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Keywords: Intensity of competition, mobility barriers, sunk costs, selection dynamics, firm growth, reallocation
JEL Codes: L11, D24, B52

1 Introduction

This paper studies the effect of mobility costs on competitive selection. Sunk costs are a special element of mobility costs, playing an important role in many models of industrial dynamics. Most models of selection-based theories of competition (e.g. Friedman 1953) are based on the reallocation of market shares. These models also figure prominently in evolutionary economics (e.g. Nelson and Winter 1982; Metcalfe 1998). The reallocation mechanism is simple: More efficient firms gain market shares at the expense of less efficient firms, where efficiency is defined in the context of the selection environment. However, newer empirical evidence suggests that market share reallocation is less important than previously assumed in selection-based theories of competition (e.g. Bottazzi, Dosi, Jacoby, Secchi, and Tamagni 2010). The main purpose of the paper is to assess this claim by analyzing how selection dynamics change when there are substantial mobility barriers and by determining what this implies for our understanding of competitive interaction.

In models of industrial dynamics mobility barriers are often conceptualized as sunk entry costs. Barriers to entry can be given structurally (technology) or created by strategic interaction (Sutton, 1998). In sunk cost models of industry dynamics, sunk entry costs determine the entry behavior of new firms, while affecting the exit behavior of incumbents. Thus, sunk costs are mobility barriers, because they constitute both entry barriers for new firms and exit barriers for incumbents (e.g. Caves and Porter 1977; Eaton and Lipsey 1980; Dixit 1989).

While most of the literature on sunk costs focuses on entry and conceptualizes sunk costs as independent of firm size, we consider sunk costs as sunk capacity costs that are proportional to capacity (e.g. Cabral 1995) and introduce them into a simple evolutionary model of economic selection. The rationale behind this is that the degree of 'sunkness' appears to be quite high for physical and intangible assets. For example, Asplund (2000) reports that the sunk cost component ranges between 50 and 80 percent for metalworking machinery. Ramey and Shapiro (2001) report similar salvage values of capital assets in the US aerospace industry. The specificity of many capital goods limits the market for used capital goods. The same is true for organizational capital, organizational routines and goodwill capital, because the costs of assembling an organizational structure and the associated routines or goodwill of the consumer are lost when, at the firm's closing, the employees go their separate ways and the products are no longer produced. However, these are better conceptualized as mobility barriers than true sunk costs. By using the model of pure selection dynamics proposed by Metcalfe (1994; 1998; 2002), we show that the presence of capacity related sunk costs slows down the speed of market selection. The empirical relevance of the theory is tested using micro-aggregated data for Austrian industries.

The paper is structured as follows: In the next section we present the theoretical model and establish the result that higher sunk costs (mobility barriers) are associated with a lower speed of economic selection. The third section presents an attempt to test the relationship by focusing on the prediction that the share of stable firms with marginal growth rates (rates of decline) is higher in industries characterized by higher sunk costs. Section 4 discusses implications of the theoretical results. We argue that our results can contribute to the explanation of the low contribution of reallocation to overall productivity growth. Section 5 concludes the paper.

2 Sunk costs in a model of selection dynamics

2.1 The set up

The basic framework is derived from the model proposed by Metcalfe (1994; 1998; 2002). We abstract from entry and exit behavior in order to isolate the effect on selection dynamics.

There are N heterogeneous firms which produce a homogeneous product at a firm-specific unit cost c_k, $k \in \{1,..,N\}$. We assume that, *ab origine*, firms do not deviate from the constant returns to scale process. Routines are assumed to be permanent.[1]

Only viable firms remain in the market. Firms are indifferent between operating and exiting the market when the loss incurred due to operating is equal to the exit cost associated with the sale of the assets and closing. The viability rule partitions all firms into viable and non-viable firms:

$$\begin{aligned} x_k > 0 \qquad & \text{if} \qquad p_k \geq e_k \\ x_k = 0 \qquad & \text{if} \qquad p_k < e_k \end{aligned} \tag{1}$$

where x_k is the quantity produced by a firm k, p_k the price and $e_k = \eta(c_k)$ with $0 < \eta < 1$ the fraction of costs that are not sunk. It may seem odd to discuss sunk costs without taking into account that sunk costs are usually fixed costs, but this formulation highlights that sunk costs and indivisibility are not different sides of the same coin. Fixed investment costs introduce different complications that are relevant, but not related to the primary objective of the paper. In addition, we assume that capacity can be adjusted in a marginal way. This assumption is certainly not realistic as adjustment is generally lumpy and occasional.

The accumulation rule states that profitable firms ($p_k > c_k$) expand their capacity according to their propensity to accumulate f:

$$g_k = \frac{\dot{x}_k}{x_k} = f[p_k - c_k] \quad \text{if } p_k > c_k \tag{2}$$

[1] The relaxation of this assumption would require the specification of specific knowledge diffusion and innovation dynamics (see e.g. Silverberg, Dosi, and Orsenigo 1988; Cantner 2002). In the discussion of the results we will relax this assumption.

$$g_k = \frac{\dot{x}_k}{x_k} = 0 \qquad \text{if } p_k \leq c_k,$$

where g_k denotes the growth rate of firm k.

Consumers switch between firms according to an impersonal customer flow model which takes into account the informational imperfection of the market, market shares and the fact that consumers switch to a new firm if this firm charges a lower price. The demand rule reads:

$$g_{dk} = \frac{\dot{x}_{dk}}{x_{dk}} = \frac{\dot{x}_D}{x_D} + \delta[\bar{p}_v - p_k]. \tag{3}$$

These three rules allow us to divide the firms into four groups. Figure 1 provides an overview on the partitioning of firms. The survival rule splits all firms in the market into surviving firms ($p_k \geq e_k$) and non-viable firms ($p_k < e_k$). The accumulation rule and the demand rule split the remaining population of firms into the group of marginal firms ($g_k < 0$), stationary firms ($g_k = 0$) and dynamic firms ($g_k > 0$).

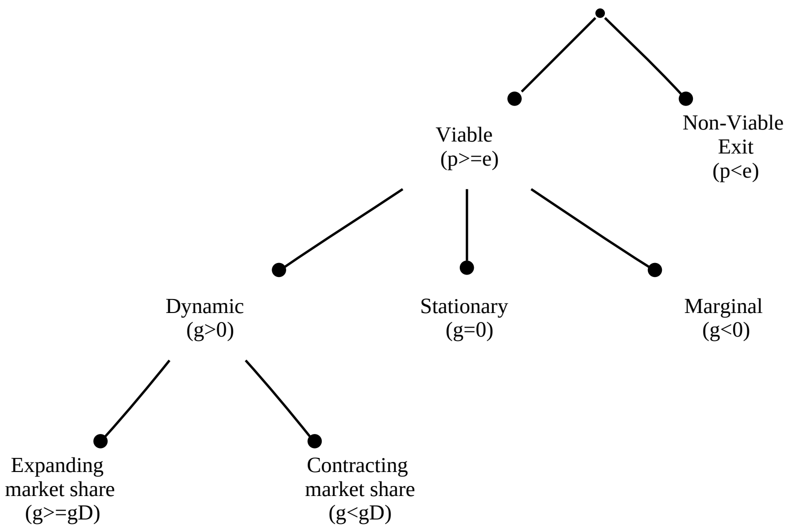

Figure 1: The partitioning of firms in the market when firms differ in unit costs and there are sunk costs

In order to investigate the aggregate selection process in the industry we need to analyze the dynamics of these three groups. Let us denote the market shares in the dynamic group with s_i, the market shares in the marginal group with m_j and the market shares in the stationary group with n_ℓ. In order to study pricing and growth we have to introduce market shares at the group level. The relationships between the market shares are:

$$\sum_k v_k = \sum_i s_i = \sum_\ell n_\ell = \sum_j m_j = 1$$

and

$$\theta_s \sum_i s_i = \sum_i v_i, \quad \theta_n \sum_\ell n_\ell = \sum_\ell v_\ell, \quad (1 - \theta_s - \theta_n) \sum_j m_j = \sum_j v_j$$

where θ_s is the market share of dynamic firms in total output and θ_n the market share of stationary firms. The market share of marginal firms is equal to $(1 - \theta_s - \theta_n)$. The changes in these shares measure market share reallocation trough competition. Market growth is related in the following way to the combined growth rates of the three groups: $g_D = \theta_s \bar{g}_s + \theta_n \bar{g}_n + (1 - \theta_s - \theta_n)\bar{g}_m$, where $\bar{g}_s$ is the average growth rate in the dynamic group, $\bar{g}_n$ the average growth rate in the stationary group and $\bar{g}_m$ the growth rate in the marginal group. The growth rate of the stationary group is zero by definition, so that the relationship between the growth rate of demand and the average growth rates within the groups is

$$g_D = \theta_s \bar{g}_s + (1 - \theta_s - \theta_n)\bar{g}_m. \tag{4}$$

2.2 Pricing behavior

The pricing behavior at the level of the groups is given by: Marginal firms do not invest, as they have no profits. They incur losses - that is, they do not pay any money to their shareholders and price according to the cost corrected for the sunk cost component $e_k < c_k$. The average price charged in the marginal group is equal to

$$\bar{p}_m = \sum_j m_j e_j = \bar{e}_m.$$

Stationary firms neither grow nor decline. Stationary firms are defined by their growth rate $g_\ell = 0$. They operate at full capacity, but do not invest. From equation (3) it follows that all stationary firms charge the population-averaged price $\bar{p}_v$. This is the only price that leads to a growth rate of zero:

$$\bar{p}_n = \bar{p}_v.$$

In terms of costs, stationary firms are located between dynamic firms and marginal firms: $c_n \leq c_\ell < e_n$.

Dynamic firms have a more complicated pricing rule, as these make positive profits and invest in new production capacities. By combining equations (2) and (3) we obtain the equilibrium condition of the pricing behavior for dynamic firms. Solving this expression for p_i yields the normal pricing behavior for a dynamic firm:

$$p_i = \frac{g_d + \delta \bar{p}_v + f c_i}{f + \delta}$$

This mark-up pricing rule depends on the growth rate of the market, own cost and the prices set by competitors. The behavior associated with this mark-up formula is rational in the sense that any higher price would result in excess capacity, given the rules of accumulation and market selection. By eliminating the average market price from the pricing equation for dynamic firms and carrying out some manipulations (see Appendix 1) we obtain

$$p_i = \frac{g_D}{f} + \frac{\delta(1-\frac{\theta_s}{1-\theta_n})}{f+\delta(1-\frac{\theta_s}{1-\theta_n})}[(\bar{e}_m - \bar{c}_s) - g_D] + \frac{\delta}{f+\delta}\bar{c}_s + \frac{f}{f+\delta}c_i. \quad (5)$$

The interaction in pricing behavior between firms is captured by the market share weighted average unit costs. The pricing behavior of the dynamic firms highlights the interdependency of the pricing behavior between all types of firms. The pricing equation depends on market expansion, the presence of marginal and stationary firms, the unit cost level in the dynamic group and the own unit costs level.

2.3 Sunk costs and the speed of selection

When we compare equation (5) to the benchmark case of no sunk costs, that is, when $\bar{e}_m$=$\bar{c}_m$ and $\theta_n = 0$, we see that the only difference to the no sunk cost case relates to the second expression in equation (5). Even if all parameters were the same - in other words if c_s, g_D, the distribution of c_i among potential firms in the market, δ and f as well as the output of the industries are exactly same between the two industries in a specific point in time t - the price set by the dynamic firms in the sunk cost industry will be higher, because the difference between costs $\bar{e}_m - \bar{c}_s$ is larger in the sunk cost industry. Furthermore, there will be more firms operating in the sunk cost industry and θ_s would therefore not be the same across the two industries. Thus, the price of dynamic firms is higher in the sunk cost industry, but the no sunk cost industry is at a different stage of the selection process, as stationary and marginal firms have a higher market share in the sunk cost industry than in the no sunk cost benchmark industry.

To illustrate this let us consider without much loss of generality the case of an informationally perfect market, where $\delta = \infty$. When the market is informationally perfect the law of one price holds, which implies a price of

$$p_i = \bar{p}_s = \frac{g_D}{f} + \bar{c}_s.$$

In this case, there are no marginal firms in the market, as they are not viable.

Let us now compare the two industries at one specific point in time. We denote the sunk cost industry with the superscript S and the industry without sunk costs with the superscript NS. Assume that the prices and aggregate output in the two industries at one specific point in time t_0 are identical. In a perfect market the presence of stationary firms with positive output level has no impact on the price. With identical distribution of unit costs it must hold that the average unit cost level in the dynamic groups is also the same at the specific point in time t_0:

$$\bar{c}_s^S(t_0) = \bar{c}_s^{NS}(t_0).$$

From this it follows that, as the growth rate of the stationary firms is equal to zero, the growth rates of the dynamic firms are equal to the market growth, $\bar{g}_s^S(t_0) = \bar{g}_s^{NS}(t_0) = g_D(t_0)$. However, note that the shares of firms operating on the market is different,

$$1 = \theta^{NS} = \theta_s^S + \theta_n^S.$$

This implies that with sunk costs there are more firms on the market. Figure 2 provides a diagrammatic comparison of the two industries. The demand schedule $D-D$ is vertical with perfect competition. The only difference between the two panels (a) and (b) is the difference in the demand schedule $(D-D)$. In panel (b) the horizontal part of the $D-D$ schedule indicates the presence of stationary firms. Stationary firms set the price equal to p and have unit costs between c_n and e_n.

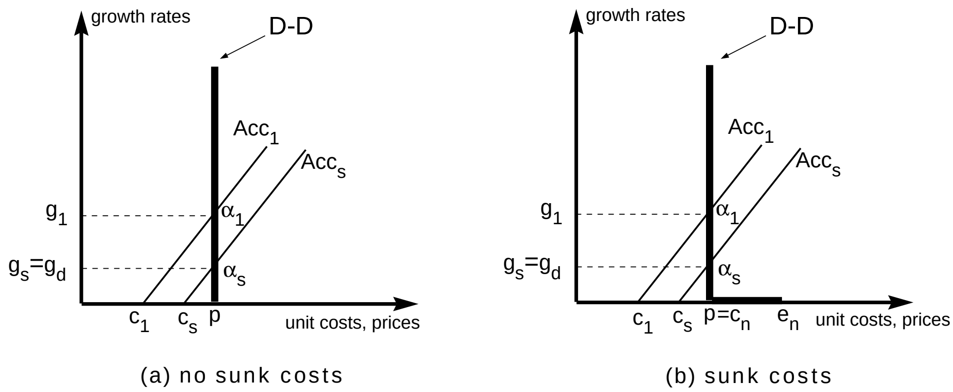

Figure 2: Comparing pure selection with sunk costs and without sunk costs at one particular point in time

But what about the speed of selection? Let us consider the rate of reduction of average unit costs, $\frac{d}{dt}\bar{c}_v$, for the two industries. As there are no stationary firms, for the no sunk cost industry we obtain:

$$\frac{d}{dt}\bar{c}_v^{NS} = \frac{d\bar{c}_s^N S}{dt} = \sum_i \frac{ds_i}{dt} c_i + \sum_i \frac{dc_i}{dt} s_i = -V_s(c)$$

where $V_s(c)$ is the variance of unit costs. We know that the second term in the rhs is 0, as unit cost (routines) are fixed. The first term is equal to $\sum_i si(g_i - \bar{g}_s)c_i$. In the case of a perfect market $\frac{ds_i}{dt} = si(g_i - \bar{g}_s) = -s_i(\bar{c}_s - c_i)$. In the sunk cost industry, in contrast, there are stationary firms on the market, and the speed of selection is different:

$$\begin{aligned} \frac{d}{dt}\bar{c}_v^S &= -\theta_s^S \frac{d\bar{c}_s^S}{dt} + \frac{d\theta_s^S}{dt}\bar{c}_s^S + \theta_n^S \frac{d\bar{c}_n^S}{dt} + \frac{d\theta_n^S}{dt}\bar{c}_n^S \\ &= -[\theta_s^S V_s(c) + \theta_s^S \bar{g}_s(\bar{c}_s - \bar{c}_n)]. \end{aligned}$$

The difference between the two industries is equal to:

$$\frac{d}{dt}\bar{c}_v^{NS} - \frac{d}{dt}\bar{c}_v^{S} = (\theta_s^S - 1)V_s(c) + \theta_s^S \bar{g}_s(\bar{c}_s - \bar{c}_n) < 0.$$

As $0 < \theta_s^S < 1$ and $\bar{c}_s - \bar{c}_n < 0$ it follows that $\frac{d}{dt}\bar{c}_v^{NS} < \frac{d}{dt}\bar{c}_v^{S}$. The negative difference implies that the rate of reduction of unit costs is faster in the no sunk cost industry. A corollary of this result is that the sunk costs industry will take longer to reach the state of rest.

This result suggests that, if we do not fix the price, but fix the number of firms and consider two industries that have the same number of firms with the same distribution of unit costs (c_v), then $p_v^S < p_v^N S$, which by construction of the model implies a slower selection speed. To see this, assume that f and δ are both equal to 1 and that the growth rate of demand is equal to zero. Furthermore assume that there are only two firms on the market. The more efficient firm has unit costs of c_a and the second unit costs c_b, with $c_a < c_b$. The average price when there are no sunk costs is $\bar{p}_v^{NS} = \frac{s_a c_a + s_b c_b}{2}$. When there are sunk costs the average price is equal to $\bar{p}_v^{S} = \frac{s_a c_a + s_b e_b}{2}$. As $c_b > e_b$, it follows that $\bar{p}_v^{NS} > \bar{p}_v^{S}$. It also follows that whenever $p_a^{NS} > p_a^{S}$ with identical unit costs, then $g_a^{NS} > g_a^{S}$. This implies that the growth rate of the more efficient firms is lower when there are sunk costs. The selection speed is reduced because sunk costs increase the incentive of firms to remain on the market.

3 An empirical test

In order to provide evidence for the role of mobility barriers and sunk costs in industry dynamics we test a specific conjecture. The result established earlier leads to the prediction that sunk cost industries should be characterized by lower growth rates of more efficient firms and lower rates of decline of less efficient firms compared to the no sunk cost benchmark. In principle, this result should carry over from sunk costs to other mobility barriers that create incentives for firms to exit later. Thus, the share of firms with low rates of growth or decline should be higher in industries with high mobility barriers and sunk costs. We call these stable firms.

This prediction based on the theoretical model is tested by using data for the Austrian industries at the two-digit level. The equation we use to test this proposition is

$$Y_i = \alpha + \beta_1 MB_i + \beta_2 X_i + \epsilon_i, \tag{6}$$

where Y_i is the share of marginal growing firms, MB_i an indicator of mobility barriers and sunk costs, X_i a set of control variables and ϵ_i the error term. If the coefficient $\beta_2 > 0$, we are not able to reject the hypothesis that higher sunk costs are associated with a higher share of marginally growing firms.

3.1 Data

We construct the firm growth indicators from Austrian social security data. These data include information on all employers and the number of employees in the Austrian private sector. Relative to the data used in most of the literature, our data have the advantage of broad coverage, as they include also micro enterprises. This administrative data set has been widely used in empirical research, especially for labour market research (e.g. Winter-Ebmer 2003), but also to study the autocorrelation of growth rates (Coad and Hölzl, 2009) and the survival determinants of Austrian firms (Kaniovski and Peneder, 2008). Lotti, Santarelli, and Vivarelli (2003) use quite similar Italian administrative data to study Gibrat's law.

In order to show the robustness of our results we employ two different shares of stable firms. We define stable firms as firms with at least 10 employees in 2002 that remained within the boundary of an average yearly growth rate of (-5%,5%) over the three-year period from 2002 to 2005. The second definition is the same, except that the admissible growth interval is changed to (-7.5%,7.5%). This robustness check is used because at the lower size bound (10 employees) the first definition only firms with 10 employees that grew to 11 employees over the three years. At the lower size bound, the second definition also includes firms that grew from 10 to 12 employees.

We restrict attention to firms with at least 10 employees, as it is known that micro enterprises up to 10 employees have a low propensity to change employment due to indivisibilities leading to fixed adjustment costs (e.g. Hölzl and Huber (2009)), and because the growth patterns of micro enterprises are particularly erratic (Garnsey, Stam, and Heffernan, 2006; Santarelli and Vivarelli, 2007). Moreover, measuring firm growth in relative terms leads to a bias towards identifying small firms as high growth firms (Hölzl and Friesenbichler, 2010; Schreyer, 2000).[2]

We use three indicators of mobility barriers that capture different aspects of mobility barriers:

1. As a proxy for tangible sunk costs associated with capital expenditures we use capital intensity at the industry level derived from the EUKLEMS database.
2. In many studies on sunk costs a measure of the minimum efficient scale of operations (MES) is used as an indicator of general sunk costs. We use the average of yearly log median firm sizes of firms with more than 10 employees over the period 2002 to 2005 as an indicator of the minimum efficient scale of operations.
3. In order to proxy for organizational capital and experience-related mobility barriers, we use the ratio of hires and separations to the

[2]For example a firm expanding from 1 to 2 employees over a three year period records an annual growth rate of approximately 26%, while a firm expanding from 100 to 120 employees records an annual growth rate of 6.26%. This is why the OECD-Eurostat definition of fast-growing firms uses this size threshold (Eurostat-OECD, 2008).

total workforce (labour turnover) as our third indicator. The idea behind this indicator is that mobility barriers relate to the valuable capabilities of employees. Experience-related cost asymmetries can be considered mobility barriers, when the acquisition of knowledge on how to use and modify technology and products is expensive and firm-specific. This interpretation builds on the learning models of industry evolution proposed by Nelson and Winter (1982), where organizational routines play an important role in determining the competitiveness of firms.[3]

Table 1: Descriptive statistics

	Observations	Mean	Std. Dev.	Min.	Max.
share of stable firms (5)	38	0.156	0.085	0.000	0.438
share of stable firms (7.5)	38	0.351	0.136	0.071	0.651
capital intensity	38	0.397	0.124	0.147	0.699
MES	38	3.268	0.426	2.757	4.413
labour turnover	38	0.230	0.132	0.117	0.810
ln (# firms)	38	5.559	1.528	2.603	8.598
avg. Industry growth	38	0.005	0.024	-0.058	0.048

We control for the size and growth rate of the industry by using the average log number of firms in the industry and industry employment growth over the period 2002 to 2005, respectively. While the model is silent on the use of industry size, controlling for industry growth is directly suggested by the model. A higher average growth rate of market demand relaxes selection pressures. Table 1 presents the descriptive statistics used in the regressions.

3.2 Results

The results are listed in table 2. Because the dependent variables is a share, we apply the fractional logit model proposed by Papke and Wooldridge (1996) with robust standard errors using a quasi-maximum likelihood estimator with heteroscedasticity-robust asymptotic variance. The tables report marginal effects at the mean.

The results clearly show that sunk cost industries have a higher share of firms with marginal growth rates than industries with lower sunk costs. Let us start with the results for the

[3]The evolutionary literature on technological regimes argues that firm-specific assets are embedded in the cross-sectional differences of the sources of knowledge that produce innovation (e.g. Winter 1984). A number of contributions have shown that industry-specific characteristics play a fundamental role in explaining the evolution of specific industries (e.g. Audretsch 1991; Malerba and Orsenigo 1995; Breschi, Malerba, and Orsenigo 2000).

Table 2: Stable firm shares and sunk costs

	(1)	(2)	(3)	(4)	(5)	(6)
	capital intensity		MES		labour turnover	
	a) Stable firm share (-5%, 5%)					
SUNK	0.2533***	0.2471**	0.1102***	0.1237***	-0.4853***	-0.4814***
	(2.817)	(2.566)	(3.588)	(5.244)	(-2.999)	(-2.964)
ln(# firms)	0.0093	0.0089	0.0200**	0.0198**	0.0107	0.0105
	(1.006)	(0.982)	(2.151)	(2.166)	(1.149)	(1.132)
avg.industry growth		0.3506		-0.6117		0.2843
		(0.650)		(-1.333)		(0.608)
Constant	y	y	y	y	y	y
Observations	38	38	38	38	38	38
aic	0.772	0.824	0.732	0.777	0.762	0.814
	b) Stable firm share (-7.5%, 7.5%)					
SUNK	0.4439***	0.4422***	0.1786***	0.2175***	-0.5184***	-0.5185***
	(2.618)	(2.612)	(2.603)	(5.454)	(-3.664)	(-3.753)
ln(# firms)	0.0037	0.0035	0.0172	0.0179	-0.0001	-0.0001
	(0.246)	(0.239)	(1.350)	(1.542)	(-0.010)	(-0.009)
avg.industry growth		0.1248		-1.8033**		-0.0029
		(0.157)		(-1.998)		(-0.004)
Constant	y	y	y	y	y	y
Observations	38	38	38	38	38	38
aic	1.034	1.087	1.005	1.036	1.031	1.083

Notes: Standard errors appear in brackets.

stable firm share (-5%, 5%). An increase in capital intensity by 1 would lead to an increase in the share of stable firms by 0.25, an increase of median firm size (MES) by 1 to an increase in the stable firms share by 0.12, while an increase by 1 of hires and separations would decrease the share of stable firms by 0.49. The results for the stable firm share (-7.5%,7.5%), which can also be found in table 2, are of larger magnitude, but have the same qualitative interpretation. An increase in capital intensity by 1 leads to an increase in the share of stable firms (-7.5%,7.5%) by 0.44, while an increase of median firm size (MES) by 1 increases it by approximately 0.20, and an increase of hires and separations by 1 decreases it by 0.52. Sunk cost industries have a higher share of marginally growing firms.

In order to provide a clearer interpretation of the results, table 3 presents predicted stable firm shares using the results in table 2. All predictions are at the mean for all variables except for the mobility barrier or sunk cost indicator (MB) under consideration. For these variables we present the results of the

Table 3: Predicted stable firm shares

	(1)	(2)	(3)	(4)	(5)	(6)
	capital intensity		MES		labour turnover	
	a) Stable firm share (-5%, 5%)					
mean(MB) - sd(MB)	0.125	0.125	0.098	0.099	0.221	0.220
mean(MB)	0.153	0.153	0.147	0.147	0.147	0.147
mean(MB) + sd(MB)	0.187	0.186	0.215	0.214	0.095	0.096
	b) Stable firm share (-7.5%, 7.5%)					
mean(MB) - sd(MB)	0.296	0.296	0.239	0.239	0.420	0.420
mean(MB)	0.350	0.350	0.345	0.346	0.348	0.348
mean(MB) + sd(MB)	0.407	0.407	0.470	0.471	0.282	0.282

Notes: Predictions of the stable firm share from results in table 2.

mean ± the standard deviation of the mobility barrier. The results show clearly that the predicted stable firm share increases with increasing mobility barriers or sunk costs.

The results confirm the conjecture derived from the model that the share of stable firms (firms with low growth rates and decline) is higher in industries with substantial mobility barriers than in industries with low mobility barriers.

One potential weakness of this empirical test is that the effects of competition only show up unambiguously at the level of the relevant market (sub-market). This suggests that two-digit industries are subject to substantial aggregation, which might obscure the empirical evidence. However, this criticism is not entirely convincing. Production technology, knowledge dynamics and demand development should bear greater similarity for firms within the same two-digit industry than for firms in different two-digit industries. If competitive selection is an important structuring mechanism of industrial organization, we suspect that this effect should also appear at higher levels of aggregation.

4 Implications for Productivity Decompositions

Many studies suggest that market competition is not well-approximated by by a simple model of selection dynamics. The most important evidence comes from productivity decompositions, where aggregate productivity growth is decomposed into (i) firm-specific changes in productivity levels (ii) changes due to the reallocation of market shares between firms and (iii) the contribution of entry and exit. In all known studies carried out in industrialized countries firm, specific changes clearly dominate the reallocation of market shares between incumbent firms. In a few studies the contribution of market share reallocation to productivity growth is even negative. Baily et al. (1996) find that growing and shrinking firms contribute equally to aggregate productivity growth. Similar results are documented by Disney et al. (2003) for the UK, Bartelsman et al. (2004) for many industrialized and developing countries and Pages et al. (2009) for South American countries (see Isaksson 2009 for a survey). The literature on firm heterogeneity and firm growth confirms these findings. Firm-level studies show that profit rates are quite heterogeneous across firms and display a high degree of persistence (Mueller 1977; Dosi 2007), while firm growth rates do not display persistence. In fact, most empirical studies relating firm growth to financial performance or productivity report that firm growth rates cannot be explained in terms of current financial performance, whether the latter is measured in terms of profit rates or growth rates of the amount of profits or productivity levels (Coad, 2007, 2010; Bottazzi, Dosi, Jacoby, Secchi, and Tamagni, 2010).

In a recent contribution to the literature Melitz and Polanec (2009) propose a new decomposition technique. They argue that the productivity decomposition methods used in the literature - the Foster et al. (1998) decomposition and the Griliches and Regev (1995) decomposition - do not allow us correctly to identify the different channels of productivity improvement. The use of fixed weights in the division of the contribution of surviving firms leads to a misrepresentation of the contributions between within-firm productivity improvements and market share reallocation. They propose the use of a dynamic decomposition based on the contribution of Olley and Pakes (1996), which decomposes aggregate productivity P between t and $t + \Delta t$ into:

$$\Delta P = \Delta \bar{p}_S + \Delta cov_S + s_{E,t+\Delta t}(P_{E,t+\Delta t} - P_{S,t+\Delta t}) + s_{X,t}(P_{S,t} - P_{X,t}),$$

where $\Delta \bar{p}_S$ is the difference in the unweighted productivities of surviving firms and captures the within-firm productivity improvement, and Δcov_S is the difference of the covariances of market share and productivity multiplied by the number of firms between t and $t + \Delta t$. This captures the contribution of reallocation. $s_{E,t+\Delta t}(P_{E,t+\Delta t} - P_{S,t+\Delta t})$ is the contribution of entry measured as the difference of the productivities between entrants and surviving firms at time $t + \Delta t$. $s_{X,t}(P_{S,t} - P_{X,t})$ is the contribution of exit measured as the difference between surviving firms and exits at time t. For Slovenian manufacturing, Melitz and Polanec (2009) show that their decomposition leads to a consistently higher contribution of reallocation to productivity growth than other decomposition methods. Nevertheless, their results indicate that the contribution of firm-specific productivity growth is three to four times larger than the market share reallocation term.

Table 5 presents the results for a dynamic Olley-Pakes decomposition of productivity growth for Austrian manufacturing over a five-year period. We look at within-firm productivity improvements, between-firm productivity reallocations and the contribution of firm turnover and distinguish, in addition, within-industry and between-industry dimensions. The results indicate that the the reallocation of market shares between firms within industries contributed 20.5% to aggregate productivity growth, while the within firm productivity improvements contributed 63.7% and structural change (the reallocation of market shares between industries) 13.9%. The contribution of firm turnover (entry and exit of firms from the dataset) is modest (1.9%). This evidence clearly shows that within-firm productivity improvements dominate the reallocation of employment shares in Austrian manufacturing.

Table 4: Dynamic Olley-Pakes Decomposition of Productivity Growth in Austrian Manufacturing: 2002 to 2007

		continuing firms		*firm*
	total	within	reallocation	*turnover*
		a) in growth rates		
within ind.	*0.165*	0.129	0.041	-0.006
between ind.	*0.038*		0.028	0.010
total	*0.203*	*0.129*	*0.070*	0.004
	b) contribution in % of overall productivity growth			
within ind.	81.3%	63.7%	20.5%	-2.9%
between ind.	18.7%		13.9%	4.8%
total	*100.0%*	*63.7%*	*34.4%*	1.9%

Source: Hölzl and Lang (2011).

Notes: The dynamic Olley-Pakes decomposition is described in the text. Firm turnover includes the contribution of start-ups, entries and exits from the sample of important firms in Austrian Manufacturing. The sample includes all firms with at least 20 employees and some firms with between 10 and 20 employees. The sample covers each year approximately 90% of annual production in the Austrian manufacturing sector.

In order to examine the role of mobility barriers as determinant of the size of the reallocation term, we use the share of the reallocation terms at the industry level and regress it on the indicators of mobility barriers used before. We use average industry employment growth between 2002 and 2007 control variable. Table 5 reports the results. We apply a weighted regression approach in order to correct for industry size and to present aggregate evidence. Due to the fact that the shares can also be negative, OLS (the linear model) is an appropriate estimator. The results clearly indicate that higher mobility barriers are associated with a lower market share reallocation term. This confirms the theory presented earlier and suggests that mobility barriers may play an important role in explaining differences in the importance of the reallocation term across industries. Mobility barriers can explain the low contribution of reallocation to productivity growth in the manufacturing sector. However, they cannot explain why the reallocation term is sometimes negative.[4]

Table 5: Share of reallocation term and sunk costs, Austrian manufacturing industries 2002-2007

	(1)	(2)	(3)	(4)	(5)	(6)
	capital intensity		MES		labour turnover	
MB	-0.8168*	-1.0377*	-0.3108**	-0.3480**	1.9961	2.1424**
	(-1.99)	(-2.00)	(-2.44)	(-2.68)	(1.69)	(1.99)
avg. Ind. Growth		3.5170*		3.6746***		3.2782*
		(2.03)		(3.48)		(2.23)
Constant	0.5468***	0.6357**	1.2390***	1.3662***	-0.1482	-0.1696
	(3.05)	(2.79)	(3.000)	(3.26)	(-0.71)	(-0.88)
Observations	21	21	21	21	21	21
adj. R^2	0.06	0.16	0.28	0.42	0.24	0.34

Notes: Weighted OLS regression with robust standard errors.

5 Discussion: Competition as learning process

The analysis of the model revealed that sunk costs slow down the speed of selection. Compared to the no-sunk cost benchmark, mobility barriers create a market imperfection that hinders the working of the competitive threat of potential entrants (Kessides

[4]This may be related to measurement of contributions to productivity growth. Nishida et al. (2011) suggest that defining aggregate productivity growth and its decompositions in terms of its impact on final demand eliminates negative reallocation effects.

and Tang, 2010). This eliminates the possibility to exploit opportunities related to inefficiency and waste through hit and run entry. At the same time, the presence of sunk costs increases the possibility of incumbents falling behind in implementing improvements and catching up to the productivity leaders, provided they obtain the necessary funding for these projects.[5] If we also take into account that most markets and even sub-markets in manufacturing are characterized by horizontal product differentiation, the expected selection pressure is considerably weakened. In an evolutionary context, Kaniovski (2005) has shown that selection dynamics in horizontally differentiated products depend on the underlying demand structure. Oligopoly models with product differentiation clearly indicate that competitive pressure is reduced when firms compete with differentiated products.

Taken together mobility barriers and product differentiation indicate that the selection environment is relatively weak compared to the often-studied benchmark case of homogeneous products and no sunk costs. This raises the question: What does competition do, if it does not weed out inefficient producers? Is it really the case that competition only works through a reallocation of market shares? Or does competition primarily work via the threat of lowered profitability? The latter view suggests that the competition mechanism cannot be identified by looking at the dynamics of market shares alone. Knowledge dynamics and learning do not necessarily show up in market share dynamics. Market imperfections due to mobility barriers and product differentiation open up the avenue for considering the mechanisms of competition as an interaction between learning and selection, where firms are subject to competitive pressure, but have time to respond by implementing projects to improve and change their products or productivity. This is likely related to changes in the knowledge base, such as innovation, knowledge acquisition and changes in management techniques. This leads to a conceptualization of competitive pressure as a mechanism that has an effect on profits, but without requirement that changes in profits affect market shares immediately. In this perspective, firm strategies and management take on much greater importance than they do in conventional accounts of competition. Van Reenen (2011) argues that one of the main mechanisms through which competition increases productivity is the improvement of management

[5] This is related to the argument presented by Currie and Metcalfe (2001), where a weaker selection environment assures that the more efficient firm can survive, while a stricter selection environment may lead to the accidental survival of the less efficient firm in a duopoly setting.

practices. This would mean that competition works through both a reallocation effect and incentives to improve management practices by adopting new techniques and experimentation. However, further research is required to go beyond speculation.

6 Concluding remarks

This paper used a model of pure selection dynamics to study the effects of mobility barriers on the speed of economic selection. The analysis of the model led to the prediction that industries characterized by higher mobility barriers should display a lower speed of competitive selection. This prediction was tested and could not be rejected by using micro-aggregated data for Austrian industries. The empirical results confirmed the importance of mobility barriers and sunk costs in industry dynamics, even in the absence of entry and exit processes.

Taken together, the theoretical and empirical results obtained in the paper could provide a basis for an analysis of the nature of the competitive process. We argued that this could open up a new perspective on the process of competition, where learning and selection are not opposing forces but complementary in creating a competitive environment that is characteristic for modern industry. One of the main messages of our discussion of the results is that simple models of myopic selection cannot account for important regularities of real world competitive interaction (see also Geroski and Mazzucato 2002). However, further research is required in order to go beyond speculation. From an economic perspective, the assumption of a fixed accumulation rule $g_k = f[p_k - c_k]$ is clearly a limitation of the model used in this paper. Providing an appropriate endogenization of the accumulation rule and introducing forward-looking behavior could provide new insights into the dynamics of evolutionary competition.

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A Derivation of the pricing rule of dynamic firms

The overall average price at the population level is defined as

$$\bar{p}_v = \theta_s \bar{p}_s + \theta_n \bar{p}_n + (1 - \theta_s - \theta_n)\bar{p}_m.$$

This expression accounts for the different pricing behaviors in the three subpopulations. By inserting the expressions of the average prices in the marginal and dynamic groups follows:

$$\bar{p}_v = \frac{\theta_s}{1-\theta_n}(\bar{p}_s - \bar{e}_j) + \bar{e}_j \tag{7}$$

$\bar{p}_s$ is obtained by aggregating the price equation for one dynamic firm:

$$\bar{p}_s = \frac{1}{\delta(1 - \frac{\theta_s}{1-\theta_n})}\left(g_D + f\bar{c}_s + \delta(1 - \frac{\theta_s}{1-\theta_n})\bar{e}_j\right) \tag{8}$$

where $\bar{c}_s = \sum_i c_i$. By eliminating the average price from the pricing equation for dynamics firms and re-arranging we obtain equation (5) in the text.

B Descriptive statistics for data used in the analysis reported in table 5

Table 6: Descriptive statistics

Variable	Obs	Mean	Std. Dev.	Min	Max
share reallocation term	21	0.141	0.253	-0.433	0.533
MES	21	3.350	0.442	2.811	4.413
CI	21	0.399	0.008	0.289	0.643
labour turnover	21	0.182	0.055	0.130	0.340
av. ind. Growth	21	-0.004	0.028	-0.063	0.054