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Innovation and Industry Development: A Policy-relevant Analytical Framework[1]

JANE MARCEAU

ABSTRACT *Public attention is increasingly focusing on the role played by product and process innovation in the economic development of modern nations. There have been many studies of national innovation systems, regional and local innovation systems, and technological and sectoral systems. There have been innovation surveys and efforts concentrating on measuring the effectiveness of different innovation systems. The 'system' debate has distracted attention from the search for policy mechanisms to encourage development in a more specific manner. The approach developed in this paper enables the analyst to both hone in on the general dynamics of industrial change as they relate to particular situations and to highlight the points that may need public or private action if a country, region or locality is to maximise the efficiency of the players in its national, regional or local innovation systems, or indeed its sectoral ones.*

Keywords: innovation, national innovation systems, industry, policy.

Introduction

Public attention is increasingly focusing on the role played by product and process innovation in the economic development of modern nations. The OECD has encouraged numerous studies on national innovation systems in member countries, studies which have been paralleled elsewhere by analysts working both in academic and public policy organisation realms.[2] Recent years have also seen the publication of studies of national innovation systems,[3] regional and local innovation systems[4] and, from a different perspective, technological[5] and sectoral systems.[6] In addition, many countries and groupings of countries have conducted innovation surveys guided by Frascati, Oslo and Canberra Manuals or have focused on specific aspects of innovation, such as technology management,[7] collaboration between firms (see the various country reports deriving from the DISKO project) or the functioning of clusters.[8] More recently, OECD member countries have also been concentrating on measuring the effectiveness of different innovation systems.[9]

This 'system' focus has taken the debate forward very rapidly. It seems, however, to have somewhat distracted attention from the search for policy mechanisms to encourage industry development in a more specific manner.

Yet, if research into innovation is to translate into faster and more sustained economic growth then the findings of research into the dynamics of innovation and the functioning of innovation systems have to be translated into suggestions for policy. This translation is not an easy process. The difficulty arises because there is very seldom a clear relationship between the focus of an innovation analyst and the concerns which a

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policy-maker must address and of which he or she must take account if policy prescriptions are to be successful bases for social development and job creation. A policy-maker must think *politically* as well as in terms of economics and the links between research and innovation. A policy-maker must think about implementation of change and about 'who' in social and economic terms he or she is going to be able to enlist to ensure that change occurs as desired.

This means first that research must be conducted with policy action in mind from the beginning; considerations of policy action can very seldom be successfully 'added on' afterwards because the paradigm of understanding is different. Both policy and politics need to be built into the conceptual frameworks used and must include notions about implementation. It is, for example, no use in the present political climate in Australia proposing radical policy interventions for industry development because they are completely politically unacceptable. Instead, the analyst who cares about industry growth must frame an approach which will go as far as possible towards the desired result by means which can be sold to decision-makers in government and business. This may seem an elementary point but it is one which is too often forgotten by analysts who wish to go far and fast but cannot work at all unless key players are on-side.

Second, the need for policy considerations to be built in early to research on industry innovation means that a common framework for the analysis of different areas of economic activity must be created. Policy-makers cannot deal with studies which use different frameworks for every industry since public policies can seldom be geared to single instances. Thus, for example, if Region A's innovation system is described using an approach different from that used to analyse the system of Region B, it is very difficult for a policy-maker to sort out the elements which can be addressed by common policies.

Policies are essentially a set of theories about social action—if I, the policy-maker, put x into place y will be the result. This means that policies must be relatively simple—x clearly leads to y—because it is too difficult to take account of all variables and the outcomes will be muddied and hard to delineate. Relationships must, however, be robust (i.e. theoretically strong) or the policies will not work. In other words, the theories which underpin the policy action must be analytically sufficiently sophisticated to ensure that x does indeed lead to y in all specified circumstances and not to some undesired result or to only partial solutions.

As indicated above, the perspective used must be capable of being used across the entire relevant policy board. If x leads to y in Industry A it is best for policy-makers if it is also likely to lead to y in Industries B to Z. The research must therefore be at the same time *general* enough to be used in a parliamentary/bureaucratic/ministerial policy framework and *specific* enough to be effective in any one set of industries A to Z. Quite a challenge!

For the analyst, the challenge is to use the theoretical and conceptual literature to build a picture which is at the same time capable of producing appropriate policy outcomes, is both comprehensive and targeted, is simple enough to work, and be seen to work, as predicted and yet sophisticated and flexible enough to take account of and be effective within the complex realities of the socio-economic and organisational ground.

The approach suggested in this paper relies heavily on some of the main findings of the international innovation literature. These concern in particular the circulation of information and knowledge as a critical ingredient in successful innovation. It also draws on the well-documented importance of close user–producer relationships in successful product development.[10] The approach also draws on the literature demonstrating the importance of research in the innovation process in many industries but also takes account of the fact that the location of research may vary and that the importance of public and private research organisations may play different roles at different times and in different industrial systems[11] and that different players in the product system may make differential use of research and research results.

The studies undertaken by our group, AEGIS, recognise that the different kinds of knowledge—know what, know how, know who, know why—are all important and include all of these in the analyses summarised here. The approach also owes much to the notion of 'systems of innovation' of different kinds since it specifically focuses policy attention on *patterns* of knowledge flows and linkages (or lack of them) and relations between institutional and other players.

The approach recognises the importance to innovative activity of both the organisations (public and private) involved in the development of a product system and the institutional arrangements in the sense of the 'rules of the game'. This is why one segment of the 'maps' shown below relates to the regulatory regime put in place through public policy action and the activities of private rule-makers such as industrial associations and public–private regulators such as standards bodies. The approach therefore also takes account of work suggesting the (potential) importance of different kinds of regulation in bringing about desired results.[12]

The approach described and illustrated in this paper thus represents a kind of template which can be used to analyse any product system (manufacturing or services) and illustrates the now increasingly common linkages between manufacturing and services as industries move up the knowledge-intensity ladder. It is designed to be used to link analysis and policy action by highlighting areas of strength and weakness in a comprehensive but also industry-specific way. Because it takes account of the broader innovation literature, for instance on the importance of research, it can be made specific enough for policy developers to be at least somewhat confident that x action will lead to y results, or at least lead in the direction conducive to getting y results if applied with more resources and/or over a longer period.

Further, the approach allows both the determination of targets for policy action since it highlights areas of need in the innovation arena studied, and the monitoring of results since activity in the arena can be re-studied in the same manner.

The framework also permits policy-makers to situate where joint public–private action is needed or where either private sector or public sector should take prime responsibility for change. The 'Action Agendas' currently under development in selected arenas by groups of private stakeholders and industry policy-makers in Australia provide one example of this joint focusing on critical areas of linkage between users, producers, research organisations and rule-makers (policy actors).

The present paper is designed simply to illustrate schematically the use of the approach in several different product systems. The strength or weakness of the knowledge/innovation flows is illustrated through the use of thicker or thinner, single or duo-directional arrows. The diagrams below represent the results of studies of different product systems which were conducted using similar methodology to highlight points for policy action. The different boxes represent the key players in the product system or 'complex' of activities studied and the areas which need to be strengthened if innovative activity is to be increased and industry development improved.

The approach taken here owes much to the re-thinkings which have come from the different lenses provided by the notion of the Triple Helix. That attention-catching notion has encouraged us to think more effectively about what constitutes each of the terms—government, industry, university. This paper is particularly concerned with these three sets of instructions and organisations as they relate to the shaping of the economic

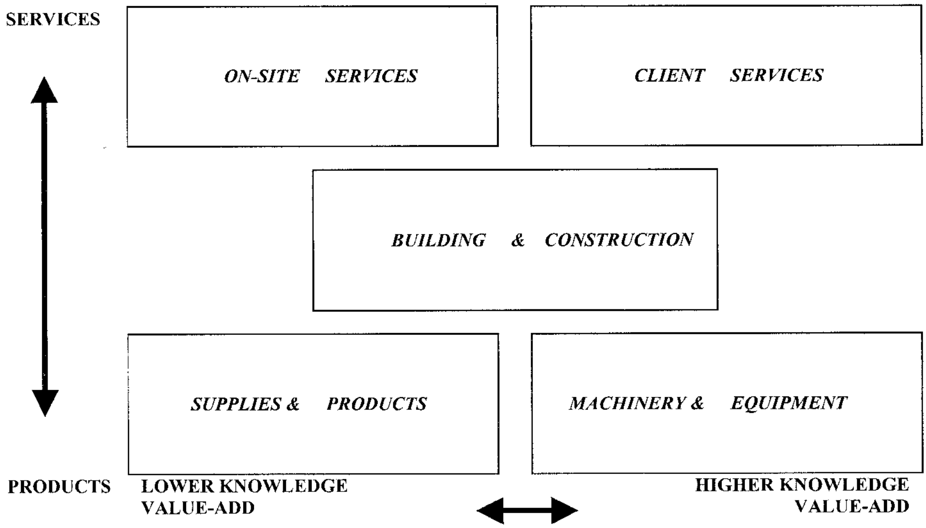

Figure 1. The component product field of the building and construction product system.

structure of Australia but the approach is intended to be generic and to adapt the Triple Helix by dividing the 'industry' player into the two camps of 'users' and 'producers' within a product system. This division is needed because neither the 'users' nor the 'producers' driving the system may be effectively located within what is normally defined as an 'industry' and because it enables the analyst to focus on what innovation theorists tell us is a critical set of interactions and relationships

The first two diagrams illustrate the way in which, prior to the study of knowledge/ innovation flows, each product system studied was itself redefined in an innovative manner. It is important to note here the reasons why we use the term 'product systems' rather than the more usual 'industry' or 'sector'.

We do so because we want to include more activities in the supply chain than is normally the case because it is clear that some of the major players in innovation and driving the industry forward were outside the industry as normally defined. The latter point was demonstrated some years ago by Senker[13] in her pioneering study of British supermarkets and their role in influencing technological change in the food product system in Britain and shown by Greig[14] writing about the Australian clothing industry in 1990. The notion of product system owes much to the ideas of David Gann at SPRU[15] and of Houghton, Pucar and Knox,[16] further developed by Houghton when he worked at AEGIS[17] in 1998–1999.

It should be understood that each diagram represents only a kind of summary snapshot of the knowledge/innovation flows concerned. In each case, a more detailed and refined picture can be obtained by taking each segment in a product system (the boxes illustrated in Figures 1 and 2) and subjecting each to the same analysis. In this way, a picture of the series of points of action needed in the whole product system can be put together and action taken at each point, with the results open to monitoring in terms of the impact on each segment and their interrelationships.

In sum, there seem so far to have been few attempts to link specific aspects of the public and private features of particular industrial systems of innovation to the functioning of specific industry segments in a way which provides a common approach to highlighting issues on which governments, or governments working with industry, can focus policy activities. The approach outlined in the present paper has been designed to overcome some of these limitations, apparent in much current work on innovation systems. In a paper of this length the approach suggested can only be outlined and the examples of its application given below are schematic in the extreme. The examples seek only to illustrate the approach, not to provide detailed analyses of any of the product systems so cavalierly presented. I am fully aware that I am touching only on a few aspects of what are in each case complex realities. The approach is only a framework; using it to good effect requires detailed empirical investigations of each product system.

Examples of the Approach: Knowledge/Innovation Flows in Five Product Systems

The Figures 1 and 2 illustrate the first step to 'de-constructing' what it is too simple to think of as an industry, in this case building and construction so as to reconstruct it in a more useful manner when considering innovation. This first breakdown (Figure 1) indicates at the same time where one should look to find the sources of innovation serving the system, since it includes potential sources of innovation such as those found in equipment manufacture and materials development and supply, and the points of strength and weakness which can be brought out by detailed empirical studies.

The dynamics of this, as of other industrial product systems are also such that there is a general movement of points of influence on the system towards greater knowledge intensity and towards greater interaction between the central producers of the goods or constructions and those who provide the client services and have the closest links with clients. As one moves from left to right of the diagram, there is also an increase in the knowledge-intensity relevant to this product system. In other words, as one moves from bottom left to top right there is an increase in knowledge-intensity and linkage to clients which in turn is linked to the move from production of products (bottom left) to production of services (top right). Our studies suggest that many industries are moving to incorporate more services within the portfolio of products which they offer and as they do so they come to rely more on links to clients because services are especially likely to be tailored to particular client needs.

Figure 2 shows in more detail how the broader component fields of the product system can be brought into the analysis of innovation. Thus, in Australia, one can re-place (re-position) the ANZSIC codes delineating economic activities so as to show the rightful place in a given product system of some activities which normally do not appear. This first 're-assemblage' of the object of study is a necessary precondition for viewing the groupings of activities and the strengths and weaknesses of their interrelationships which are illustrated in the main body of this article.

Industry 1. Toolmaking

This industry is one which is characterised in Australia by clusters of small, independently owned toolmaking rooms. They are mostly dependent for business on large clients, owned overseas, who operate the manufacturing firms that use tooling. In Australia, these are essentially automotive companies clustered geographically in Melbourne and Adelaide. These traditional clients have been joined in some cases by large telecommunications companies that make telephone handsets or mobile phones. They are also complemented by a range of small manufacturing clients.

The Australian Federal Government put in place between 1994 and 1996 a policy called the Business Network Program (BNP) which was designed to assist small compa-

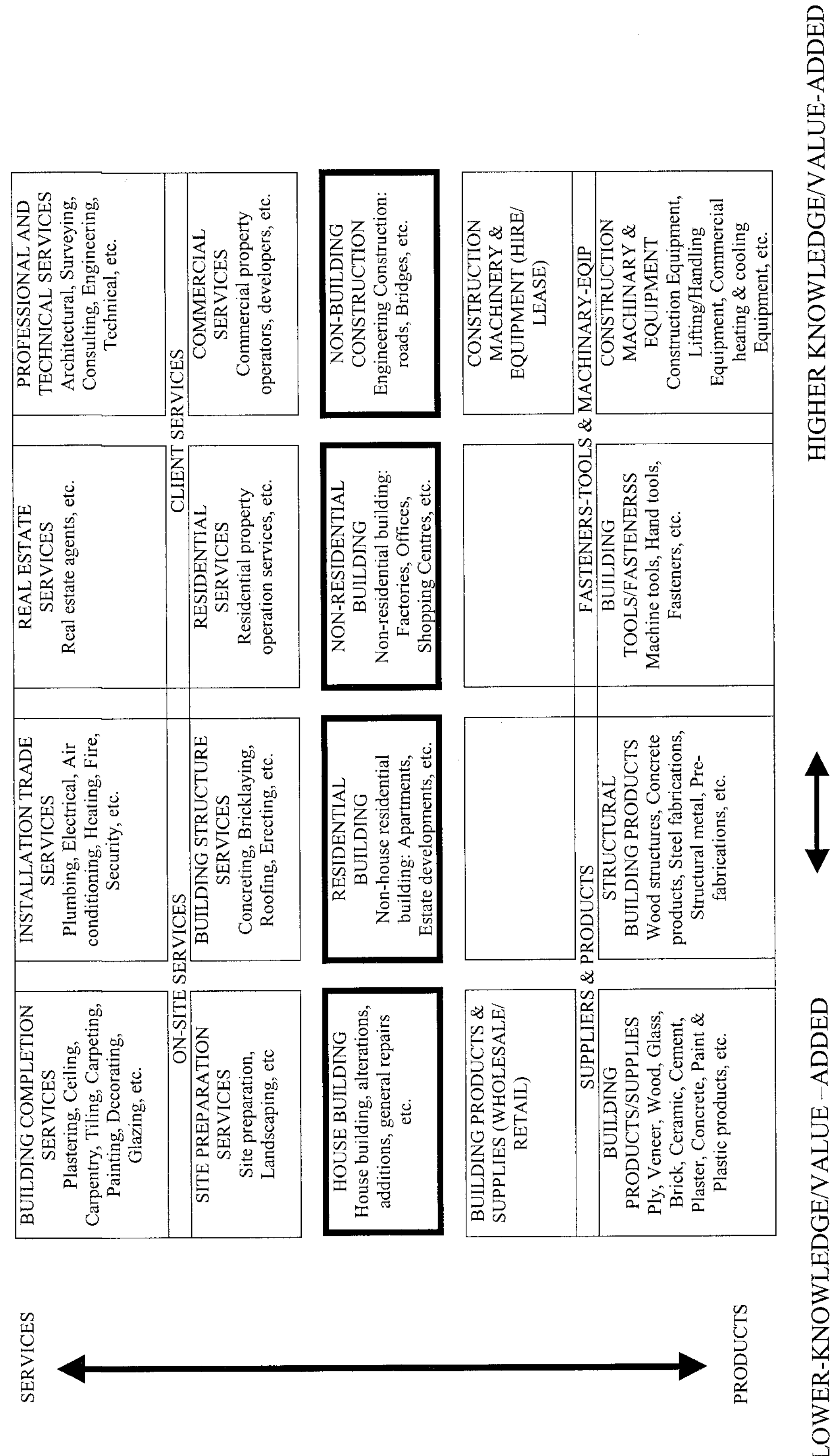

Figure 2. Details of the component product fields of the building and construction product system.

nies in a variety of industries to create networks to obtain market scale. A very few such networks were created among toolmakers. Of these, only a small handful were successful in the sense that they were set up and survived at least until the end of the BNP.

The BNP attempted to encourage firms to create horizontal networks to develop the scale needed to deal more effectively with their dominant clients and to find new markets to counterbalance the cyclical nature of the dominant form of demand for toolmaking.

The toolmaker networks proved both hard to create under the conditions of the BNP and to maintain once created. The basic reason for the problems was the failure of the policy-makers to distinguish the dynamics of different industries and indeed to attempt to impose a 'one size fits all' set of rules of action. The rules could not permit the effective creation of networks because they assumed that the industry was operating in only one way.

There were two critical factors missing from the policy understandings underlying network creation in toolmaking. The first was understanding that most of the toolmakers were using techniques which were at the end of their trajectory. In toolmaking the essential element missing in enterprises in addition to reasonable scale was sufficient investment in the technologies of the future. Some of these technologies are physical and some organisational. Some are skills-related and derive from the poor linkages with the public education and training system and with the research capacity of the nation in the realm of new materials. Provision of policies to address marketing scale alone could do nothing to address the other issues which a broader analysis of the dynamics of client industries and other areas of public sector R&D could have made visible.

A 'Triple Helix' or 'complexes' analysis of the position of toolmakers would have revealed the situation illustrated in Figure 3. The dynamics of the industry mean that most small toolmakers, who have no links to leading-edge R&D, poor links to training and retraining organisations and few user–producer links with clients on an egalitarian basis, will not survive beyond the next few years. The shift in the broad regulatory framework took no account of their position of vulnerability as small firms using old technologies. The users adjusted to the new deregulatory, open-market situation by switching on the one hand almost entirely to cost reduction at home and on the other to overseas design and fabrication of the tooling needed. The R&D institutions that were working on the next generations of materials for use in making tools did not involve any small potential clients in the processors nor share any relevant developmental information with them. Moreover, the small toolmakers had received training from public institutions which themselves had little sense of the dynamics of their client industries and thus little idea of the shift upwards on the knowledge-intensity curve so as to incorporate client services, such as design, into their own operations which the toolmakers needed to make. In turn, these training institutions had little connection with the R&D institutions which were creating new materials and the associated production technologies which could ultimately be expected to render the training offered outdated.

In addition, any effective public policies to assist the toolmaking sector need to take account of the dynamics of the diverse product systems served by the toolmakers. Doing this adequately involves bringing together knowledge generated by and within the large user firms, R&D institutions and training organisations as well as better understanding of the implications of regulatory shifts. In order to deal with these different elements, a *package* of policy mechanisms is essential, rather than reliance on just one assistance approach.

Without such a package, the dynamics of the industry mean that only the large and specialised toolmakers will survive since these are the only ones able not only to afford

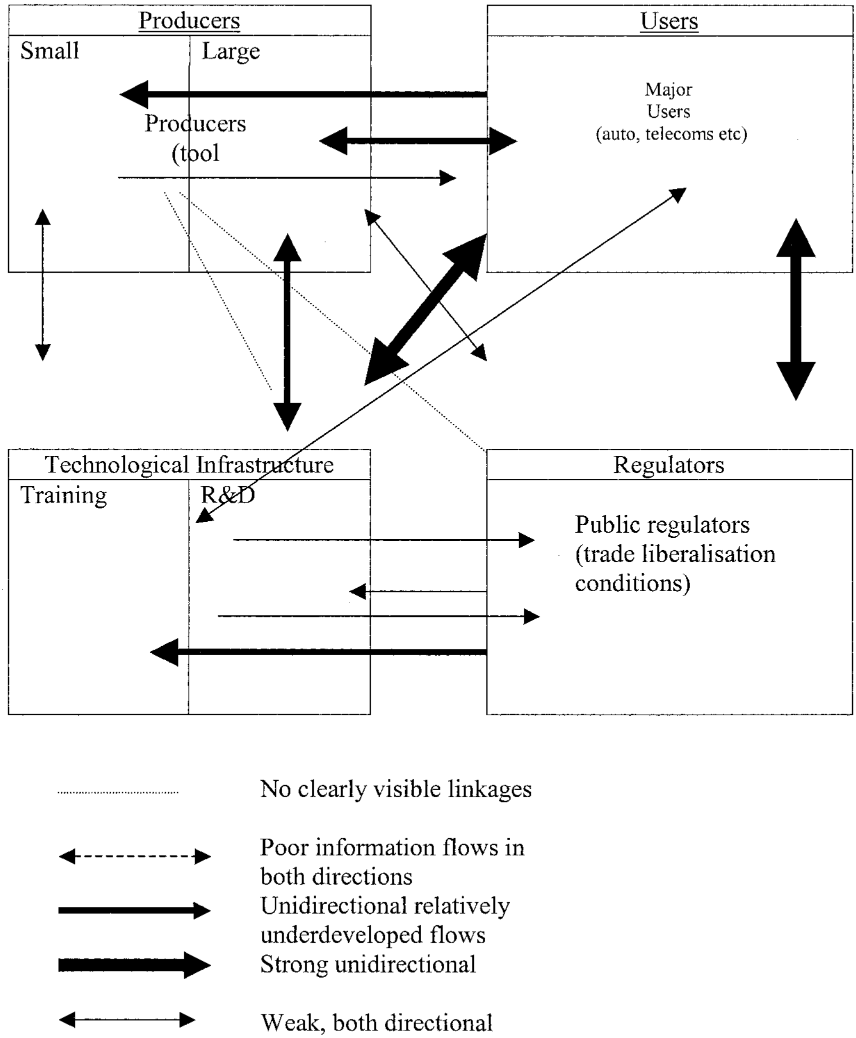

Figure 3. Knowledge/innovation flows in the toolmaking product system.

the new equipment and organisational changes needed but also to have the relevant information about what was needed. This broader analysis would have shown the need for investments in all kinds of collective infrastructure and could have encouraged the use of the successful toolrooms, those which are operating as part of the activities of major component suppliers to the dominant tooling clients, as training institutions since they would have the markets to sustain the other investments needed. For such firms, collective training could have become a business activity generating income to be used to maintain their broader tooling activities at the leading edge of world practice and to diffuse new technologies.

Industry 2. Textiles, Clothing, Footwear and Leather (TCF&L)

This example illustrates the need to ensure that policies developed take account of the dynamics of the interaction of different players in a sector or group of industries with others. Governments in Australia tend to think that textiles, clothing, footwear and leather industries constitute a closely interconnected product system. This view ignores the fact that the drivers of the different segments currently operate quite distinctly but also can be drawn together, developing better linkages, by the operations of new technologies, more specifically information technology (IT). In this case, consideration of the relationships between the different sets of players could indicate much more clearly the way forward for the product system than could other analyses.

In the TCF&L product system the key players within Australia, as elsewhere, are not industrial at all but are to be found in the service arena.[18] Clients here, of course, are the major retailers. In effect, the retailers operate like automotive vehicle-makers or lead firms in the building and construction product system. By selecting principal/preferred suppliers among firms producing clothing the retailers are able to impose higher standards of quality assurance, new management methods, notably 'Just-in-Time' (JIT), as well as particular price and delivery/stock-holding regimes. This means that the users' patterns of information collection and sharing are critical for the development of the industry. In turn, however, some elements of the clothing segment can be considered 'assembly' industries since they bring together materials and components, trimmings and design. If clothing producers are closely linked to their end markets and their suppliers they can push the same demand further down the line.

In the case of interaction between retailers, clothing manufacturers and the textile industry, however, relations are more complex. This is in part because the textile firms are larger, more technologically sophisticated and/or more internationally attuned than are their local clothing clients. In this case, the dynamics of the industry see textile firms decreasingly linked to local clothes producers because their major clients are overseas. In turn, the clothing firms are tending both to import more materials, so side-stepping Australian textile firms, and to fight back against retailer power by entering the retail market themselves, either as store holders in their own names or as operators of specialist sub-stores. In the case of TCF&L, the dynamics introduced by regulatory change operate in conjunction with a highly concentrated retail sector (one retail firm has about 70% of the discount clothing market), and combine to de-link the different elements of the supply chain. In this situation, our analysis is illustrated in Figure 4(a) and (b)

One policy element that the government should focus on in such circumstances is the one which enables companies to link better together. Information technology is critical to innovation in TCF&L, as indeed it is in all the product systems discussed in this paper. In addition, policies for linking R&D and training institutions to the different segments of the product system in a more coherent manner are similarly important.

Industry 3. The Furnishings Product System

The furnishings product system overlaps with that of TCF&L because it uses many of the same materials and components. It is equally also best understood as a field dominated largely by non-industrial players and as an 'assembly' industry, albeit, like clothing, one very simple in comparison with the automotive sector or with building and construction.

The furnishings product system in fact rapidly shows itself to be not one but three systems, two of which have the greatest importance for driving the industry forward. One is the domestic furnishings segment, or rather the significant part of it which is driven by large retailers operating JIT and preferred supplier systems consisting of several tiers. The retailers co-ordinate the work of the first tier suppliers while these in turn co-ordinate the production activities of the next tier where appropriate.

The second major segment in the system is that of office furnishings. Again, this

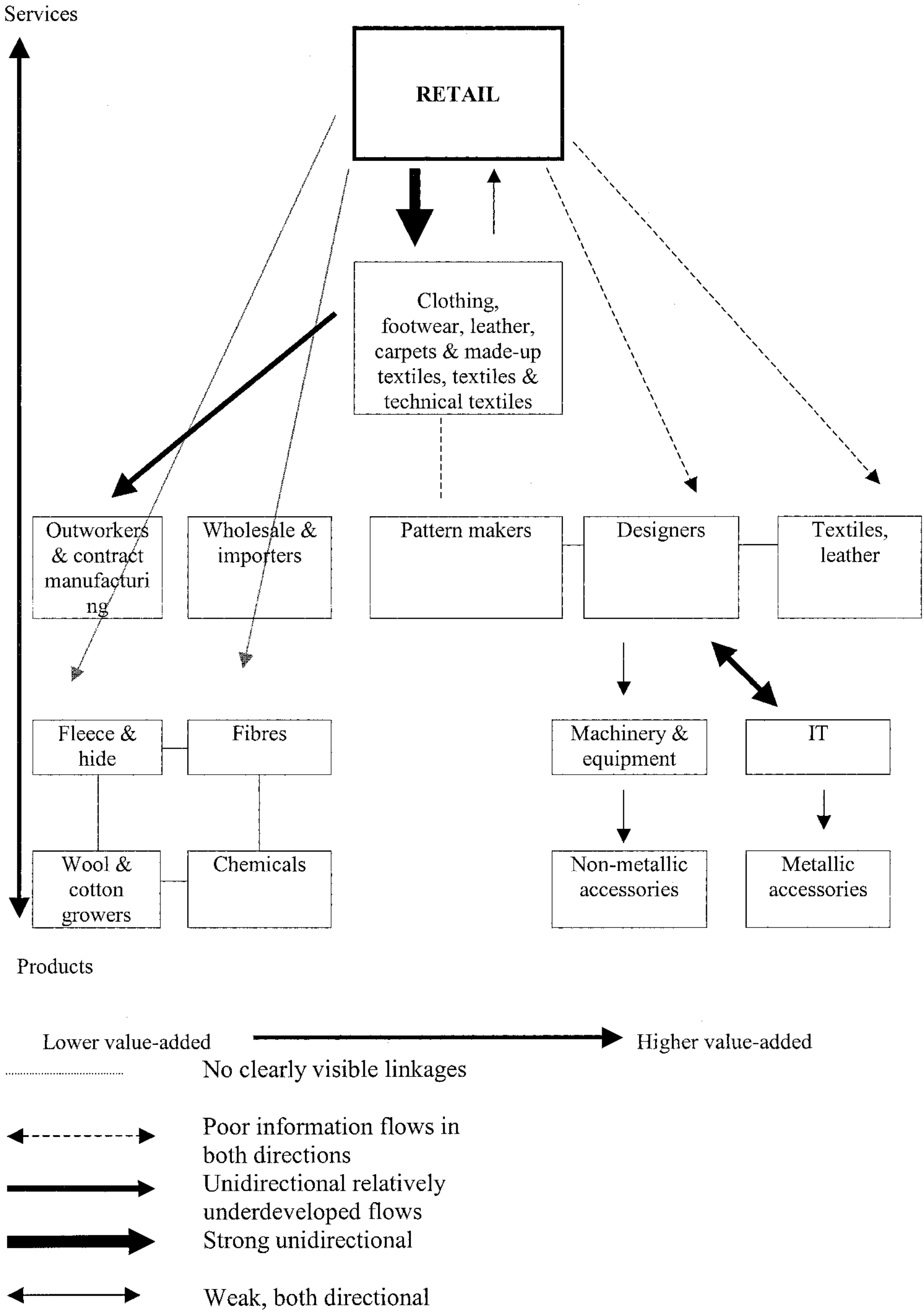

Figure 4. (a) Knowledge/innovation flows in the TCF&L product system: the reach of the retail driver.

segment is driven by companies not normally included in the main product system. In this case, the drivers of the segment are the interior designers who work either for large architectural practices or office design firms. In the latter case, the most successful firms

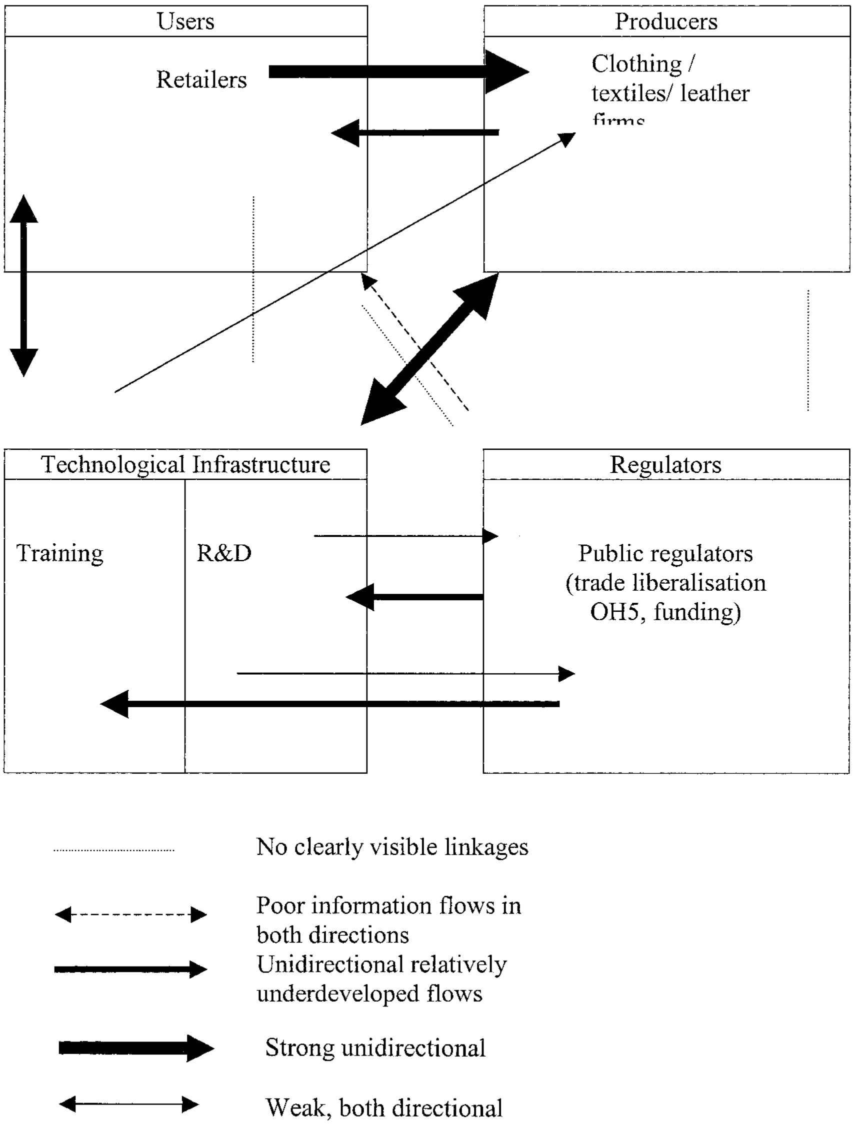

Figure 4. (b) Knowledge/information flows in the TCF&L product system.

are so far from the central core of the product system as usually considered that they do not even define themselves as exclusively concerned with office fit out. Instead they have developed rafts of services which include advice to corporate clients on work flow, team building and presentation of the company itself, activities well beyond the concept of the furnishings sector but critical now to maintaining firm competitiveness. No longer does an office furniture maker ask a client how many desks and chairs are needed: the office fit out or renovation becomes an occasion for rethinking much of the client's work activity through an interactive process in which furnishings become items occupying only a somewhat residual position.

The third segment is the craft furniture segment, essentially composed of small companies operating a craft production system. These are increasingly either going out of business, producing for specialised designers or creating commissioned items for individual shops or clients.

In each of these cases, the information sent to the producers by users is becoming critically important. The success of producers relies, therefore, on investment both in the clarity of the signals sent by users and in the areas which impact on the capacity of the producer to respond to the signals. It is on this that public policy intervention should focus. Here, too, then, of course, good IT systems are critical. But our analysis again shows that the information flows between R&D and training institutions need attention.

One problem with the furnishings product system is that, in the main, trades training is the dominant form of qualification in the assembly part of the product system and it has been developed without any reference to the structure and dynamics of the industry. The leaders of the industry consider their workforce to be skilled but, although the proportion of skilled workers in the trades qualifications sense is quite considerable, the training people receive involves no reference to design, to design for manufacturing for the mass market or even large batch production or to the new principles of design for ergonomic workstations and so on. Moreover, there is no expectation within the industry that firms invest in retraining of workers as a normal part of business activity.

Further, few firms invest in any form of R&D. While 'assembler' firms in many fields seldom undertake R&D themselves, being more focused on co-ordination and process activities and on incremental changes than on radical new product development, in furnishings this is particularly unfortunate because the 'assembler' firms receive input from other areas which also undertake little R&D. The chemical field (foams) is the most knowledge-intensive supplier industry. These firms are consistently large and more powerful than their furnishing clients and, while their technological power may be capable of pushing innovation down the chain, in many cases their clients do not have the 'reception skills' or complementary assets to receive and incorporate the new components or materials innovations offered.

It will be seen from the examples given in Figures 1–5 that in the different product systems studied the regulators have played little role and apparently have little influence except insofar as they determine the degree of trade protection or liberalisation. In furnishings this is equally the case. It is interesting that the most innovative sub-field of furnishings is that of children's furniture. This is precisely the field where regulations concerning flammability and other aspects of safety have had most bite and promoted most R&D inside both furnishing assemblers themselves and their critical suppliers.

Industry 4. Building and Construction (B&C)

Analysis of the building and construction product system indicates very considerable complexity and variation as between segments. In this case, in order to pinpoint areas of difference more clearly we analysed the different segments separately.

The B&C product system is an assembly industry *par excellence*. A few large lead firms co-ordinate inputs in terms of labour, materials and components for the creation of constructed products on individual sites. Many of the changes of management practices made in recent years in the product system mirror those of the automotive industry and explicit comparisons between the two have been made.[19]

The B&C assemblers or 'lead' firms co-ordinate the creation of highly complex products. They have to be highly knowledge-intensive in the sense of ensuring that knowledge about the functioning over time of materials and components is incorporated into the design and the specifications of items used as well as the correct

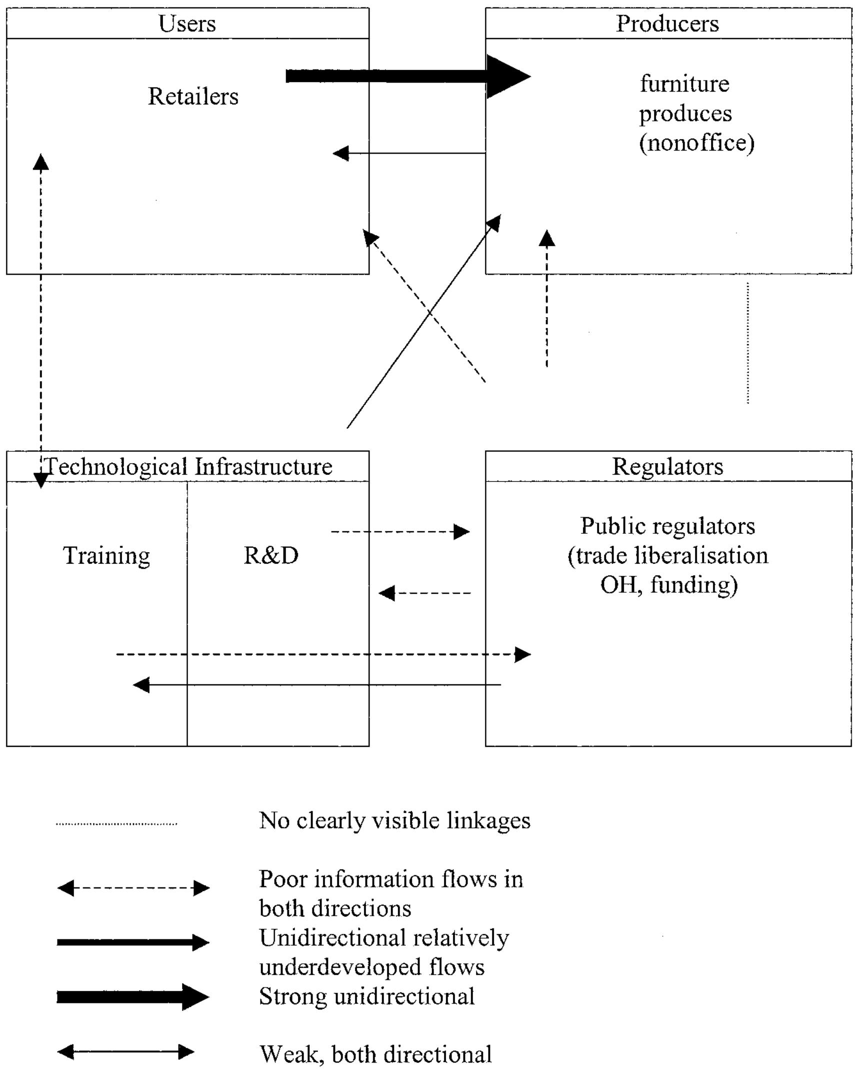

Figure 5. Knowledge/innovation flows in the furnishings product system.

use of the items on site. The lead firm or designer must also ensure that any new products or materials developed interact safely and effectively with others. No one wants their building to fall down!

The lead firms in the B&C product system do not undertake much formal R&D themselves but they are heavy users of high levels of embodied knowledge and of professionally trained personnel (architects, engineers, quantity surveyors, IT specialists, etc.) and they are currently making significant organisational innovations as well as using new materials and new construction technologies.

One of the most important factors that has been impacting on this product system in recent years in Australia, however, is not technological at all. It lies in major shifts in both the regulatory frameworks which shape activity in the field and their implementation at the public–private interface. A shift in the rules of the public game has meant a gradual withdrawal by government from many construction activities that had previously been the domain, in both design and in construction, of the public sector. In the decade following the mid-to-late 1990s, Australia saw a tremendous increase in the private provision of public infrastructure and a shift from regulation via initial specification to regulation in use, with a new focus on the different aspects of risk management as a core skill in the field. A regulatory paradigm shift thus occurred at the same time as technological shifts and may have been more important as a stimulant of innovation.

These concurrent shifts have had many implications for innovation in the product system. Lead firms have suddenly been faced with a great deal more responsibility in relation to selecting and co-ordinating all materials and components needed by often highly complex developments, with a focus on performance in use. To some extent, this shift in responsibility from public to private sector and from initial testing and standardisation to performance-testing through use may have had the effect of increasing conservatism in the system as each tries to assess and manage its share of the risks. In addition, the private financial system has become increasingly involved, adding new elements to the relationships between equity holders and constructors which have to be considered in innovation.

It could have been timely for governments to take this opportunity to create a regulatory framework which encourages the industry to move forward, notably in the use of sustainable energies and in the reduction of embodied energy use and improvement in waste management. Unfortunately, in Australia this opportunity has largely not yet been taken. Thus, although, for example, in the solar energy field Australia has a well-functioning complex of activities (R&D, training, production knowledge, components) that could have been the basis for a great leap forward in environmental management terms and the development of exports, a critical stimulatory mechanism, this time a regulatory one, has been missing. This has delayed the development of a strong solar energy industry in Australia, as well as reducing the incentives to reduce energy use and waste.

What we see in Figure 6 are good relations between users (of cells) and producers of cells (in part, however, made overseas using Australian technology) and between these and research institutions and the utilities that determine input to the grid. The diagram also shows the insufficient input from regulators needed to stimulate systematic activity on development sites, although there are some good individual projects. Thus, for the Olympic site, ten-year-old technologies have been used rather than those at the leading edge. Lack of push from the regulators has meant that the production of cells and both the research and production of such 'components' of buildings as PV (photovoltaic) cells incorporated into facades have lagged. The implementation of available knowledge has taken much longer than it should have, giving the potential for firms offshore to move ahead of Australian technology. By using voluntary guidelines, by not monitoring outcomes of use of new technologies so as to provide objective information to potential users and by not mandating reductions in either energy in use or embodied energy, a great opportunity to move to the leading edge of the new building and construction paradigm was foregone. This in turn has probably meant that potential high-knowledge jobs have not been created.

Industry 5. Medical Devices

This section will be short as I have published work on medical devices elsewhere. The critical point to note when considering the development of innovation in medical devices is the conflict between payments systems to the health sector and particular local

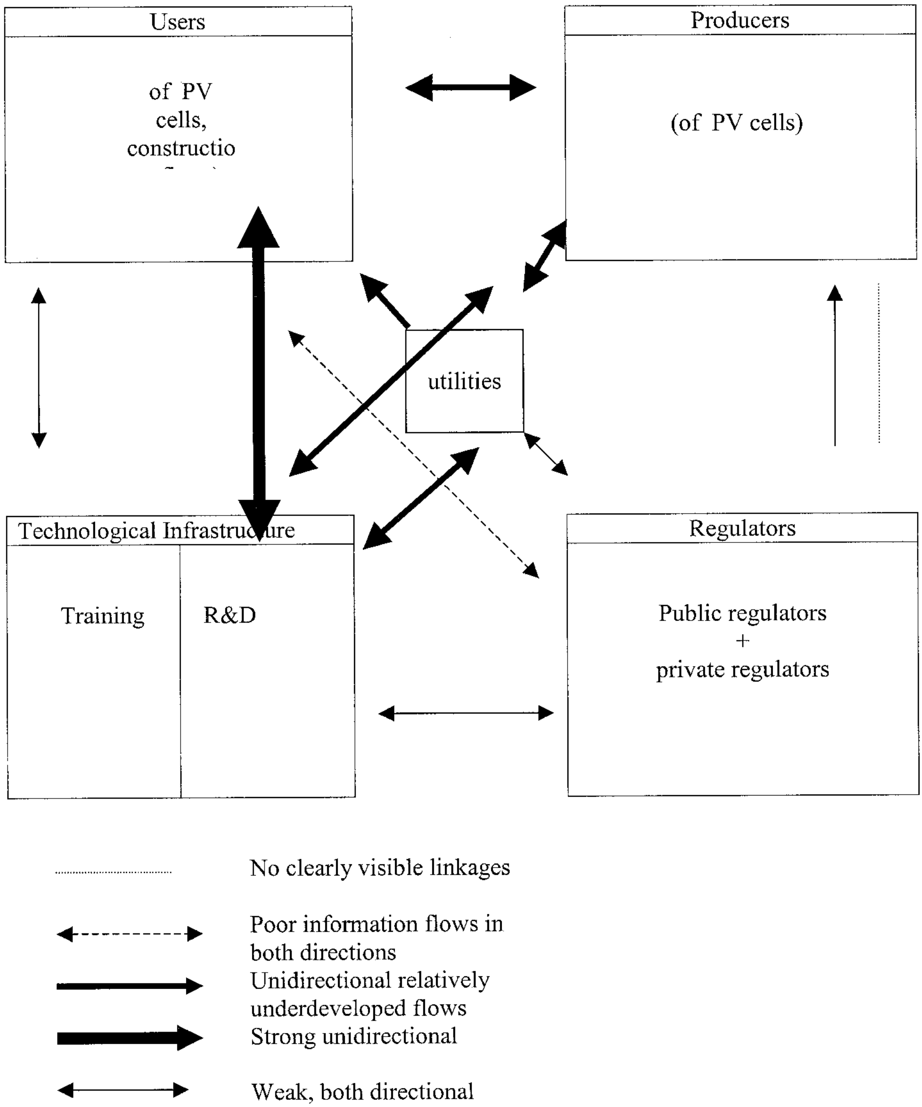

Figure 6. Knowledge/innovation flows in the energy efficiency segment of the building and construction product system.

organisational arrangements which encourage close user–producer interaction, experimentation with instrumentation or equipment or new product development.

The locus of initial development of ideas—hospitals—is very often also the context of the application of research and the site of regulated experimentation but is not the locus of production. Increasingly, however, the functioning of this locus of innovation, which spans the walls of both generating and implementing organisations, is being disrupted by stronger demands by authorities, including public policy-makers, for cost reduction in medical devices and equipment as well as a reduction in the acceptance of risk associated with the use of new products and processes because of increasing litigation. Payments systems to hospitals in Australia are complicated and fragmented by the interaction of two systems of funding in the public sector (State and Commonwealth),

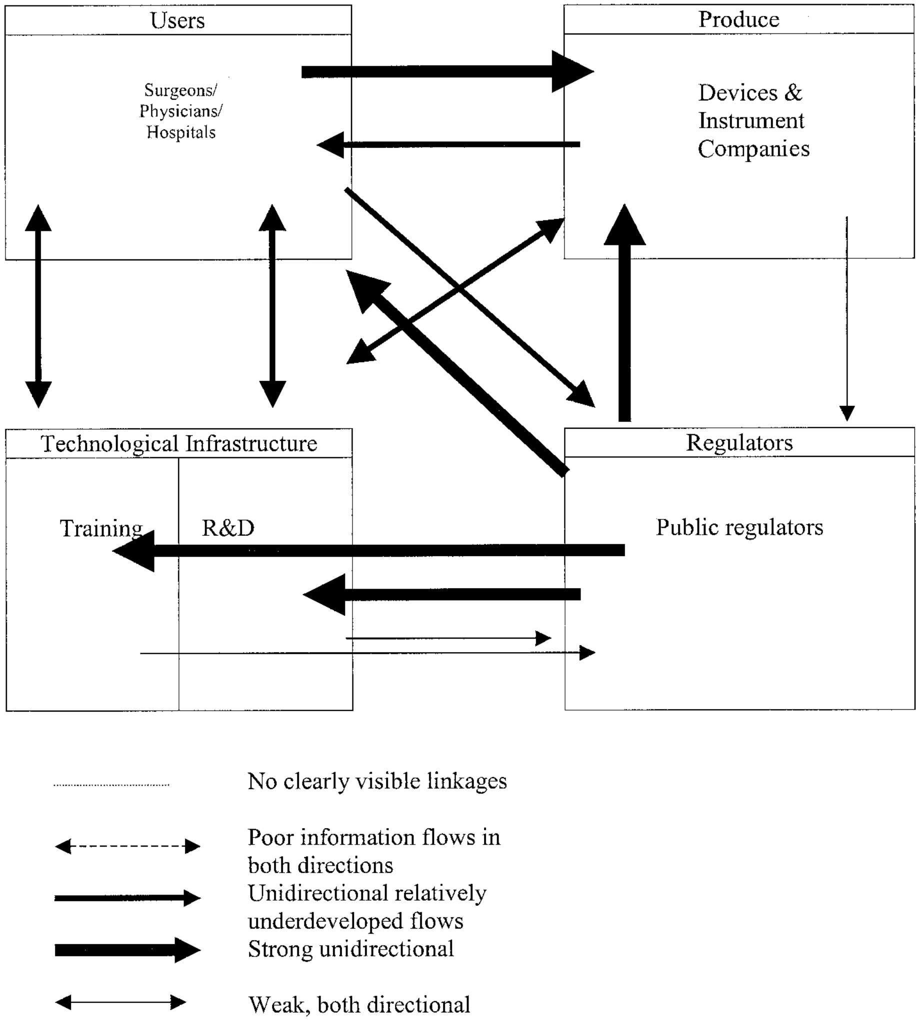

Figure 7. Knowledge/innovation flows in the medical devices segment of the health product system.

thus making the operation of the locus of innovation subject to two sets of major regulatory agencies which increasingly work at odds with each other. In addition, the increasingly wide public–private funding divide is encouraging the relocation of research out from the context of application (hospitals). In many cases also, new purchasing systems, while organisationally 'rational' in terms of reducing the direct costs of products and services, risk destroying the critical links behind successful medical innovations.

In the case of medical devices, therefore, our analysis (Figure 7) shows a failure of 'excessive' regulation, not of the technologies *per se*, but of the rules determining a structure which is increasingly unable to cope with the most direct demands upon it. Add to this an organisation of medical services which gives power to individual medical practitioners to treat all patients who seek their assistance but provides few strong incentives for innovation and one can see that a critical node in the medical innovation system is in poor shape.

Conclusions

This paper has attempted in a very schematic way to suggest the usefulness of an approach to analysing the dynamics of industrial change which enables policy-makers to find more effective points of leverage and hence to maximise the socio-economic and industry development potential of public policies. By using an identical approach to indicating the strong and weak points in selected industrial product systems the paper has sought to show a way to suggest the most important domains where actions need to be taken to encourage more effective innovation. Sometimes these actions need to be taken by the private sector, sometimes by government and increasingly by government and industry working together.

The different examples given indicate how the approach can work in highly divergent areas of economic activity with equally useful results. In many cases, the analysis also shows the importance for developing effective policies of analysing trends outside the sector as normally perceived. It is clear that one often cannot either understand or affect trends in manufacturing fields without considering that the drivers of change lie elsewhere, in the service sector, for example, or even outside the industrial system itself.

In the case of construction, for instance, the drivers of innovation lie in good part in regulatory shifts, which again are 'outside' the product system but work in conjunction with the technological changes happening within. It is the combination of regulatory and technological changes (especially IT, new materials and prefabrication) and the entry of significant additional players (financial institutions) that is driving the industry in new directions. In the medical device sector it is the clash of regulatory regimes which seems to be having deleterious effects on the outcomes of a system where users, producers and research institutions have otherwise developed close links and some effective innovation sub-systems. In tooling, it is critical to understand the dynamics of another industry or set of industries—here industrial users are the critical players. The producers of tooling and the selection of research agenda in local R&D institutions operate largely within a framework determined by decision-makers playing on a scale which is global, or at least major regional, rather than Australian. In this field, too, regulatory changes are also beginning to have an impact. The push for better environmental outcomes as seen in emissions regulations, for example, encourages the client vehicle-building industries to use new materials for their components. In turn, the new materials mean different materials for tools and a move to greater prominence of firms with close links to R&D institutions. In furnishings and TCF&L the key users are in the service sector and the key to innovative success lies in developing close links with clients and investing heavily in the technologies which reinforce them.

In all industries, the universal push to greater reliance on skills such as those of design to enhance firm level competitiveness means that players must give greater prominence to developments in the knowledge-generation areas of policy activity and to ensuring effective knowledge diffusion through policies for training and new equipment purchase, encouraging the spread of critical technologies (such as advanced IT). In most product systems, the broad spread of players is increasingly co-ordinated via an IT network which is supported and at the same supports a series of managerial innovations as well as other shifts in technologies developed and utilised.

The approach illustrated in this paper enables the analyst to both hone in on the general dynamics of industrial change as they relate to particular situations and to highlight the points that may need public or private action if a country, region or locality is to maximise the efficiency of the players in its national, regional or local innovation systems, or indeed its sectoral ones.

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