

Technological Regimes and Industrial Dynamics: The Evidence from Dutch Manufacturing

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Technological Regimes and Industrial Dynamics: The Evidence from Dutch Manufacturing

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Abstract

Previous empirical research has shown that the observed inter-sectoral variety in the rates and form of organisations of innovations is related to differences in the underlying technological regimes. Further, theoretical models of industry dynamics suggest a similar relationship between the structural and dynamic properties of the firm population of an industry and its underlying technological regime. Using productivity differences between entrants and incumbents as a proxy for the technological regime of an industry, this paper, on the grounds of a longitudinal firm-level database on the Dutch manufacturing sector, shows that differences between industries with regard to their structural and dynamic properties are strongly related to their underlying technological regimes.

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Machiel van Dijk is from the Maastricht Institute. He was a participant in the Young Scientists Summer Programme at IIASA in the summer of 1998.

Technological Regimes and Industrial Dynamics: The Evidence from Dutch Manufacturing

Machiel van Dijk

1. Introduction

This paper deals with the empirical relationship between industrial dynamics and technological regimes. A technological regime can be defined as a particular combination of opportunity, appropriability, cumulativeness conditions and properties of the knowledge base, common to specific activities of innovation and production and shared by the population of firms undertaking those activities. In the literature on technological regimes, a distinction is usually made between two major patterns on innovative activities. The first one, called Schumpeter Mark I (SM-I), is characterised by key role played by new firms in innovative activities, whereas in the second one, Schumpeter Mark II (SM-II), this key role is fulfilled by the large and established firms.

The differences between the two regimes are mainly related to differences in the appropriability, cumulativeness and knowledge conditions. Given these differences, industries with different underlying technological regimes are likely to differ with respect to their dynamic and structural properties. For instance, in SM-I industries, we may expect a turbulent and large population of small firms, low profit rates, and low entry barriers. SM-II industries might be characterised by a more stable and small population of large firms, high profit rates, and high entry barriers. The aim of this paper is to test whether these differences actually exist, by using firm-level data on the Dutch manufacturing sector.

This paper has the following structure. The next section presents a brief overview of both theoretical and empirical literature on technological regimes. Section 3 describes the firm-level data used in this paper. These data will be used to test a number of hypotheses, related to the presumed differences between industries with different underlying technological regimes. These hypotheses are formulated in section 4, and tested in section 5. Section 6 concludes this paper.

2. Technological regimes: the interpretative framework

During his life, Schumpeter held two rather different views of the innovative process. The first view, expressed in “The Theory of Economic Development” (Schumpeter, 1912), emphasises the role of new entrepreneurs in the innovative process. By introducing new ideas and innovations, new, small firms challenge the incumbent firms, contributing to what Schumpeter called the process of “creative destruction”. However, the emergence of giant enterprises and industrial research laboratories during the first half of the twentieth century changed Schumpeter’s view of the innovative process. In “Capitalism, Socialism and Democracy” (1942), Schumpeter calls attention to the key role of large firms as engines of economic progress by accumulating non-transferable knowledge in specific technological areas. Hence, his second view of the innovative process could be described as “creative accumulation” (Malerba et al., 1997). According to Freeman (1982), the main difference with Schumpeter’s first view is: ‘... *the incorporation of endogenous scientific and technical activities conducted by large firms. There is a strong positive feedback loop from successful innovation to increased R&D activities setting up a ‘virtuous’ self-reinforcing circle leading to renewed impulses to increased market concentration.*’

Schumpeter’s two views constitute the basis of the two metaphorical archetypes of technological regimes underlying the analysis of this paper. Before turning to the actual differences between these regimes, let us first focus on the individual determinants of technological regimes in general.

To repeat, in line with Breschi et al. (1996) we define a technological regime as a particular combination of opportunity, appropriability, cumulativeness conditions and properties of the knowledge base, common to specific activities of innovation and production and shared by the population of firms undertaking those activities.

Opportunity conditions refer to the likelihood of innovating, given a certain research effort. This may depend on, for instance, the extent to which a sector can draw from the knowledge base, the technological advances of its suppliers and customers, and major scientific advances in universities.

Appropriability conditions reflect the possibilities of protecting innovations from imitation and of appropriating the profits from an innovation. Possible appropriability devices¹ are patents, secrecy, lead times, costs and time required for duplication, learning curve effects, superior sales efforts, and differential technical efficiency due to scale economies.

¹ See Levin et al. (1984).

Cumulativeness conditions refer to the extent to which the innovative successes of individual firms are serially correlated. They are related to the cognitive nature of the learning process (e.g., learning by doing), and depend on the extent which '*...today's technical advances build from and improve upon the technology that was available at the start of the period, and tomorrow's in turn builds on today's.*' (Nelson, 1995).

Finally, with regard to the properties of the knowledge base, Dosi (1988) distinguishes the following three aspects of knowledge: (1) the level of specificity, (2) the level of tacitness, and (3) the extent to which the knowledge is publicly available. The first aspect reflects that knowledge can be universal and widely applicable, or more specific to particular 'ways of doing things'. The second aspect has to do with the extent to which the knowledge is well articulated, or whether it is more tacit, mainly learned through practice. The third aspect relates to the fact that some knowledge is open and public, e.g., scientific and technical publications, whereas other knowledge is more private, because it is protected by secrecy or patents, or simply because it is tacit anyway.

In the literature on technological regimes, two opposite archetypes are usually distinguished. Since opportunity conditions do not necessarily differ between the regimes², the differences between them are mainly related to differences in appropriability, cumulativeness conditions and patterns of access to knowledge. A Schumpeter Mark I regime is characterised by low appropriability and cumulativeness conditions, and the knowledge is mainly specific, codified and simple. In a Schumpeter Mark II regime, these three conditions are reversed: appropriability and cumulativeness conditions are high, whereas the knowledge is mainly generic, tacit and complex.

The main contribution of the technological regime framework is that it suggests an explanation for the observed inter-sectoral variety in the rates and forms of organisation of innovations. Empirical evidence supporting this interpretation can be found in Malerba et al. (1995) and Breschi et al. (1996). By using patent data for four countries (Germany, France, United Kingdom and Italy), Malerba et al. (1995) construct a group of indicators of two Schumpeterian patterns of innovative activities. '*A widening pattern of innovative activity, is related to an innovative base which is continuously enlarging through the entry of new innovators and the erosion of the competitive and technological advantages of the established firms in the industry. A deepening pattern of innovation...is related to the dominance of a few firms which are continuously innovative through the accumulation over time of technological and innovative capabilities.*' (Malerba et al., 1995). Opposite technological regime conditions apply to these two patterns. The widening pattern is determined by a relative 'ease' of innovating, low appropriability and low cumulativeness conditions. This facilitates the continuous entry of new innovators and impedes the persistence of monopolistic advantages. Deepening patterns are also influenced by a relative 'ease' of innovating, but here high appropriability and cumulativeness conditions apply, which facilitates the

² Both high and low opportunity conditions can underlie one of the regimes (i.e., the Schumpeter Mark I regime).

accumulation of technological knowledge and allows innovative incumbents to build up advantages over entrants.

Malerba et al. (1995) group the empirical proxies into four types: concentration of innovative activities, size of the innovating firms, change over time in the hierarchy of innovators, and the relevance of new innovators. After applying these indicators to 33 technological classes, the authors find the following results. First, patterns of innovative activities differ systematically across technological classes. Second, they observe that across countries, remarkable similarities emerge in the patterns of innovative activities for each technological class. In the same technological class the indicators approximately have the same values across countries. Third, two groups of technological classes can be defined, in which innovative activities are organised according to the widening and the deepening patterns of innovative activities. In general, mechanical and traditional sectors show a widening pattern, whereas chemicals and electronics show a more deepening pattern. Especially the second result ‘...*suggests strongly that “technological imperatives” and technology-specific factors (closely linked to technological regimes) play a major role in determining the patterns of innovative activities...*’ (Malerba et al., 1995).³

Breschi et al. (1996) estimate the impact of a number of technological regime variables on patterns of innovation (defined by the specific combination of entry, stability and concentration of the innovating firms) across industries. They find considerable evidence for the existence of a relationship between sectoral patterns of technical change and the nature of the underlying technological regime. Especially the deepening patterns of innovative activities seem to be related to high degrees of cumulateness and appropriability, and high importance of basic sciences relative to applied sciences. Another interesting conclusion is that widening patterns of innovation are associated to either very high or very low opportunity conditions. The authors explain this result by the ambiguous effects of opportunity conditions on concentration. High levels of opportunity facilitate the entry of new innovative firms, which leads to an increase in the population of innovators and thus lower concentration levels. But also low opportunities can have a negative effect on concentration, by impeding the persistence of major differences in innovative rates among firms.

In conclusion, there is considerable evidence for the hypothesis that a relation exists between the pattern of innovative activities in a sector and its underlying technological regime. However, although the previously mentioned authors have used some demographic indicators, they have only employed these indicators to the population of firms registered in patent databases. The question that naturally follows concerns whether a similar relationship exists between the structural and dynamic properties of the full population of firms in an industry and its underlying technological regime.

³ Malerba et al. (1996) perform a similar analysis with a different dataset, however the results are ‘*remarkably consistent*’.

Such a relationship, running in first approximation from the latter to the former, has indeed been suggested by, e.g., Nelson and Winter (1982), Winter (1984) and Dosi et al. (1995). In Dosi et al. (1995), technological regimes (together with ‘market regimes’, indicating the relative speed at which selection occurs) are used to explain the empirically observed intersectoral variety in the industrial structures and dynamics. In the model, each technological regime is defined by the stochastic processes determining the ‘competitiveness’ of entrants and incumbents. For instance, in one regime, called Schumpeter Mark I, the competitiveness of incumbents remains the one they were endowed with at their birth. Hence, in this regime they never learn, as opposed to the Schumpeter Mark II regime. Here, learning by incumbents is highly cumulative: in each period the competitiveness of incumbents is stochastically augmented by a factor that is positively related to their relative competitiveness (i.e., *vis-à-vis* the average competitiveness of the industry). Thus, in Schumpeter II regimes, ‘success breeds success’. Finally, an Intermediate Regime is defined, in which the competitiveness of incumbents essentially follows a random walk with a positive drift.

Interestingly, the simulation results show that within a Schumpeter I regime some intertemporally stable, but lowly concentrated, structures emerge. This is not the case for the other two regimes that display an irregular long-term cyclicity. Moreover, in a Schumpeter II regime the average time that the industries spend in highly concentrated structure is longer than in an Intermediate regime. Hence, disruptions occur less frequently under Schumpeter II, but they induce major discontinuities when they occur. With regard to firm size distributions, the simulations show that the less skewed size distribution appear under Schumpeter I regimes, whereas the most skewed appear under Schumpeter II.

Besides these comparisons between the three regimes, the experiments by Dosi et al. (1995) also allow for an analysis of different parameter settings within the regimes. Three parameters are considered here: the technological opportunities for incumbents, the technological opportunities for entrants, and the level of market selection. In general, higher opportunities for incumbents lead to a smaller population of firms, higher concentration, and lower market turbulence.⁴ Higher technological opportunities for entrants lead to exactly opposite results: a higher number of firms, lower concentration, and higher market turbulence. Finally, a higher level of market selection has a negative effect on the number of firms, and a positive effect on concentration.⁵ Hence, higher selective market forces (more ‘efficient’ markets) ‘...*tend to yield, in evolutionary environments, more concentrated market structures, rather than more “perfect” ones in the standard sense.*’ (Dosi et al., 1995). In conclusion, this model clearly displays a relationship between the structural and dynamic properties of an industry and its underlying technological regime.

Since our aim is to establish the same relationship empirically, the present paper is in a sense the empirical counterpart of Dosi et al. (1995). In section 4, a number of

⁴ Measured as the sum of the absolute changes in market shares.

⁵ No clear relationship was found between market selection and turbulence.

hypotheses will be derived to test whether the relationship between regimes and industrial properties indeed exists. However, let us begin by describing the data (which unfortunately restrict the testability of some hypotheses, especially those with regard to the entry and exit of firms).

3. The data

The Statistics Netherlands manufacturing database that is used here captures all firms with more than twenty employees (working 15 hours or more weekly) that have been active in the Dutch manufacturing sector between 1978 and 1992. Furthermore, it contains 4,415 observations of firms employing less than twenty employees. Some of these observations represent firms that are initially or ultimately below the threshold of twenty employees, but also about 600 firms that stay below twenty employees throughout their presence are included.

In total, there are 84,248 observations representing 10,011 firms, of which 2,838 firms are present throughout the whole period. These continuing firms on average capture 57.3 and 55.5 % of respectively total manufacturing employment and sales. The remaining firms are only temporarily present in the dataset; on average they are observed for 5.5 years. Although these firms enter and exit the database, defining them as entrants and exiters is not appropriate in most of the cases. For the period from 1986 and onwards, Statistics Netherlands provides information about the specific reasons why firms enter or exit the database. The majority of the entering and exiting firms appear or disappear because of passing the threshold of twenty employees. On average, only 8.9 % and 21.1 % of the firms entering and exiting the database are respectively greenfield entrants and closedown exiters. Unfortunately, the data do not allow us to distinguish them.

4. Hypotheses

As mentioned in section 2, previous empirical research used data on innovation activities performed by the firms to study the technological regime of an industry. For instance, Breschi et al. (1996) found that sectoral patterns of technological change, like concentration and turbulence of the population of the innovating firms, were related to the underlying technological regime. Unfortunately, the dataset used here does not include variables indicating the innovative activities of the firm. Hence, in order to test whether the technological regimes are related to the structural and dynamic properties of the industries, we need another criterion for dividing the industries into a SM-I group and a SM-II group. The classification of industries into “regimes” that follows is an indirect implication of Breschi et al. (1996) and is also part of the “reduced form” formalisation in Dosi et al. (1995).

Given the conditions of the SM-I regime, i.e., low levels of appropriability and cumulateness and open, codified and relatively simple knowledge, this regime prevents the persistence of monopolistic advantages and is therefore relatively more favourable to entrants than to incumbent firms. Conversely, the high levels of appropriability and cumulateness conditions and the generic, tacit and complex knowledge of the SM-II regime allow incumbents to continuously accumulate knowledge and capabilities and hence create circumstances unfavourable to entering firms. A meaningful criterion should display this difference between the regimes with regard to the conditions being more favourable to entrants than to incumbents, or *vice versa*. We therefore propose the average labour productivity⁶ of successful entrants relative to the average labour productivity of incumbents as a demarcation criterion between the two regimes, because it reflects the (*ex post*) difference between them with respect to the performance or competitiveness of incumbents *vis-à-vis* new firms.

Using labour productivity as an indicator for the performance of a firm, we define an industry as a SM-I industry if in that industry the average productivity of successful entrants is higher than the average productivity of incumbents. Conversely, an industry is SM-II if the average productivity of incumbents is higher than the productivity of successful entrants. According to this criterion, our total sample of 106 industries is divided in 58 SM-I industries and 48 SM-II industries.

Given the differences in the appropriability, cumulateness and knowledge conditions, industries with different underlying technological regimes are likely to differ with regard to a number of indicators. These expected differences could be classified in two major categories. The first category consists of static measures, like the firm size distribution, the second category more reflect the dynamic properties of the industry, e.g., the process of entry and exit. We will first derive some hypotheses related to inter-industry differences with respect to both set of variables.

According to Malerba et al. (1995), a typical SM-I industry is characterised by the presence of many small firms and low entry barriers. Furthermore, the constant inflow of new entrepreneurs with new ideas, products and processes continuously challenge the established firms and wipe out their quasi rents associated with previous innovations. In SM-II industries, this situation is reversed: large firms prevail, entry barriers are high, and the high profit rates of incumbent firms are persistent. Additionally, Audretsch (1997) suggests that the degree of capital intensity also shapes the technological regimes: a routinised technological regime (which resembles a SM-II regime) is more capital intensive than an entrepreneurial technological regime (SM-I regime). These characterisations allow us to derive the following hypotheses:

⁶ The average labour productivity is calculated as follows. First, for each firm the average labour productivity (real value added over number of employees) over its whole observation period is calculated. Second, per industry the (unweighted) means of the firms' average labour productivity is calculated, both for the group of continuing firms as well as for successful entrants. A continuing firm is defined as a firm present in the dataset in 1978 and in 1992, a successful entrant is defined as a firm present in 1992, but not in 1978.

1. The share of small firms⁷ is higher in SM-I industries than in SM-II industries.
2. Concentration levels are lower SM-I industries than in SM-II industries.
3. Entry barriers are lower in SM-I industries than in SM-II industries.
4. Capital intensity is lower in SM-I industries than in SM-II industries.
5. In SM-I industries, profit rates are lower than in SM-II industries.
6. The profit rates of incumbents are lower in SM-I industries than in SM-II industries, whereas the profit rates of entrants are higher in SM-I industries than in SM-II industries.
7. In SM-I industries, entrants are more profitable than incumbents, whereas in SM-II industries incumbents are more profitable than entrants.

This last hypothesis reflects the relative advantage that entrants should have over incumbents in SM-I industries, and vice versa for SM-II industries. Hence, this hypothesis tests for differences between entrants and incumbents *within* each technological regime. Hypothesis 6, however, compares the differences within the group of entrants and the group of incumbents *between* the technological regimes. Given the patterns of knowledge accumulation in the two regimes, entrants in SM-I industries should be more successful than entrants in SM-II industries, and *vice versa* for incumbents.

With respect to dynamic properties of industries with different underlying technological regimes, section 2 already mentioned the observed difference in the stability of the population of innovating firms (see Malerba et al., 1995). Here, the focus will be on all firms in the dataset, regardless of their patenting behaviour. Differences in the stability of this population can be measured by looking at the amount of turnover (in terms of shifts in market shares) due to entry and exit. Moreover the turbulence within the group of incumbent firms can be examined here: SM-I industries are expected to show a less stable population of incumbent firms than SM-II industries. This leads to the following hypotheses:

8. In SM-I industries, the amount of turnover due to entry and exit rates is higher than in SM-II industries.

⁷ The statistical definition shall be presented in section 5.

9. The turbulence within the group of incumbent firms is higher in SM-I industries than in SM-II industries.

Another potential difference between the two groups of industries is likely to be the share of entrants and incumbents in the total growth in productivity. Given the nature of the two regimes, we can expect the contribution of entrants to productivity growth to be higher in SM-I industries, and the contribution of incumbents to be higher in SM-II industries. Hence, we can derive the following hypothesis:

10. The contribution of entrants to productivity growth is higher in SM-I industries than in SM-II industries, and *vice versa* for incumbents.

Before turning to the next section, in which the hypotheses will be tested, a final remark should be made about one important limitation of the data. It was mentioned in section 3 that only firms with more than twenty employees are fully represented in the data. The consequence of this is that what we call entering and exiting firms are mainly firms crossing the observation threshold. It might seem awkward then to propose a number of hypotheses related to the process of entry and exit. However, if for instance the regime of an industry is favourable to new and small firms, it is likely that it is easier for these firms to grow and pass the observation threshold than in an industry with a regime favourable to large and established firms. To put it stronger, excluding firms with less than twenty employees, even if involving an inevitable censoring of observations, is not likely to distort neither the classification of industries into the two regimes, nor their associated characteristics. Therefore, there is reason to believe that if there are differences between industries with different underlying technological regimes, these differences will be statistically significant, regardless of whether the firm observation threshold is set at twenty, at ten, or at zero employees.

5. The hypotheses tested

For every hypothesis, we will calculate the means of the relevant variables for the two groups of industries, and test whether the differences between the means are in line with the hypothesis tested and whether the means are significantly different between SM-I and SM-II industries. In the tables that follow, the specific variables used for testing the hypothesis can be found in the first column. In the second and third column the means of these variables are listed for both groups of industries, together with their standard errors. The rest of the table shows the output of a *t*-test of the null hypothesis that the means of the different groups of industries are the same. Because the *t*-statistic can only be computed if the variances of the two populations are equal, an *F*-test is performed to test the hypothesis that the sample variances are equal. The value of the *F*-statistic (the highest sample variance divided by the lowest sample variance) is listed in the fourth column. Between brackets the corresponding *p*-values can be found,

indicating the significance level at which the observed F value is not significant (given the degrees of freedom).

When this p -value is higher than 0.05, the hypothesis that the sample variances are equal is accepted. The t -statistic (of the hypothesis that the true means of the different groups of industries are the same) is then calculated on the basis of a pooled-variance estimate. If the p -value is lower than 0.05, the hypothesis that the sample variances are equal is rejected, implying that the t -statistic cannot be computed for the difference in sample means. In that case, an approximation of t is computed, based on a separate variance estimate. In column five the value of the t -statistic is listed. The corresponding p -value can be found between brackets, indicating the probability of the occurrence of a value larger than t . The lower this p -value, the less likely it is that the true means of the groups of industries under consideration are the same. An asterisk indicates that t is approximated.

Hypothesis 1: *The share of small firms is higher in SM-I industries than in SM-II industries.*

The share of small firms, here defined as firms having less than 100 employees, can be measured as the annual mean of their share in the total population of firms (MNSMFPRS), or as the annual mean of their share in total industrial sales (MNSMFRSL). These variables, expressed in percentages, are listed in table 1.

Table 1 Variable	Mean (standard error)		Group means T-test	
	Schumpeter Mark 1	Schumpeter Mark 2	F-statistic (p-value)	T-statistic (p-value)
MNSMFPRS	71.3 (2.19)	64.5 (3.08)	1.64 (0.08)	1.84 (0.07)
MNSMFRSL	38.0 (2.94)	29.3 (3.39)	1.10 (0.74)	1.94 (0.06)

As the results in table 1 show, there is considerable evidence for this hypothesis: the share of small firms is significantly higher in SM-I industries.

Hypothesis 2: *Concentration levels are lower in SM-I industries than in SM-II industries.*

To test this hypothesis we calculated for each industry two concentration measures. The first is the annual mean of the Herfindahl-index (MNERHIN), which is the weighted average of the market shares of all firms in the industry (the market shares are used as the weights). The second is the annual mean of the total market share of the largest four firms in the industry (MNCR4SHR).

Variable	Mean (standard error)		Group means T-test	
	Schumpeter Mark 1	Schumpeter Mark 2	F-statistic (p-value)	T-statistic (p-value)
MNHERFIN	12.1 (1.96)	13.8 (1.61)	1.78 (0.04)	-0.68 (0.50)*
MNCR4SHR	47.8 (2.71)	54.4 (3.41)	1.32 (0.32)	-1.52 (0.13)

* approximated

As table 2 shows, there are no significant differences between SM-I and SM-II industries with regard to concentration levels, hence rejecting the hypothesis.

Hypothesis 3: *Entry barriers are lower in SM-I industries than in SM-II industries.*

Hypothesis 4: *Capital intensity is lower in SM-I industries than in SM-II industries.*

Advertising intensity, capital intensity, and the minimum efficient scale of an industry are often considered as important entry barriers. We cannot test for differences with regard to advertising intensity, since advertising expenditures are not in our data set. Also, there are no data on the capital stock of firms in our set; however we can roughly approximate capital intensity by the annual mean of the ratio of investments to sales (MNRLINV). Finally, a proxy for the minimum efficient scale is the median plant size of the industry (MEDSIZE).

Variable	Mean (standard error)		Group means T-test	
	Schumpeter Mark 1	Schumpeter Mark 2	F-statistic (p-value)	T-statistic (p-value)
MNRLINV	5.89 (0.27)	6.78 (0.39)	1.72 (0.05)	-1.91 (0.06)
MEDSIZE	68.6 (7.01)	86.3 (8.85)	1.32 (0.31)	-1.59 (0.11)
SURVRATE	73.1 (2.71)	65.5 (3.79)	1.62 (0.08)	1.67 (0.10)

* approximated

As table 3 shows, in SM-I industries “capital intensity” (as proxied here) indeed appears to be lower than in SM-II industries. Further, there is some weak evidence that the median size of firms in SM-I industries is lower than in SM-II industries. Hence, the evidence for hypothesis 3 is rather strong when *ex ante* measures of entry barriers are applied. By using the proxy for capital intensity as an indicator for entry barriers, hypothesis 4 was automatically tested as well, and accepted. We also measured entry barriers *ex post* by calculating for each industry the number of successful entrants (firms

not present in 1978, but still present in 1992) relative to the total number of entrants over the whole period (SURVRATE). Measured in this way, entry barriers are higher in SM-II industries than in SM-I industries at the 10 percent significance level.

Hypothesis 5: *Profit rates in SM-I industries are lower than in SM-II industries.*

Hypothesis 6: *The profit rates of incumbents are lower in SM-I industries than in SM-II industries, whereas the profit rates of entrants are higher in SM-I industries than in SM-II industries.*

Hypothesis 7: *In SM-I industries, entrants are more profitable than incumbents, whereas in SM-II industries incumbents are more profitable than entrants.*

For measuring profitability, we use the annual mean of the ratio of gross profit to sales. For testing hypothesis 5, the mean of this ratio of all firms in the industry is calculated (MNRLPROF). For hypotheses 6 and 7, we use respectively the mean of this ratio of all continuing firms (INCRPROF), and of all successful entrants (ENTRPROF) in each industry. The results, expressed in percentages, are listed in the table 4.

Variable	Mean (standard error)		Group means T-test	
	Schumpeter Mark 1	Schumpeter Mark 2	F-statistic (p-value)	T-statistic (p-value)
MNRLPROF	8.13 (0.40)	9.72 (0.49)	1.28 (0.37)	-2.55 (0.01)
INCRPROF	8.51 (0.44)	10.5 (0.79)	2.64 (<0.01)	-2.23 (0.02)*
ENTRPROF	12.5 (1.00)	7.82 (2.18)	3.82 (<0.01)	1.97 (0.05)*

* approximated

Hypothesis 5 is accepted: the average profitability in SM-I industries is significantly lower than in SM-II industries. The same applies to hypothesis 6: profit margins of incumbents are significantly lower in SM-I industries than in SM-II industries, while profit margins of entrants are significantly higher in SM-I industries than in SM-II industries. Note, however, that compared to the other values, the standard error of the mean of average profitability of successful entrants in SM-II industries is remarkably high, hence weakening the evidence for hypothesis 7. Within the group of SM-I industries, entrants are significantly more profitable than incumbent firms, which is confirmed by a paired groups *t* test. For each industry, the difference between INCRPROF and ENTRPROF was calculated. Subsequently, for SM-I and SM-II industries the mean of these differences was computed. For SM-I industries, the hypothesis that the true means of these differences are equal to zero was rejected (the *t*-value is equal to -3.79). However, for SM-II industries the same hypothesis could not be

rejected, given the t -value of 1.14. Hence, incumbents do not appear to be significantly more profitable than entrants in SM-II industries.

Hypothesis 8: In SM-I industries, the amount of turnover due to entry and exit rates is higher than in SM-II industries.

There are two ways of measuring the magnitude of the process of entry and exit. The first one simply measures annual firm entry and exit rates, by counting the number of entering and exiting firms and dividing them by the total number of firms active in the industry. Accordingly, the share of sales of entering and exiting firms in total industrial sales can be calculated for each year in order to measure annual sales entry and exit rates. In the table 5, the industrial means of the annual firm entry and exit rates (ENTRYRT and EXITRT), as well as the industrial means of annual sales entry and exit rates (ENSALERT and EXSALERT), all in percentages, are listed in table 5.

Variable	Mean (standard error)		Group means T-test	
	Schumpeter Mark 1	Schumpeter Mark 2	F-statistic (p-value)	T-statistic (p-value)
ENTRYRT	8.72 (0.62)	8.36 (0.59)	1.32 (0.32)	0.41 (0.68)
EXITRT	8.40 (0.61)	8.22 (0.51)	1.74 (0.05)	0.22 (0.83)
ENSALERT	4.57 (0.38)	3.45 (0.40)	1.09 (0.77)	2.00 (0.05)
EXSALERT	4.71 (0.46)	3.38 (0.34)	2.21 (0.01)	2.26 (0.02)

The second way is to measure cumulative entry and exit rates. These measures reflect the significance of entry and exit in the long run. The cumulative entry rate is the share of entrants in the total number of firms (ENRTRTCM) or total sales (SLENRTCM) at the end of a given period, i.e., 1992. The cumulative exit rate is the share of exiting firms in the total number of firms (EXRTRTCM) or total sales (SLEXRTCM) at the beginning of the period, i.e., 1978. The means of these variables, in percentages, are listed in table 6.

Variable	Mean (standard error)		Group means T-test	
	Schumpeter Mark 1	Schumpeter Mark 2	F-statistic (p-value)	T-statistic (p-value)
ENRTRTCM	47.7 (2.14)	41.7 (2.89)	1.47 (0.16)	1.68 (0.09)
EXRTRTCM	48.3 (1.67)	42.6 (2.46)	1.64 (0.08)	1.78 (0.08)
SLENRTCM	34.6 (2.30)	23.5 (2.98)	1.37 (0.26)	3.00 (<0.01)

Variable	Mean (standard error)		Group means T-test	
	Schumpeter Mark 1	Schumpeter Mark 2	F-statistic (p-value)	T-statistic (p-value)
SLEXRTCM	36.2 (2.92)	27.1 (3.15)	1.03 (0.94)	2.12 (0.04)

Annual firm entry and exit rates do not differ significantly between the two groups of industries. However, annual sales entry and exit rates are indeed higher in SM-I industries than in SM-II industries. With respect to cumulative entry and exit rates, the evidence is stronger. Both measures differ between the two groups at the 10 percent significance level. The cumulative entry and exit sales rates are different between SM-I and SM-II industries at the 5 percent significance level. Therefore, both for the short and the long term perspective there is considerable evidence that the amount of turnover due to entry and exit rates is higher in SM-I industries than in SM-II industries.

Hypothesis 9: The turbulence within the group of incumbent firms is higher in SM-I industries than in SM-II industries.

Two measures are proposed here. The first one (SLSRTURB) measures the short run turbulence within the group of incumbent firms. For each year and for each continuing firm (i.e., firms present in 1978 and 1992), the absolute change in market share is calculated. Next, for each industry the sum of the absolute changes in market shares is computed for each year. Finally, the annual mean of the sum of changes is calculated for each industry. The second measure (SLLRTURB) measures the long run turbulence. For each continuing firm, the absolute change in market share between 1978 and 1992 is calculated. The long run turbulence of an industry is then equal to the sum of absolute market share changes of the continuing firms within that industry. The results are listed in table 7.

Variable	Mean (standard error)		Group means T-test	
	Schumpeter Mark 1	Schumpeter Mark 2	F-statistic (p-value)	T-statistic (p-value)
SLSRTURB	13.8 (0.93)	10.8 (0.47)	4.70 (<0.01)	2.93 (<0.01)*
SLLRTURB	26.2 (1.45)	25.3 (1.71)	1.15 (0.61)	0.40 (0.69)

* approximated

Only when measured in the short run, the amount of turnover is significantly higher in SM-I industries than in SM-II industries. The long run measures of turbulence are approximately equal for the two groups of industries.

Hypothesis 10: *The contribution of entrants to productivity growth is higher in SM-I industries than in SM-II industries, and vice versa for incumbents.*

Baldwin (1995) provides an elegant way of calculating the contribution of entering, exiting and continuing firms to the total productivity growth of an industry in a given period. The total growth of labour productivity (TOT) between 1978 and 1992 can be expressed in the following way:

$$\begin{aligned} \text{TOT} = & \text{SHEN92} \times (\text{APEN92} - \text{APEX78}) + \text{SHIN92} \times (\text{APC92} - \text{APC78}) \\ & + (\text{SHIN92} - \text{SHIN78}) \times (\text{APC78} - \text{APEX78}) \end{aligned}$$

where SHEN92 is the labour share⁸ of entrants in 1992, SHIN78 and SHIN92 the labour shares of continuing firms in 1978 and 1992. APEN92 and APEX78 denote the real value added per worker for respectively entrants in 1992 and exiters in 1978. Finally, APC78 and APC92 are the real value added per worker for continuing firms in respectively 1978 and 1992.

In this expression, assuming that the share of continuing firms in total industrial employment is held constant, the first term (DIFENEX) captures the change due to the difference in productivity between entrants and exiters and the second term (PROGCONT) reflects the growth in productivity due to progress in continuing firms. The effect of actual share changes is captured by the third term (SHARECHS).

For each industry with positive productivity growth⁹, we calculated the three terms and divided them by total productivity growth in order to get their shares in total productivity growth. In table 8 the mean values for the three terms are listed (standard error of the mean in parentheses), for both groups of industries.

Table 8	Mean (standard error)		Group means T-test	
	Schumpeter Mark 1	Schumpeter Mark 2	F-statistic (p-value)	T-statistic (p-value)
DIFENEX	60.7 (12.2)	19.4 (4.45)	9.81 (<0.01)	3.17 (<0.01)*
PROGCONT	42.3 (9.42)	76.2 (5.78)	3.45 (<0.01)	-3.07 (0.04)*
SHARECHS	-3.03 (7.10)	4.35 (4.38)	3.41 (<0.01)	-0.88 (0.38)*

* approximated

⁸ The labour share of, e.g., entrants in 1992 is equal to the number of workers employed by successful entrants in 1992 divided by the total number of employees in the industry in 1992.

⁹ This restriction ruled out 6 SM-I industries and 8 SM-II industries, but this had only little impact on the outcomes.

If we compare the difference in the contribution of entrants and incumbents between the two regimes, we find support for hypothesis 10. The contribution to total productivity growth of entrants is significantly higher in SM-I industries than in SM-II industries, and conversely for SM-II as compared to SM-I industries. The results also indicate that within the group of SM-I industries, the contributions by entrants and continuing firms to total productivity growth are not significantly different. This is confirmed by a paired groups t test, similar to the one applied at testing hypothesis 5 (t -value equal to 0.89). However, within the group of SM-II industries, the contribution by entering firms is much lower than the contribution made by incumbents (t -value equal to -6.08).

6. Conclusions

The main conclusion from the analysis of the previous section is that the results indeed suggest that the structural and dynamic properties of the industries are strongly related to their underlying technological regimes. Obviously, the two groups of industries show considerable differences with regard to most of the selected variables, which in all cases have the right sign, and thus corroborate the hypotheses. For only a few variables the differences are not significant.

With regard to firm size distribution, we have found considerable evidence for the hypothesis that the share of small firms is higher in SM-I industries than in SM-II industries. However, no significant differences were found for the concentration levels of industrial sales. The two groups of industries showed a slight difference with respect to the median firm size; however, using a proxy for capital intensity as an alternative measure for entry barriers provides some stronger, although circumstantial evidence that entry barriers are higher in SM-II industries than in SM-I industries. Further, overall profitability is significantly higher in SM-II industries, and incumbent firms in SM-II industries are more profitable than incumbents in SM-I industries, whereas the opposite holds for entrants. Within SM-I industries, entrants are more profitable than incumbents. Within SM-II industries however, incumbents are not significantly more profitable than entrants.

With regard to the dynamic measures, we have found that both short run as long run indicators show that the amount of turnover due to entry and exit is higher in SM-I industries than in SM-II industries. Interestingly, however, this goes together with the evidence that the annual firm entry and exit rates did not differ significantly between the two groups of industries.

The measures of turbulence within the group of incumbent firms showed some mixed results. This variable was only significantly different when measured as year to year changes. If the full period was taken into account, the turbulence within the group of incumbents is approximately the same for SM-I and SM-II industries. Finally, the

contribution of entrants to total productivity growth is higher in SM-I industries than in SM-II industries, whereas incumbents contribute much more to total growth of productivity in SM-II than in SM-I industries.

These results show that technological regimes explain to a considerable extent differences between industries with regard to their structural and dynamic properties. Admittedly, the caveat here is that we used the average productivity of successful entrants relative to the productivity of incumbents in an industry as a proxy for its underlying technological regime. But given the nature of the two stylised technological regimes considered here, the (*ex post*) performance of entrants relative to incumbents is reasonable proxy for assessing the relative favourable conditions of a regime towards small and new firms, or towards large and established firms in the opposite regime.

Further analyses, directly using proxies for the actual opportunity, appropriability, cumulativeness and conditions of knowledge accumulation, would certainly provide a stronger basis for testing whether technological regimes explain the observed differences between industries. However, the results of the present analysis are in our view strong enough to support to '*...interpretations leaning toward an evolutionary approach [which] emphasize sector/technology-specific patterns and invariances in the way agents learn...as determinants of both structures and dynamics.*' (Dosi et al., 1997). Obviously, many open questions remain, but we hope that the analysis presented here has provided more evidence on the links between technological regimes, patterns of innovation and industrial dynamics.

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