	Dynamic products	Authors' use of analytical criteria	1980-1988	COMTRADE – SITC (REV3@?)
Jaffee, Steven and Gordon (1993); World Bank (1994)	Identify high margin export sectors	Product Income elasticity of demand	Single Cardinal	Trade data	3-digit	7/17	Income elastic products	Authors' use of analytical criteria	Late 1980s-early 1990s	SITC REV2
Pavitt (1984)	Identify sectors of technological intensity and their links with firm-size	Process Nature of innovation	Multiple Ordinal	Database of innovations	11 2-digit, and 26 3- and 4-digit ISIC	4 (37)	Supplier-dominated; Production intensive (Scale-Intensive and Specialised Suppliers); science-based	Judgement of engineering experts	1945-1980	Significant UK Innovations – SPRU database
Leamer (1987)	Test the Heckscher-Ohlin theorem on the determinants of international trade.	Process Factor intensity	Multiple Cardinal	Trade data, skills, factor inputs	2-digit 3-digit	10 (61)	2 primary products (petroleum and raw materials), 4 crops (forest products, tropical/ Mediterranean agricultural products, animal products) and 4 manufactures (labour-intensive, capital-intensive, machinery, chemicals).	Author's judgement, secondary sources, use of analytical techniques	1948-1973	Trade data from UN sources; capital from national accounts, resources from various sources, skills from ILO Yearbook. Sectoral definitions of capital and labour intensity based on 1963 US data, and drawn from Hufbauer 1970.
UNIDO (1988)	Explore LDC capability in capital goods production	Process 103 indicators	Multiple Cardinal	Unspecified, but focus on manufacturing process	High	4 (1,100)	capital goods used: to produce other capital goods; used to produce intermediate goods; used to produce consumer goods; used across sectors.	Engineering experts using analytical criteria	Unspecified – but 10 year period of allocation	UNIDO database

Table 1: Summary of Sector Taxonomy Studies (cont.)

Study	**Purpose**	**Indicator** **Process/ product** **Type**	**Single or multiple criteria** **Ordinal or cardinal measurement**	**Type of data**	**Level detail**	**# sector categ-ories/ subsec-tors**	**Categories**	**Basis of allocation**	**Time period**	**Source of data**
Forstner and Ballance (1990)	Identify determinants of global trade	Process and product Factor endowments; product cycle goods	Multiple Cardinal	Capital, labour (skilled and unskilled); trade data	3-digit	4/25 3/147	High- and low- growth, labour- and capital-intensive Ricardian, H-O, product cycle	Authors' use of analytical criteria; secondary sources	1970 and 1985 1960s, 1970s and early 1980s	ISIC (national accounts), ISCO (ILO) with concordance to SITC US
Wood (1994) Wood, and Berge (1997); Wood and Mayer (2002) Wood and Mayer (1998)	Explain distribution of income and employment Explain differential LDC exports of manufactures Explain differential LDC exports of processed and unprocessed primary products	Process Factor intensity	Multiple Cardinal Multiple Cardinal Multiple Cardinal	Labour (skilled and unskilled); trade data Skills and trade data Trade data, educational data and resource data	3-digit 2- and occasional 3-digit 3-,4- and occasional 5-digit	3 (NA) 4 (11) 6 (188)	Primary, processed primary, narrow manufactures Unprocessed- and processed- primary, labour- and skill-intensive manufactures Processed/unprocessed minerals, metals, fuels; Processed/unprocessed dynamic agricultural products; Processed/ unprocessed static agricultural products	Authors' use of analytical criteria; secondary sources Judgement of author	US 1981, UNIDO early 1990s	ISIC with concordance to SITC COMTRADE Skill levels from Barro and Lee; SIC concordance to SITC; SITC COMTRADE Skill levels from Barro and Lee; SIC concordance to SITC; SITC COMTRADE ; dynamic income elastic trade data from unpublished sources
UNCTAD 1996	Explain source of upgrading in NIEs	Process Skill-, capital-technology and scale-intensity	Multiple Ordinal	Trade data	2- and occasional 3-digit	5 (38)	Non-fuel primary; labour- and resource-intensive; low-skill, low-capital and low-technology; medium- skill, medium-capital and medium technology; high- skill, high-capital and high technology;	Authors' use of analytical criteria; secondary sources	1965, 1975, 1985 and 1994	SITC COMTRADE

Table 1: Summary of Sector Taxonomy Studies (cont.)

Study	**Purpose**	**Indicator** **Process/ product** **Type**	**Single or multiple criteria** **Oo rdinal or cardinal measurement**	**Type of data**	**Level detail**	**# sector categ-ories/ subsec-tors**	**Categories**	**Basis of allocation**	**Time period**	**Source of data**
Marsili (2001)	Identify sectors of dynamic comparative advantage	Process Various, based on limitations of R&D (input) and patent (output) statistics	Single Cardinal	Various – incl patents, R&D, skills, citations	Mostly 2-digit SIC, some 4-digit	Various but key is 5 (18)	Learning-regimes: - science-based; fundamental process; complex systems; product engineering; continuous process.	Author's use of analytical criteria	Various – mostly 1990s	US National Science Federation SPRU database on patents and global firms PACE database on European innovation
Choudhri and Hakura (2000	Identify manufacturing sectors with rapid productivity growth	Process Total Factor Productivity	Single Cardinal	Input and output data	2-digit	4 (9)	Non-Manufacturing; High-, medium- and low-TFP growth	Use of analytical criteria	1970-1993	OECD International Sectoral Database.; UNIDO Industrial Statistics Database (Indstat3) UN SNA; Feenstra, Lipsey and Bowen (1997)
OECD (1992)	Identify high-technology sectors to promote industrial development	Process R&D intensity in production (direct and indirect)	Multiple Ordinal	R&D data	2- and occasional 3-digit	6 (36)	Non-fuel primary; labour-intensive manufactures; differentiated products requiring specialised suppliers; scale-intensive manufactures; science-based manufactures	Authors' use of analytical criteria	Late 1980s	US R&D data converted to SITC data
OECD (1994), updated 2003.	Identify high-technology sectors to promote industrial development	R&D intensity in production (direct and indirect)		R&D data	3- and occasional 4-digit	4 (27)	High-tech; medium-high etch; medium-low tech; low-tech	Authors' use of analytical criteria	Early 2000s	R&D data from 10 OECD countries converted to SITC data
Hatzichronoglou, (1997)	Identify high-technology sectors to promote industrial development	R&D and innovation intensity of products		R&D and production data	4-digit	9 (76)	Aerospace; computers-office; electronics-telecomms; pharmacy; scientific instruments; electrical machinery; chemistry; non-electrical machinery; armaments	Judgement of engineering experts	1988-1995	R&D data from 6 OECD countries, converted to SITC data

Table 1: Summary of Sector Taxonomy Studies (cont.)

Study	**Purpose**	**Indicator** **Process/ product** **Type**	**Single or multiple criteria** **Ordinal or cardinal measurement**	**Type of data**	**Level detail**	**# sector categ-ories/ subsec-tors**	**Categories**	**Basis of allocation**	**Time period**	**Source of data**
EUROSTAT (1995), cited in Pearson and Jagger (2003).	Identify sectors with technological intensity	Process Skills	NA Ordinal	NA	2-digit SIC	6 (78)	Primary production; High-tech Manufacturing; Medium-high-tech-manufacturing; low-tech-manufacturing; Knowledge-intensive services; Other services	NA	NA	NA
Lall (2000)	Identify export sectors which promote dynamic comparative advantage	Process Technology-intensive and capability building criteria	Multiple Ordinal	Not specified	3-digit SITC Rev2	5 (9) (230)	Primary products; Resource-based products; Low-tech products; Medium-tech products; High-tech products	Judgement of researcher	Late 1990s	UN COMTRADE
Acha et al (2002)	Identify complex production system products – "high cost, engineering-intensive products, systems, networks and constructs"	Process Unit costs, volumes, customisation, design variety, diversity of knowledge; number components/subsystems, interaction with users	Multiple Ordinal	Gross wages/ employee; purchases of IT services; purchases of telecoms; expenditure on branding and advertising	3-digit and 4-digit SIC92	1 (503 4-digit and 253 5-digit)	Complex production system products	Judgement of authors and use of analytical criteria	1997-1999	UK Annual Business Inquiry
Schmoch et al (2003)	Link between technology and economic performance	Process Innovation and production indicators	Single Ordinal	Patent statistics and SIC categories	2-digit SIC and 65 IPC patent classes	44 SIC 65 IPC	NA	Use of analytical criteria	1997	European Patent Office

Study	**Purpose**	**Indicator** **Process/ product** **Type**	**Single or multiple criteria** **Ordinal or cardinal measurement**	**Type of data**	**Level detail**	**# sector categ-ories/ subsec-tors**	**Categories**	**Basis of allocation**	**Time period**	**Source of data**
Neven (1994)	Identify factor content of trade in order to asses welfare impact of trade between EU and E. Europe.	Process Labour-intensity, capital-intensity, wage levels, skills	Multiple Cardinal	Wages, value added, investment, skills	NACE 3 and some 4 digit	5 (140)	(i) *High-tech, high human capital* (high wages/VA, high avg wage, high white collar) (ii) *High human capital, low invest* (low invest/VA, high avg wages, high wage/VA) (iii) *Lab intensive* (low avg wage, high wage/VA, low invest/VA) (iv) *Labour and capital intensive* (high invest/VA, low avg wage, low white collar, intermediate wage/VA) (v) *Human capital and invest intensive* (high avg wages, intermediate wages/VA, high invest/VA, high white collar)	Cluster analysis	1985-1990	SIC - Germany (triangulated with other 11 EU countries)
Davies and Lyons et al (1996)	(i) assemble a Europe-wide industrial database (ii) develop new taxonomies of industrial structure	Process Innovation	Multiple Ordinal (binary category)	Scale, R&D, advertising, ownership	3-digit NACE	100 (4)	Based on advertising and R&D	Use of analytical criteria (R&D and advertising intensity)	1987	Advertising – UK commercial agency; R&D from UK and Italy census of production
Aiginger (2000)	Identify sectors where quality rather than price is significant factor	Product Quality-elasticity	Single Ordinal	Trade – unit values and trade balance	3 digit SIC	3 (93)	High, medium and low "Revealed Quality Elasticity"	Original indicator using trade (price and volume) data	1988-1998	EUROSTAT
Sutton (1998)	To explore the link between R&D intensity and concentration	Process and product Innovation intensity and product homogeneity	Multiple Ordinal	R&D, advertising intensity, product homogeneity	4- and some 5-digit SIC	2 (34 and 119)*	R%D Intensive and Low R&D, low-advertising intensive	Use of analytical criteria	1977	US Census of Manufacturing and Fair Trade Commission
* Sutton's analysis uses 34 R&D intensive sectors (R&D/sales ratio of >4%) and bottom 50 sectors with low R&D and advertising intensity control group. However, the 50 low-innovation control group is never indentified so we use the 119 sector population of low-innovation intensive firms from which the 50-sector sample was constructed										

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Each of these elements is relevant for different uses. However, in choosing a set of classifications for price analysis in this innovation-focused paper,[6] we have taken account of the following issues:

- Loosely-speaking it is possible to distinguish three types of sectoral classifications – those focusing on product characteristics (income elasticity, for example), those on factor content (notably capital and labour intensity), and those targeted at innovation intensity; clearly it is the latter focus which will inform this unit-price analysis

- Many of the sectoral classifications which have been developed use very old data. The problem is not just with the age of the data, but also that where they involve structural relationships (for example, factor intensity) the nature of these input-output relationships might have changed significantly over time.

- We have striven to achieve as much details as possible and have therefore tried to go for maximum sectoral disaggregation, in most cases extending the initial 2- and 3-digit level classifications to the 6-digit level. The reason for this is that our complementary analysis has shown that the incidence of unit-price trends is directly related to the degree of disaggregation[7]

- We have confined the analysis to manufacturing sectors. Resource-based sectors have already received extensive price-analysis (notably by the terms of trade literature – see, for example, Singer, @) and our ultimate objective is to chart the growing competitiveness in the manufacturing sector and changes in the intra-manufacturing sector's terms of trade. Services are excluded because they are not covered in the EU COMEXT database.

Based on these criteria, we have tested unit-price trends for the following taxonomies:

- Lall's distinction between resource-based, low technology, medium technology, engineering and high technology sectors at a 3-digit level (although we have decomposed this to the 6 digit level). This categorisation has the distinction of being recent (late 1990s) and detailed; however, the downside is that the allocation of sectors reflects the judgement of the author, which is inevitably based on partial knowledge.

- Davies and Lyons' distinction between sectors with no quality focus, R&D intensive sectors and R&D+advertising intensive sectors at the 2-digit level (we have extended this to the 4-, and 6-digit level). This has the advantage of recognising both formal R&D inputs and firms' investment in market-based and product-oriented intangibles. It is also based on the application of criteria (the share of R&D and advertising in sales). The downside is that these sectors are defined on the basis of 1987 data.

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6 Unit price analysis of other sectoral groupings will be considered in future papers.

7 As Schott observes, "using industry-level data [is] problematic because much of the factor proportions action occurs at a level that is hidden from researchers" (Schott, 2002: 3).

- UNCTAD's categorisation of labour/resource intensive, low-skill/low-tech/low capital intensive, medium-skill/medium-tech/medium-capital intensive, and high-skill/high-tech/high-capital intensive sectors at the 3-digit level (we have extended this to the 6-digit level). The strengths of this nomenclature are that it is linked to an analysis of inter-country technological capabilities and is based on multiple criteria (more closely reflecting the complexity of factors affecting competitiveness). On the other hand, much of the data on which these judgements were made – based on an assessment of individual UN desk-officers rather than the application of criteria – is dated.

- Neven's distinction between high-tech/high human capital, high human capital/low invest, labour intensive, labour/capital intensive, and human capital/investment intensive sectors has two primary strengths. First it is based on multiple criteria, and is trade-focused. Secondly the sector categorisation is derived from cluster analysis which is an inductive approach which arguably better reflects sector characteristics than the didactic and often personal methodologies used by other authors. The downside is that it reflects (West) German economic structure (albeit triangulated with other industrially advanced countries) and is dated (1985-1990). We have extended his 4-digit level taxonomy to the 6-digit level.

- The OECD process categorisation is based on R&D inputs into production and distinguishes low technology, medium-low technology, medium-high technology and high-technology sectors. It uses data from the second half of the 1990s, but is only based on a single criterion (which we know from the literature provides only a partial perspective on innovation) and is defined at a high level of aggregation. We have extended their 2-digit level taxonomy to the 6-digit level.[8]

- The COPS classification of sectors provides a new and stimulating taxonomy of a specific category of sectors. We have extended their 3-digit classification to the 4- and 6-digit level.

- Marsili focuses explicitly on sectors which are characterised by barriers to entry to distinguish low technology, medium-low technology, medium-high technology and high-technology sectors. She provides a number of different classifications, but the one which we have used is that which focuses on knowledge-related and human resource-specific skills. We have extended her sector descriptions to the 2-, 4- and 6-digit level. One of the drawbacks of this classification is that it is based on US sectoral employment patterns in 1992.

- UNCTAD recently produced an analysis of the 20 most rapidly growing products in global trade (Mayer, Butkevicius and Kadri, 2003). We have excluded resource and primary products, and have expanded the 13 3-digit manufacturing classification to 237 6-digit sectors.

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[8] There is also an OECD product–oriented sector taxonomy based on a judgement of engineering experts (Hatzichronoglou, 1997); we had not completed the estimations for this taxonomy at the time of writing this paper.

In drawing on these technological trajectories we have had to undertake a great deal of work in translating the various nomenclatures used - SITC (various Revisions), ISIC (various revisions), NACE (various revisions) and ISCO – into the HS nomenclature utilised in the EU COMEXT database. In deepening the detail of the analysis we have also extended the 2- and 3-digit classifications to 4- and 6-digit levels. Inevitably there are also some cases where the translation between the process-oriented ISIC production taxonomies are not adequately captured by the product-oriented trade classifications (HS/SITC), although we have utilised the established protocols for this translation.

3. Results

The results which follow are preliminary and report our initial findings in relation to a the sectoral groupings discussed above. They are presented in part to illustrate the types of findings which we are expecting to generate, and hence are a reflection of methodology as well as of initial research findings.

So what emerges from the analysis of price trends of the various sectoral taxonomies? If we pursue the hypothesis that the higher the technological content the smaller the number of sectors with declining unit prices, then, broadly speaking:

1. The hypothesis is sustained with regard to the taxonomies provided by:

    - Lall –engineering and high-tech sectors show no evidence of declining prices, whereas resource- and low-tech sectors (and medium technology) do. The virtue of the Lall taxonomies is that we have been able to generate data for a relatively large number of sectors and with a considerable degree of disaggregation (6-digit sectors)

    - Davies and Lyons – there appears to be a clear correspondence between prices and innovation input at all three levels of aggregation; the 6-digit sample is relatively large.

    - UNCTAD – at a high level of aggregation, and with a large sample of sectors, there does appear to be a correspondence between innovation and price trends.

2. Neven's multi-factor taxonomy provides mixed support for the hypothesis. At a high level of disaggregation (6-digit level) and with a large sample, there are mixed results: high-tech/high human capital has a low incidence of price fall, but labour intensive and labour/capital intensive sectors have an even lower tendency.

3. There are no discernible sector differences arising form the use of the OECD process and Marsili taxonomies.

4. The COPS and dynamic products do not distinguish innovation content amongst sub-sectors, but are said to be innovation-intensive sectors. They thus provide no opportunity for intra-taxonomy comparison, but the percentage of sectors with slope which have negative slopes is relatively high compared to similar ratios in other taxonomies.

Table 2: Summary of preliminary findings

Categories	Number	Significant slopes		Negative slope	
		Number	%	Number	%
Lall: 6 digit					
Total	87	29	33	14	48
Resource-based	20	16	80	14	88
Low technology	26	14	54	9	64
Medium technology	13	9	69	9	100
Engineering	11	2	18	0	0
High technology	16	5	31	0	0
Davies and Lyons					
2-digit					
Total	10	3	30	3	100
No quality focus	9	2	22	2	100
R&D intensive	2	2	100	1	50
R&D+Advertising intensive	0	0	NA	0	NA
4-digit					
Total	31	21	68	11	52
No quality focus	25	16	64	13	81
R&D intensive	4	2	50	1	50
R&D+Advertising intensive	4	1	25	0	0
6-digit					
Total	36	16	44	13	81
No quality focus	10	8	80	8	100
R&D intensive	22	10	45	8	80
R&D+Advertising intensive	28	10	36	5	50
UNCTAD : 6-digit					
Total	86	53	62	41	77
Labour/resource intensive	22	17	77	15	88
Low-skill/low-tech/low capital intensive	8	4	50	4	100
Medium-skill/medium-tech/medium-capital intensive	11	0	NA	0	NA
High-skill/high-tech/high-capital intensive	31	15	48	11	73
Neven: 6 digit					
Total	72	50	69	34	68
High-tech, high human capital	23	7	30	4	57
High human capital, low invest	27	10	37	8	80
Labour intensive	24	14	58	7	50
Labour and capital intensive	32	18	56	13	72
Human capital and invest intensive	0	0	NA	0	NA
OECD (Process): 6-digit					
Total	84	51	61	42	82
Low	26	5	19	4	80
Medium low	13	4	31	4	100
Medium high	24	4	17	4	100
High	20	8	40	7	88
COPS					
4-digit	33	16	48	6	38
6-digit	13	11	85	9	82
Marsili:					
2-digit					
Total	22	4	18	4	100
Low	16	3	19	3	100
Medium low	4	1	25	1	100
Medium high	0	0	NA	0	NA
High	2	0	0	0	0
4-digit					
Total	64	42	66	40	95
Low	50	28	56	26	93
Medium low	17	12	71	12	100
Medium high	3	3	10	3	100
High	4	4	10	4	100
6-digit					
Total	40	29	73	25	86
Low	19	15	79	13	87
Medium low			NA		NA
Medium high	16	11	69	9	82
High	5	3	60	3	100
Dynamic Products (UNCTAD)	237	138	58	110	80

There is an alternative way of interpreting these results which we consider illegitimate. This is to assume that innovation intensity is indeed reflected in price performance (which is the subject of our hypothesis discussed above). In this case, Table 2 can be interpreted as a way of assessing which of the taxonomies best reflects innovation intensity - Lall, Davies and Lyons and UNCTAD taxonomies are most clearly validated, Nevens receives indeterminate validation and the OECD process and Marsili taxonomies are considered in an adverse light.

The results reported in Table 2 reflect the application of our data-base and methodology to a series of taxonomies drawn from the literature. We have two primary concerns about these received taxonomies. First, in most cases they are based on dated economic structures even though we have deliberately excluded some of those such as the classic and frequently-cited study by Leamer which relies on pre-1973 data on economic structures (and which to our surprise – shock? - is still used in contemporary classifications). And, second, they are all based on aggregative 2-digit and 3-digit data (which we have "opened out to the 6-digit level). This is particularly problematic since our complementary analysis shows that high levels of aggregation mask important sectoral characteristics (and see Celi and Smith 2003 for corroboration of these findings).

For this reason our future analysis will be based on an integration of two large, detailed and contemporary UK databases – the ONS annual business survey covering 78,500 enterprises for the period 1997-20010, and the DTI Oslo-manual survey of 8,173 enterprises for the period 1998-2000. Both of these databases are detailed at the 5-digit ISIC level. An additional virtue of these databases is that we should be able to further analyse unit-price trends by different types of firms. These databases allow us to distinguish sectors on the basis of the following categories:

Single factor and innovation intensity

- Capital intensity
- Labour intensity
- ICT intensity
- Advertising intensity
- ICT intensity

Multiple factor intensity (based on Neven's taxonomy)

- High-tech, high human capital
- High human capital, low invest
- Labour intensive (a composite index)
- Labour and capital intensive
- Human capital and invest intensive

An extension of the Sutton Criteria (drawn on by Davies and Lyons)

- Intramural R&D and extramural R&D (>1% sales)
- Marketing intensity (>1% sales)
- R&D intensity and marketing expenditure (>1% sales)
- Patent intensity (Ratio of patents to sales, and to number of workers).

4. Conclusions

The analysis reported in the sections above has, we believe, two distinctive features. First, rather than replicating the static price analysis found in much of the literature (Celi and Smith, 2003; Schott, 2002; Aiginger, 2000), we have focused on changes in prices. And, secondly, we have given primacy to sectoral disaggregation. Our complementary analysis of sectoral price trends (using a larger number of sectors than those involved in this paper on innovation-intensive sectors) shows that the higher the degree of disaggregation, the greater the incidence of price trends. This is what we would expect, and comes as no surprise (although it is striking how much of price analysis – for example on terms of trade and the employment impact of trade – is undertaken at levels of aggregation which conflate inter- and intra-industry trade).

However, each of these distinctive features has its own weaknesses. With regard to price-trends, the short duration of the data-base (1988-2002, albeit with monthly data) makes it difficult for any acceptable statistical technique to verify trends, even though at a microeconomic level we have much evidence of falling prices, particularly after the 1997 Asian crisis. And, secondly, the patchiness of the EU COMEXT data base reduces the number of sectors for which we can use acceptable statistical techniques to determine price trends.

Nevertheless, as reported in Table 2, we believe that the data does show some link between unit price trends and innovation – that is, that the greater the innovation content, the smaller the tendency for prices to fall. The major unfinished research with the taxonomies available in the literature is to increase the population of sectors in each of our categories and to deepen the analysis to take account of the degree of slope (positive and negative). In addition, we will exclude electronic sectors from the calculations since there is prima facie evidence in these innovation-intensive sectors that price falls do not only reflect intense competition, but technological progress.[9] In this case, it will be the degree of relative price fall which will need to be correlated with innovation intensity. However, we will also be constructing our own taxonomies, based upon the integration of two very detailed and up-to-date UK databases.

To complete the circle we return to the contribution made by Keith Pavitt and SPRU colleagues to the understanding of sectoral patterns of innovation and the consequences of this. We have addressed a suggestion made by Keith in 1980, and

[9] Although our detailed analysis of the telecoms sector shows that only 53% of these 6-digit sectors showed a decline in prices.

explored briefly by his colleagues in their 1980 volume on the role which innovation played in UK economic performance. Our broader intent is to use this data to explore not just global patterns of sectoral innovation, but also (in the neo-Schumpeterian tradition of SPRU and the IDS) the distributional implications of this global system of innovation. In doing so we hope that we will have developed one of the methodologies which can be used, holistically and in collaboration with other indictors such as R&D inputs and patent outputs, to reflect the technological content of different sectors.

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