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13
1998

VARIETY AND DIVERSITY

Considerations for empirical research on innovation

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The paper benefited from discussions with Prof. Keith Pavitt, Dr. Nick Von Tunzelman, Dr. Ashish Arora and comments from Dr. P. Saviotti and Dr.G.Dosi at the first presentation in the EAEPE Conference 1994.. The usual disclaimer applies.

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This report is from Sub-Project 2.6, 'Indicators of diversity and variety at firm level', of the IDEA (Indicators and Data for European Analysis) Project. IDEA is Project No. PL951005 under the Targeted Socio-Economic Research Programme, Area 1 (Evaluation of Science and Technology Policy Options in Europe), Theme 1.3: *Methodologies, Tools and Approaches Relevant for the Preparation, Monitoring and Evaluation of Science and Technology Policies.*

An overview of the project as a whole, covering objectives, work programme, and results, including downloadable reports, can be found on the IDEA Web-site:

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ABSTRACT

Recent theories of innovation have stressed the importance of variety and diversity among firms. This is a potentially important policy issue, sine politics which are apparently 'neutral' with respect to an industry or even the economy as a whole, may have widely different impacts, because of inter-firm differences in innovation strategies and inputs. This paper explores the conceptualization of variety in the more recent evolutionary theories of innovation and technological change, and goes on to investigate the difficulties of meaningfully applying such a concept in empirical analyses of inter-firm differences.

The main point relates to the interpretation of variety in technology and behaviors and how it can be ascertained by looking essentially at empirical, quantitative differences in the real world. This basic idea is that in interfirm comparisons, some way has to be found of meaningfully separating the innovative variety of a more behavioral (strategic) nature, from more "structural" (permanent) differences due to different markets and selection contexts in which firms operate. Empirical evidence is provided in order to show that not all observable diversity in performances reflect behavioral differences. Often such differences reflect differences in some key dimensions related to the i) industries, ii) technologies and iii) environmental conditions which define different contexts of competition between firms.

The main implication for empirical research is that in the analysis of innovation-performance relationships in inter- firm comparisons the notion of variety is useful only to the extent that there are defined criteria for the selection of the firms. This in turn requires the previous identification of: i) the key dimensions defining the boundaries to firm strategies, and consequently ii) the level of aggregation at which at inter-firm similarities and differences of more strategic-behavioral nature can emerge.

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THE CENTRALITY OF BEHAVIORAL VARIETY IN THE EVOLUTIONARY APPROACH

Evolutionary theories of growth and technological change are in relatively early stages of development. Some writers (Hodgson 1993) would argue, however, that some form of evolutionary theory were already present in the conception of more orthodox contributions in economic theory. With their emphasis on the disequilibrating and endogenous nature of technological change it could be argued that present day evolutionary theories recapture some of the holistic traditions in the analysis of technological dynamics, competition and growth that marked both the early classical analysis (especially Marx), and Schumpeter, to this question (Dosi, 1984). However, recent theories of technological change that start with Nelson and Winter (1982), are also fundamentally different in terms of the way that they conceive the structure and the evolution of the economy. One of the key features which distinguishes the modern day evolutionary theories is the *emphasis on variety and its essentially behavioral connotation*.

The concept of variety stressed in this approach is not a simple statement regarding the existence of technological difference in the economic and productive system. Differences across industrial sectors, in the form of different production functions are recognized within the neo-classical framework. In this approach however such differences do not imply a micro variety of innovative conducts. Nor is variety of behaviors seen as the engine of the evolution of the systems. Conditions of production are exogenously given and known so that asymmetries among firms operating in the same market are not conceivable in a equilibrium state.

What really distinguishes evolutionary theories in our opinion, is the behavioral micro foundations that these theories start from and the importance accorded to this heterogeneity in behaviors. These differentials in behavior ultimately occur due to different knowledge bases of firms and the bounded rationality of their behaviors. Overtime these differentials in behavior cumulate to produce asymmetries between firms and could even account for observed differences in market structure. (Nelson and Winter 1982).

Marx had also stressed the importance of the introduction of new processes and products as a source of heterogeneity in the system. However, innovative activities were seen as a result of more objective forces related to the increasing competitive pressure which accompanied recession periods, and to which sooner or later both innovators and imitators are subjected to. This led the system towards periodic phases of convergence, during which more efficient techniques are widely adopted (at least among the survivors), and periodic phases of divergence where new products and processes are created. The conceptualization of innovative activities as the major competitive weapon in the presence of sequences of divergence and convergence associated with the innovation and diffusion stages of industrial growth are also at the heart of Schumpeterian business cycles.[1]

Evolutionary theories depart from each of the previous approaches with respect to one or more of the following features. The distinctive features which characterize the evolutionary conceptualization of variety are the following :

i) Variety and heterogeneity are a *permanent feature* of economic systems;
ii) Variety is *inherently part of the competitive process "at work";*
iii)Variety is the direct result of *divergent strategic behaviors of firms* (where the strategic connotation of these behaviors relies upon another key assumption viz. the existence of limited rationality of the agents - especially as far as innovation is concerned, given the unpredictability of the result of innovative activities).[2]

All the three features mentioned above make the evolutionary approach different from earlier approaches to the study of industrial dynamics. The first feature distinguishes the evolutionary approach from both Schumpeterian and Marxist perspectives. Both these approaches explicitly stress the existence of a "convergence stage" where competition exercises its pressure on firm behaviors compelling them to adopt best practice techniques through the

[1] Marshall,whose name is usually associated with partial equilibrium analysis and the representative firm, recognised the role of vareity and evolution in the functioning of economic systems. To explain the existence of vareity of firm behaviours he called attention to a life cycle theory of the firm, where the increasing take over of management from owners in the running of the firm as firms grew old gave rise to different behaviours.

[2] The behaviouralist perspective associated with conditions of limited rationality is explicit in the following statement by Nelson and Winter: "In the spirit of Simon, Cyert, March, and other behaviouralist theorists, we argue that firms cannot optimize in any formal sense because their decision problems are too complicated for them to comprehend fully" (Nelson and Winter, 1978). To some extent therefore the different responses to this problem of limited rationality are contained in different organizational and routine behaviors of firms, that are the source of the basic heterogeneity of the system.

diffusion and imitation stage.[3] Thus, in this theoretical perspective, variety increases in the system and also decreases.[4]

In this paper we want stress and focus upon the implications for empirical analysis of the third connotation of variety, which characterizes most theorizing in the evolutionary tradition and in our view most clearly distinguishes them from the Neo-classical and Marxist perspectives. Even at the risk of some over simplification of the heterogeneity of thought that is present within the evolutionary stream itself, *we argue that a key aspect in such theories is that they clearly stress a behavioral-strategic connotation of variety*. In our discussion we will consider the works of Nelson and Winter, Dosi, and Metcalfe, as representative of this kind of viewpoint. Saviotti uses a somewhat different notion of variety which is consistent in its conclusions about industry structure and dynamics with the evolutionary tradition but the concept of variety employed by him, does not require a behavioral foundation.

The term "behavior-strategic" is used by us to characterise the notion of variety used in this approach because :

(i) It is explicitly or implicitly recognized that there exists a significant room for strategic maneuver and diversity in innovative conducts, to which are then associated the different performances in the real world
(ii) The approach stresses the importance of starting from a clear understanding and specification of micro foundations of behaviors in order to shed light on macro phenomena such as the state and dynamics of systems and structures.[5]

Behaviors, of course, are not considered boundless. The cumulative and localized nature of technological change, as well as the consolidation of behavioral routines in innovative activities, are stressed. Dosi for instance states that "Once the cumulative and firm-specific nature of technology is recognized, its development over time ceases to be random, but is

[3] Dosi keeps a more equidistant and prudent position. He states that "Ceteris paribus, therefore there is reason to think that the process of imitation and diffusion makes for convergence. But asymmetries in the capabilities of firms impose limits on this tendency and its strength remains to be determined" (Dosi, 1988, p. 1159).

[4] This conceptualization is consistent with Saviotti (1991) but not with Metcalfe (1987).

[5] The attempt of giving a solid a rigorous micro-foundation to macro-economic theory and phenomena (alternative to the neoclassical one) is one of the most ambitious goals of evolutionary theory. This is explicitly addressed by Dosi (1984, 1988).

constrained to zones closely related technologically and economically (e.g. related markets and distribution network) to existing activities" (Dosi, 1988, p. 1131).

At the same time, the cumulative nature of technology is seen also as the single most determining factor explaining: (i) the permanence of technological asymmetries among firms, that is the presence at each point in time of worse and better technologies and performances (ii) the presence at each point in time, of alternative and competing technologies, that is, that have not yet been ordered by the market. The asymmetries in (i) are seen as sort of objective boundaries which consistently limit firm's innovative conducts and strategies. "....the existing pattern of technological asymmetries represent a sort of 'factor of order' which limits the set of feasible strategies available to each firm and tend to order them hierarchically" (Dosi and Orsenigo, 1989, p. 28).

These technological asymmetries, however, still have a clear behavioral origin associated with them. This is because technological asymmetries (along with chance) reflect differences in the level of technological capabilities across firms, which are the result of firms behaviors and strategies in innovation (searching processes), with market forces eventually permitting the more successful learning paths to survive. *Because innovation is seen as the major competitive weapon, major differences in performances are primarily related to the different successes (or appropriateness) of past innovative behaviors and strategies along with the effect of chance*.[6]

SOURCES OF HETEROGENEITY VERSUS SOURCES OF TRUE BEHAVIORAL VARIETY

The stress on behavioral variety of firms as the mainspring of selection through competition recalls into economics the biological metaphor of evolution through natural selection. (See Hodgson (1993) for a full discussion). In biological models of evolution there are two main sources of the generation of genetic variety. They are mutation and Mendelian sexual recombination. In analysing the behavioral variety of firms that are other wise similar, some form of bounded rationality explains the origin of differences in behavior and cumulativeness or pathdependency takes on the role of heredity.

In the economic sphere, there is however, no equivalent of sexual recombination, and so mutation becomes the only source of maintaining variety in the system once the origin of this variety is given from conditions of bounded rationality. Further, unlike genetic mutation, a mutation or change of firm behaviors can be expected to be significantly affected by the economic environment facing the firms and partly the result of conscious decisions by firms either due to a change in the rationality or way of perceiving its constraints, or a difference in its objectives.

Consequently the behavioral variety that is observed is a consequence of three factors: the bounded rationality of firms, differences in the objectives of different firms and differences in economic environments. The last source of difference in economic behaviors however can hardly be termed as "behavioral variety". In evolutionary terminology this is equivalent to saying that economic evolution is Lamarkian rather than Darwinian in nature.

As a digression it is worth noting the slight methodological wrinkle involved in this kind of analysis when compared to the neo-classical analysis of firm behaviors. In the en-classical theory of the firm different firm performances are the result of different constraints or different objectives, but not different behaviors. In evolutionary analyses different performances are the consequence of behavioral diversity but different behaviors also incorporate the different constraints that face the firm.

If differences in behavior are always linked to differences in initial conditions, histories experience, etc. it is theoretically very difficult to separate differences in initial conditions and differences in behavioral heterogeneity. Yet, a distinction between these two sources of different performances is a must for any sensible industrial policy. If the role of initial conditions in explanation of poor performances is high then policies must have a role to play in improving performance by changing this set of initial conditions. The same argument would however be difficult to make if it turned out that true behavioral diversity (different motivations, perceptions of the firm etc.) were at the root of better or worse firm performances.

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[6] The presence of stochastic features in innovative activities and their result is particularly present in Nelson and Winter 1978, 1982.

One way of distinguishing between the two sources of economic variety is to ask *under what circumstances may one observe selection on the basis of true behavioral variety ?* This could help us to understand the level of aggregation at which selection takes place on the basis of true behavioral variety. We will refer to this level of aggregation as the homogenous competitive context, to distinguish it from other levels of aggregation such as industry, markets, economies etc. The next section will deal with the defining of such a context.

Empirical data in the social sciences, unless generated through controlled simulations, are almost inevitably available at levels of aggregation that cannot be controlled by a researcher. The interpretation of this data within a framework of evolutionary economics will be better informed by knowledge of where the limits to selection based on true behavioral variety lie. This constitutes the main motivation for the writing of this paper. The two last sections outline this through two examples.

THE EMPIRICAL IMPLICATIONS OF A BEHAVIORAL STRATEGIC CONCEPTION OF VARIETY

The implications of the behavioral-strategic conceptualization of variety outlined in the first section, for empirical research into the determinants of differences in performances is fairly straightforward. It would follow from what was argued above that when relationships between innovative conducts and performances are studied and tested from an evolutionary perspective, then the firms taken into account have to be firms that are effectively technologically competing with each other or have done so in a recent past. Only in this case can the differences in performances actually observed and underlying technological asymmetries be attributed or associated to a variety in technological behavior and strategies.

The stylized fact from which we have to start in empirical work is that at each point in time economic systems are constituted by a large variety of products, processes, technologies and performances. These differences reflect both firm behaviors and more structural differences in the nature of markets, production processes and technologies within which firms operate. Innovative conducts and structural conditions of technology are interrelated aspects. It has in fact been emphasized that the differences in behaviors, organizational modes, structural aspects of industries all together define sector specific technological patterns and technological regimes (e.g. Winter 1984; Nelson 1986; Pavitt 1984; Dosi 1988).

In dynamically linking the variety of firms' innovative conducts to technological and economic performance, *evolutionary theories largely stress differences in firm behaviors as a major determinant of technological asymmetries across firms and structural changes*. This could be interpreted as implying the existence of a fairly large room for firms' behavioral and strategic maneuvers in technological change. Extending this argument to its logical extreme would suggest that firms belonging to different national, technological and market contexts (industries, technological fields) could be meaningfully compared in terms of their technological behaviors and conducts and the latter to economic performances. The actual extent of room of maneuver in innovation conducts is however limited by a number of environmental factors.

Taxonomic exercises have tried to give some order and to qualify the notion of behavioral variety, both in terms of its content and locus. Sector specific characteristics of industries and technologies have been identified on the bases of different sources of innovation, technological appropriability and opportunity conditions, to which have been associated different market structures and barriers to entry and movement (e.g. Pavitt 1984). The implication of these kind of classifications is that variety in firm innovative behaviors occurs within the context of different technological regimes and different bases of technological and market competition.

Even so, the state of the art in defining such boundaries is still unsatisfactory. Opportunity and appropriability conditions alone are not sufficient to define technological boundaries of firms innovative conducts. Further, they are not easy to define or quantify in empirical research. The problem of the choice or definition of the key technological dimensions defining the boundaries has to be tackled jointly with that of defining the level of aggregation at which inter-firm similarities and differences are expected to emerge.[7] The methodological problem which remains is that of defining the characteristics which can warrant a sufficient level of homogeneity in the competitive bases.

[7] The non adequacy of the industrial classification in singling out technological regimes condition seems confirmed by the results of the two recent "Yale" surveys on inter-firm and inter-industry differences in the levels of technological appropriability and opportunity conditions. These studies have revealed the presence of a surprisingly high intra-sector variance with the result that "for many of the questions only a very few industries are distinctively different from the average" (Cockburn, 1992, p. 4).

As a first approximation, based on the knowledge of numerous case studies and empirical studies in industrial economics, it may be possible to define these homogenous competitive spaces in terms of similarities in the nature of some key characteristics of the environments in which firms operate. These key characteristics could be :[8]

(i) Sameness of the industrial sector : for e.g. nature of the technological process based on the physical properties of products and processes
(ii) Sameness of the final market such as nature of users, price attributes of competition, quality characteristics etc.
(iii) Similarity of technology, underlying knowledge bases and the broad inter linkages of these competencies
(iv) Similarity of institutions and environments e.g. Geographical localization, Government-academic-industry linkages, infrastructures, information flows etc.

To define more specifically such limits to firms strategic behaviors in innovation is beyond the scope of this paper. However, the recognition that each of the above characteristics imposes limits to the amount of variation in behaviors is important to an understanding of why the notion of variety, itself a behavioral concept, must be limited. Indeed each of these features could be interpreted as defining a certain kind of limit to the nature of competition between firms, and aggregation could be considered in terms of any of these limits to competition.

The above discussion also suggests that the boundaries to behavioral variety may reside ultimately in the boundaries of competition itself. To some extent the boundaries of competition change and often as a result of the process of competition. Thus, every 'gale of creative destruction' (cf. Schumpeter (1939)) erodes the bases of competition between producers and historically this has been the greatest challenge generated by technical change. Theoretical and empirical formulations of what is involved in these changes have to be explicit in the mapping between technological changes and the type of boundaries they generate for competition between firms if they are to be accurate in their analyses of reality.

[8] Inevitably only further research can estimate the actual error involved in such an approximation.

With the help of some empirical evidence provided in the next section we wish to show that using a very broad and unqualified concept of variety and heterogeneity, when the minimum requirements regarding the definition of homogenous competitive contexts are not clearly stated (e.g. with respect one or more of the four dimensions mentioned above) can be quite misleading in its conclusions. The lack of clarity on what is meant by variety and what is the source of change in variety presents problems for empirically interpreting the multidimensional nature of inter-firm differences in innovation and performances as due to behavioral variety, when it is heterogeneous firms that are compared, across heterogeneous spaces. [9]

SOME EMPIRICAL EVIDENCE

Before presenting the empirical data, a brief description of the principal statistical tool employed in the two empirical analyses is in order. Both studies are cross-sectional and proxy the behavioral differences between firms in terms of some performance indicators. Thus, in the case of the first study the differences in innovative behaviors across firms and sectors, are sought to be captured in terms of different expenditures of firms on R&D, Investment and D&E. In the second study differences in operational efficiency parameters, such as Per input consumption in real terms (e.g. electricity consumption per ton of steel in KWHrs.), is taken as a proxy for technology use and capability (a behavioral variable). In the first study data is studied over different industries, but within the same country, viz. Italy. In the Athreye (1994) study, a single process technology is considered, and its use studied in British and Indian firms, i.e. the economic environment is allowed to vary. It may be noted that both empirical studies do not conform to the minimum features defining a homogenous competitive context in the previous section.

The variation of the data set is then subjected to an analysis of variance. This is faithful to the notion of variety as the spread of a particular characteristic. If different behaviors can be expressed in terms of different characteristics, then ANOVA tests ask the following question: Is the spread of the values observed around an average value more significant statistically than the difference in the average value itself. Thus, if the intra-group variation is more significant (i.e. the F value on the ANOVA is not statistically significant), then it is concluded that

[9] This has probably been one reason behind the popularity of simulation techniques for testing theories in an evolutionary framework. See for example the works by Dosi.

behavioral variety is the principal explanatory factor, for the variation in the data. If however, inter-group variation is significant, then non-behavioral or structural factors due to objective differences in markets and technologies, both broadly defined, are concluded as being the more important factor explaining the variation of the data set.

Inter-firm versus inter-industry differences in technology and production

The empirical evidence from Evangelista (1994) based on an analysis of inter-firm and inter-sector differences in the composition and intensity of both disembodied and embodied features of innovative activities is presented in Table 1.

Table 1: F-Values and R-Sqd. in the Analysis of Variance, at different levels of industrial aggregation. Source: Evangelista (1994)

Indicators	*Variables*	*F-values and R-squared*	*3 Digit Level 108 sectors*	*2 Digit Level 30 sectors*
Structural	SALES	F	14.52	45.54
		R-Sqd	0.18	0.16
	INVMAC	F	7.36	15.18
		R-Sqd	0.10	0.06
	VA	F	11.34	29.78
		R-Sqd	0.15	0.11
Innovative intensity	INCOST	F	5.22	11.03
		R-Sqd	0.07	0.04
	R&D	F	7.29	20.92
		R-Sqd	0.10	0.08
	D&E	F	6.40	20.58
		R-Sqd	0.09	0.08
	INV	F	6.78	12.43
		R-Sqd	0.09	0.05
Innovative composition	YR&D	F	9.05	27.33
		R-Sqd	0.12	0.10
	YD&E	F	13.58	37.99
		R-Sqd	0.17	0.14
	YINV	F	18.00	49.85
		R-Sqd	0.21	0.17

Notes: a) Description of variables used: Sales: Sales per firm (billions of lire). INVMAC: Investment in machinery per employee. VA: Value-added per employee. INCOST: Total innovation costs per employee. R&D : R&D expenditures per employee. D&E : Design and Engineering expenditure per employee. INV: Innovative investment expenditure per employee. YR&D : R&D expenditures as % of total innovation expenditures. YD&E: Design and Engineering expenditure as % of total innovation expenditures. YINV : Innovative investment expenditure as % of total innovation expenditures. b) All F-ratios reported above were statistically significant at the 5% level.

The main results based on the outcome of a simple ANOVA test are the following:

1) Industrial sectors effectively define gross differences in technology and production characteristics. Such differences do not seem to be confined to the level and nature of disembodied technological opportunities and capabilities which could be considered

behavioral features, but also include more embodied technological features of production such as capital intensity of production and scale factors. These features of particular sectors may be regarded as structural in the sense that they relate to characteristics that have emerged for the industry over a long historical period and experience of market formation. Thus, firms in the textile industry are technologically and structurally different from firms in the office machinery sectors, both in terms of level of innovative activities carried out, their composition, nature of production processes and organization of production. The extent and nature of the inter-sector differences also define these differences as structural in another sense viz. they do not seem to leave much room for firms to move from one sector to another.[10]

2) Industrial sectors, however, even when taken at a high level of disaggregation (e.g. 104 sectors at the 3-digit level) explain only a part of the inter-firm differences in technology, as is evident from the low R-squared values in Table 1.[11] The high inter-firm, and intra sector variance found within the sectors suggests that industrial sectors by themselves do not fully define the homogeneous contexts that we described in the previous section.[12]

3) The *level* and *nature* of the intra-sectoral variance found (which includes disembodied and embodied characteristics of innovative activities plus organizational features of production) suggests that only to a limited extent this could be interpreted as behavioral innovative variety. To a large extent this variance reflects the presence within the industrial sectors of different products, production processes to which are associated different technologies and technological capabilities, both of a disembodied and an embodied nature.

These findings[13] have therefore the following implication for empirical research:

While industrial sectors discriminate between broad technological and production characteristics of firms, they are not an adequate unit of analysis to effectively define

[10] It is however possible to measure and qualify the technological closeness of firms belonging to two technologically different sectors, using cluster analysis (Evangelista, 1994). The ANOVA results in Table 1 are also reported for such clusters.

[11] Both these points about the effectiveness of industrial sectors in separating firm performances are in line with another important study on US firms' differences in profitability and market share, viz. Schmalensee (1985).

[12] This has also been shown, using the same data-base, by Cesaratto and Mangano, 1993.

[13] The use of the non-parametric Kruskal-Wallis test (not reported here) supports this interpretation given to the simple ANOVA results.

homogeneous technological competitive contexts, that is areas where one could look for alternative and competing technologies at work, as well as technological asymmetries. Consequently only to a limited extent the result of analyses on inter-firm intra-sectoral innovation-performance relationships can be interpreted (especially when a high level of aggregation is chosen), as the result of behavioral differences.

One possible reason for the inappropriateness of the industrial sector in defining boundaries is that the SIC classification is largely a classification based on the similarities in use of the product. In terms of the characteristics of homogenous competitive spaces in the previous section, they are aggregations based on feature (ii). But the other underlying differences, e.g. in technology, which could be associated with differences in the nature of materials, process of manufacture and the nature of technological competencies to design and generate new products and new processes, could be quite different for the different lines of business present in each sector, and sometimes the same line of business in a particular sector.

Selection, competition and behavioral variety in differing environments.

In this section the heterogeneity of firm behavior arising as a consequence of different economic environments is considered and discussed. The difference in environments has usually been discussed in relation to differences in policy environments, e.g. protected versus competitive, open versus closed economies, and export led versus import substituting growth. However, the difference in environments is also closely related to different stages of economic development. Economic development affects the nature of markets, nature of users and is characterized by a greater market integration of the economy, both regional and industrial. The notions of differentiation and complexity that are usually discussed as being quite related to the concept of variety, become extremely relevant when we compare the behavior of the organism (firm) in environments that differ in this way.

In a study of 28 steel making units in India and Britain by Athreye (1994), she has shown that there was considerable inter-firm variation in behaviors as expressed in the operational efficiency parameters of firms. Though using the same process technology, British firms reacted to a different market environment compared with Indian firms. The British firms faced a contracting industry (steel), while in India, the same industry was expanding. The composition of the users of the final products was also different in terms of their demands for price and quality and the trade-off between the two that were acceptable. This imposed a

different weight of price or quality as the major attribute of competition in the two countries. Both because the users were industrial users and the industry in Britain was a contracting industry, producers by and large paid a lot more attention to the quality dimension of their product. This necessarily imposed a greater awareness and attention to technological aspects of production which in turn were reflected in relatively lower levels of real input consumption.

In contrast, Indian producers using the same technology faced a market consisting of largely household based demand which effectively implied that price cheapening strategies secured by and large larger market shares. Further, the situation of relative scarcity and supply constraint tended to focus attention upon price more than quality and this was reflected also in material substitutions that were efficient in price terms but not necessarily in terms of a better quality of the product or better real input consumption. The latter situation was worsened by input scarcities with regard to scrap and electricity.

The differences in these environmental conditions of the same (technological) market were related to the different stage of development in the two countries and the consequent differences in the structure of the economy, and in turn implied a different bases for competition in the market for the firms in the two countries. Not surprisingly, these also give rise to fairly different decision rules for the firms in the two countries. Simple ANOVA tests on the total variation, in certain real input consumption parameters (which proxy technical performance) reported in Table 2 below, revealed that the variation between the two groups of firms, viz. British and Indian, was far more important and statistically significant than the variation within the group of firms in explaining this total variation, lending some support for the argument of the importance of differences in the production and market environments in explaining firm behaviors. Once again, descriptive statistics like variance reported in 2b revealed a high degree of inter-firm variance in both countries which still does not characterize true behavioral variety since it contains the effects of differences in markets..[14] In terms of the key characteristics defining homogenous competitive context we can see that even technology and sector together (features (i) and (iii)) cannot provide a useful level of aggregation within which behavioral variety could be observed and assessed.

[14] In view of the different variances of the two groups and also the different numbers involved, a Kruskall-Wallis one-way ANOVA was also performed. The advantage of this test is that it is non-parametric. However, the results were remarkably similar. This test is not reported here.

Table 2: Results of one-way ANOVA by country. Source: Athreye (1994)

Variable	*Degrees of freedom*	*F-ratio*	*F- probability*
HEATS	(1,24)	3.31	0.081
TAPTIME	(1,23)	5.34	0.030
TONNAGE	(1,23)	30.60	0.000
PRODUCTI	(1,24)	27.30	0.000
DRI	(1,24)	33.80	0.000
ELECTRIC	(1,23)	19.16	0.000
REFRACTO	(1,21)	3.07	0.095
ELECTROD	(1,24)	21.48	0.000
YIELD	(1,23)	5.62	0.027

Notes: a) Description of variables used: HEATS : Number of heats per day. Will vary with the product-mix of the firm. TAPTIME : Heat time length (in minutes). Expected to vary with varying product-mix of firm. TONNAGE : Tonnage per heat. PRODUCTI : Production per day, in tons. DRI : Proportion of directly reduced iron used in scrap charge (%). ELECTRIC: Electricity consumption per ton in KWh. REFRACTO: Number of heats after which refractory is re-lined, expected to vary with product-mix. ELECTROD: Electrode consumption in kgs. per ton of steel produced. YIELD : Steel yield per ton of scrap. b) The variables that are significant only at a 10% level are the ones where the internal product-mix of the firm is important

Table 3: Average value and variance of important variables by nationality. Source: Athreye (1994)

	Indian firms		British firms	
Variable	*Mean*	*Std deviation*	*Mean*	*Std deviation*
HEATS	8.41	2.89	11.41	5.59
TAPTIME	171.25	46.35	130.44	33.67
TONNAGE	25.56	13.35	86.89	41.25
PRODUCTI	192.18	100.78	1232	823.99
ELECTRIC	736.31	162.59	482.22	79.03
REFRACTO	320.00	240.18	1508.75	2664.19
ELECTROD	5.05	0.87	3.29	1.00
YIELD	0.85	0.12	0.94	0.02

These empirical results in part reflect the limits to inter-firm comparisons. Any theory that attempts to start from an underlying behavioral variety of firms has to take the limits imposed by the four key features identified in the 'empirical implication' section explicitly into account. This would facilitate and focus better the purpose and conclusions of comparative and also historical studies.

CONCLUSIONS

This section will recapitulate the main arguments of the previous sections. This paper tried to highlight the problems associated with empirically trying to interpret behavioral variety as underlying the differences in firms' technological and innovative performances.

The first section has tried to show that a behavioral notion of variety underlies the recent evolutionary conceptual framework and differentiates it from several of the previous economic theories. This was followed by a discussion of the sources of behavioral variety and heterogeneity. To the extent that economic behaviors are Lamarckian and influenced by the environment within which firms operated, such variety could not be ascribed a behavioral origin and so, does not constitute true behavioral variety.

We then asked the question : *at what level of aggregation may one observe selection based on true behavioral variety?* The limits to any inter-firm comparisons of true behavioral variety to be observable and interpretable in some finite time frame, must be circumscribed by a homogeneous context, that still needs to be identified. The problem of defining the governing bases of competition between firms remains open and deserves deeper empirical and theoretical investigation.

However, this constitutes the first step before any evaluation of the importance of behavioral variety for evolution of technologies and economic systems can be made. The next section provided our intuitive approximation of such a condition. The empirical problems associated with observing differences (and heterogeneity) in the real world and interpreting them as reflecting inter-firm behavioral variety was also highlighted. The remaining sections then sought to provide particular empirical examples of the difficulties of interpreting what are largely differences observed in the real world as behavioral variety.

The first example on the Italian Innovation Data, outlined the need to demarcate a clear and homogenous basis on which to observe the variety of firm innovative conducts. It was pointed out that both the appropriate key dimensions and a level of aggregation had to be arrived at, in order to make behavioral variety more meaningful in empirical research. This is because industrial sectors provide a first but still imperfect approximation of this homogeneity in competitive bases. Future work based on a sub or meso sector level, looking both at the essential nature of technological activities and production processes and related technological competencies, could be more promising in this regard.

The second example showed that environmental differences are fairly important in explaining total variation of technological parameters. In this study the environmental factors were associated first of all to different levels of development of the economy. Further, the high

inter-firm variance was associated with a sharp product market segmentation. Behavioral variety is therefore explained more by the different rules of competition between the two environments and the two product market segments.

Implicitly, in this paper we have chosen to term the non-behavioral differences, between sectors as in the first study, and between market environments as in the second, as structural differences. This is informed by the understanding that any evolution (especially of the governing environment viz. industry, technology) imposes a pattern and structure which limits the behavior of firms.

If our understanding and analysis are correct, then even if we could in reality observe this "homogenous competitive context" defined on page 9, it would allow the inhabitation of very few firms, which would then be selected or not selected on the basis of behavioural variety alone. On the other hand, structural differences broadly defined appear to separate firm performances quite well though they undoubtedly do not offer complete explanations. Thus, we could, in conclusion, ask for a rethinking of the following two questions:

How endogenous or exogenous to firm behaviors are market structure conditions?

What dimensions of market structure could we term behavior dependent and what dimensions are behavior independent ?

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