A Theory of Entry and Exit with Embodied Technical Change

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Abstract

The paper presents a vintage capital model that is consistent with the the relationship between the rate of embodied technical change and the rate of entry and exit across industries. In the model, the costs imposed by the regulation of entry may bias the sectoral composition of an economy towards industries in which the rate of technical change is low – an effect termed *technological skew*. This prediction matches the empirical relationship between institutional entry costs and several indicators of sectoral composition across industrialized economies.

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1 Introduction

This paper studies an equilibrium model of entry and exit with sectoral choice. In the model, a central determinant of the firm lifecycle is the rate of *embodied technical change* (ETC): the rate at which the frontier technology moves ahead of incumbent firms. The paper shows that the costs imposed by the regulation of entry may affect an economy's sectoral composition, leading countries in which the cost of entry is high to specialize in industries in which the rate of embodied technical change is low.

The model contains the following features. Industries differ among themselves in terms of the rate of ETC. Entrepreneurs direct their activity towards the industries in which entrepreneurship is most profitable. *Caeteris paribus*, the equilibrium frequency with which entrepreneurs shut down and replace their firms in each sector is positively related to this rate, a result that is consistent with cross-industry data.

The sectoral composition of the model economy is endogenous, resulting from the optimal decisions of entrepreneurs. Thus, the paper provides a tractable framework in which to address questions of cross-country differences in industry composition.

In particular, I focus on the *regulation of entry* as a factor of these differences. The regulation of entry is an important nexus of public and private activity and, moreover, the cost of entry is a central element of models of industry dynamics.[1] As such, the costs imposed by the regulation of entry are a topic with potentially significant implications for theory and for policy. Cross-country differences in the size of the service sector and the information technology (IT) sector have been the object of much attention and, notably, these are sectors in which the rate of ETC is relatively high. Moreover, both of these sectors tend to be smaller in countries in which the costs imposed by the *regulation of entry* are high.[2]

The behavior of the model economy is consistent with these findings. If firms are replaced more frequently in industries in which embodied technical progress is rapid, entry costs may have greater impact in such industries. As a result, the model predicts a relationship between sectoral composition and the magnitude of entry costs. In particular, entry costs skew the composition of the model economy away from industries in which the rate of ETC is high. I call this effect *technological skew*. Significantly, the model does not require that the rate of ETC be correlated with any other industry features, such as different skill requirements or industry lifecycle stages: in a canonical vintage capital model, the rate of ETC *alone* can deliver these

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[1] See for example Hopenhayn (1992), Ericson and Pakes (1995).

[2] See Gust and Marquez (2004) and Messina (2005).

results, through its effects on firm dynamics.

Section 2 surveys the empirical relationship between entry, exit, and the rate of ETC. Section 3 introduces the model, while Section 4 characterizes the equilibrium. Sections 5 discusses the implications of the results, and Section 6 concludes.

2 Empirical patterns of entry, exit and ETC

This section discusses the sectoral distribution of entry, exit and ETC across industries. It also surveys the recent empirical literature on the regulation of entry, and reports some additional findings.

2.1 Entry and Exit

Recent work finds that entry and exit rates differ persistently across industries.[3] Industry entry and exit rates tend to be closely related to each other, and to dominate any cyclical variations. This suggests that entry and exit are primarily due to industry-specific factors, and that these factors are relatively stable over time. For example, if technological factors are responsible, long-run differences in the rate of technical progress might account for these cross-industry patterns, whereas transition

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[3] Dunne et al (1988) study US manufacturing using the Census of Manufactures, whereas Brandt (2004) considers data for both manufacturing and services, for several OECD economies, using data from Eurostat and the OECD.

dynamics or industry responses to aggregate shocks would be unlikely to do so.

In a comprehensive study of several industrialized countries, Brandt (2004) finds the following patterns of cross-industry variation. First, IT-intensive industries appear to undergo particularly high rates of firm turnover. Second, rates of entry and exit are higher in service sector industries than in manufacturing industries – see Figures 1 and 2. Indeed, Brandt (2004) finds that industry fixed-effects for rates of entry and exit are not significant for most manufacturing industries, whereas they are for most service industries. This suggests that the determinants of entry and exit vary more substantially across the service sector (and between services and manufacturing) than across manufacturing industries.

FIGURES 1 AND 2 ABOUT HERE

2.2 Embodied Technical Change

This paper asks whether the rate of embodied technical change can account for broad cross-industry patterns of entry and exit. The concept of ETC has been found to account for several other features of industry dynamics: for example, in a related model, Mitchell (2002) accounts for industry differences in the optimal scale of production on the basis of industry differences in the rate of ETC, whereas

Sakellaris (2004) and Samaniego (2006a) account for lumpy investment patterns at the establishment level. Campbell (1998) develops a vintage capital model to account for the cyclical variability of aggregate entry and exit.

TABLE 1 ABOUT HERE

Cummins and Violante (2002) provide industry indices of embodied technical change for the United States. They find that the rate of ETC varies significantly across industries. Moreover, these differences are highly persistent, dominating any short-term variation. Thus, the industry rate of ETC is a technological factor that satisfies the same broad properties as industry rates of entry and exit.

Furthermore, the rate of ETC is generally higher in service industries than in manufacturing, and the rate of ETC is significantly higher for IT than for other forms of capital, as well as being higher in IT-intensive industries than in the remainder. Thus, the pattern of entry and exit across industries is similar to the cross-industry variation in the rate of ETC. Indeed, Table 1 shows that the industry-specific entry and exit rates of Brandt (2004) and the ETC rates of Cummins and Violante (2002) are significantly positively correlated.[4]

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[4] The industry classifications of the two data sets do not exactly correspond. In particular, the financial services sector and the retail sector are more disaggregated in the Brandt (2004) data. "Not imputed" considers only industries with a direct correspondence, whereas "imputed" assumes

2.3 Sectoral Composition and The Regulation of Entry

It is significant that the service and IT sectors have both been the object of recent attention – because the size of these sectors is not uniform across countries, and because they have been emphasized for their substantial statistical contribution to employment and growth. Given that these are the sectors in which rates of entry and exit are highest, one might ask whether cross-country differences in the way entry is regulated could be responsible for these patterns of sectoral composition.

Furthermore, in industries in which the rate of ETC is high, firms may become obsolete more rapidly than otherwise. Consequently, one might expect the sectoral make-up of countries in which the costs imposed by the regulation of entry are high to be *skewed away* from such industries. I term this effect *technological skew.* In particular, it suggests that the service sector should be smaller in countries in which entry costs are high, and that IT should be less prevalent. The paper henceforth concentrates on these predictions as indicators of technological skew.

As a measure of institutional barriers to entry, the paper adopts the index developed by Djankov et al (2002), denoted ENT. As for indicators of sectoral composition, service sector shares are reported in OECD (2000). Several measures of IT use are available from Coppel (2000) and from Pilat and Lee (2001):

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the same rate of ETC for all such industries in the Brandt (2004) classification. "Not imputed" considers 59 industries and "imputed" considers 37.

1. aggregate measures, including the share of IT in aggregate spending (ITSP), and the share of IT in private sector employment (ITEMP); and
2. measures of capital use, including the log number of internet hosts (HOST), the log number of secure servers (SERV) relative to the population,[5] and the number of personal computers per capita (PCS).

Data are available for 20 OECD countries. An advantage of concentrating on industrialized economies is that it is not unreasonable to assume that they can draw from a similar set of technologies. See Table 2 for a list of sectoral indices.

TABLES 2 AND 3 ABOUT HERE

Table 3 reports the correlation between ENT and each of the sectoral indicators. These correlations are negative in all cases and highly significant except for employment in the IT sector, which may be because limited production of IT does not necessarily preclude its use. Figures 3 and 4 also reveal clear negative relationships.

FIGURES 3 AND 4 ABOUT HERE

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[5] A host is any computer with full two-way access to the internet, whereas a secure server is any computer that contains websites that may be accessed over the internet and which supports encryption.

A potential concern is that these relationships may be due to a separate policy variable that is correlated with both ENT and sectoral composition. In particular, Samaniego (2005) identifies labor market regulations that make costly the firing of workers as just such a policy. Messina (2005) also argues that broad product market regulation may be related to the size of the service sector. Hence, it is of interest to see whether the inclusion of alternative policies affects the results of Table 3.

Nicoletti et al (2000) provide measures both employment protection (EPL) and product market regulation (PRO), and in what follows we shall consider these also. In addition, other policies that directly affect the firm lifecycle might also generate technological skew.

TABLES 4 AND 5 ABOUT HERE

Table 4 provides a comprehensive list of the policy variables considered, and the Appendix outlines the reasons for their inclusion, as well as reporting the correlations between the policy and sectoral make-up variables. Indeed, some of the policy variables other than ENT are also negatively correlated with the sectoral indices, although only for the case of EPL are the correlations of comparable magnitude. Also, many of the policy variables are correlated amongst themselves – in particular, the correlation between ENT and EPL is fully 51%. Thus, "policy clustering" does appear to be a feature of the data, suggesting that simple correlations between policy variables and sectoral indicators should be interpreted with some caution.

On the other hand, Table 5 displays the results of regressing the set of policy variables on each indicator of sectoral composition. The policies with the most significant results are ENT, EPL and PUB. Thus, ENT does appear to be independently related to sectoral composition. Coefficients are standardized, which implies that an increase in entry costs of one standard deviation is related to, for example, a decrease in the share of GDP devoted to IT of about 40% of the cross-country standard deviation, or a decrease in the PC base of 50% of the standard deviation. The evidence on PUB is somewhat weaker, however, as it only appears related to the IT indices and not to the size of the service sector.[6]

I conclude that the evidence is consistent with the presence of technological skew resulting from the regulation of entry. This is robust to the use of several indices of sectoral composition, to the inclusion of other forms of regulation as alternatives, and to different specifications. Interestingly, there is insufficient evidence to conclude that there is an unambiguous relationship between sectoral composition and any of the other policies – with the notable exception of employment protection.

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[6] To check the robustness of these results, I regressed all combinations of the policy variables on each of the sectoral indices, to see whether the sign of the relationship between sectoral composition and the policy variables is sensitive to the number or identity of the policies included. The only policy variables that are fully robust by this criterion turn out to be ENT and EPL.

3 Economic Environment

Time is continuous, and indexed by $\tau \in \mathbf{R}$. There are C countries, and two industries, which may be interpreted as services and manufacturing, or as IT-intensive and non-IT-intensive. Each industry i is characterized by an industry-specific parameter $g_i \geq 0$ – the rate of *embodied technical change.* g_i is the key technological parameter of the model and will be discussed in brief. Good i sells at price $p_{i\tau} > 0$. There is also a numeraire good, with price 1 in each period. Product markets are competitive, and there are no barriers to international trade. Hence, firms are price-takers, and prices are common across countries. Countries differ with regards to their institutions – in particular, they differ in terms of *institutional entry costs*, the cost of starting a new firm. The entry cost in country c is $E_c > 0$, in units of the numeraire.[7]

3.1 Entrepreneurs

In each country, there is a unit continuum of entrepreneurs who maximize their expected lifetime utility, discounting the future at rate ρ. At each moment in time, an entrepreneur allocates a quantity 1 of a divisible, non-durable entrepreneurial resource. This resource is useful for opening *production sites.* If $e_{ic\tau}$ units of this input

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[7] De Soto (1990) and Djankov et al (2002) find that the bulk of entry costs involves the time that it takes to satisfy entry regulations. The numeraire may thus be interpreted as time or foregone leisure.

are used in any particular industry i in country c, the number of new production sites generated is given by a function $k\left(e_{ic\tau}\right)$. $k' > 0$ and $k'' < 0$, so there are decreasing returns to entrepreneurship in each sector. In addition, $\lim_{e_{ic\tau}\rightarrow +0} k'\left(e_{ic\tau}\right) = \infty$.

Once a production site is created, the entrepreneur may construct a firm there at cost E_c in terms of the numeraire. At any date, the entrepreneur may close any firm she is operating and replace it with a new one – also at cost E_c. Production sites close exogenously at Poisson rate ζ.[8] Let $r = \rho + \zeta$.

Let $W_{ic\tau}$ equal the expected value of a new production site in industry i, in country c at date τ. Then, each period τ, entrepreneurs in country c solve the following sectoral choice problem:

$$\max_{\substack{\{e_{ic\tau}\}_i \geq 0 \\ s.t. \\ \sum_i e_{ic\tau} \leq 1}} \sum_i W_{ic\tau} k\left(e_{ic\tau}\right). \tag{1}$$

3.2 Firms

A firm in industry i is endowed with the production function $y_\tau = e^{g_i v}$, where τ is the date, y_τ is output, and v is the *vintage* of its technology – the date at which

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[8] Thus, the entrepreneurial resource may be interpreted as a sector-specific investment that decays at rate ζ. $\zeta > 0$ is required for the environment to be stationary.

That entrepreneurs may be active across sectors is consistent with the finding of Lazear (2004) that entrepreneurs tend to be generalists rather than specialists. That they do not create firms across borders reflects the strong "home bias" found by French and Poterba (1991) *inter alia*.

the firm was set up. Again, the key parameter is g_i, the rate of ETC. The feature that the productivity of an individual firm does not progress at the same rate as the frontier is the defining characteristic of vintage capital models.

The expected value of a firm born into this environment at date v is

$$\int_{v}^{T+v} e^{-r(\tau-v)} p_{i\tau} e^{g_i v} d\tau \tag{2}$$

where T is its planned lifespan.

One might not find it surprising for entry costs to decrease the prevalence of industries in which the rate of ETC is high if those industries are also relatively new. To clarify that it is the rate of ETC itself that is responsible for the results, and that no other industry characteristics are necessary, nor any transition dynamics, the paper employs assumptions that generate a stationary model framework. In particular, we assume henceforth that $p_{i\tau} = p_{i0} e^{-g_i \tau}$. In a related model, Mitchell (2002) shows that this price sequence is consistent with demand being unit-elastic.[9]

Let $t \equiv \tau - v$ be a firm's age. This will greatly simplify notation in what follows.

Define $V(T; g_i, p_{i0})$ as the expected value of a new firm in industry i with planned

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[9] See also Mitchell (2000) and Samaniego (2005).

lifespan T. Then,

$$V(T; g_i, p_{i0}) = \int_0^T e^{-rt} p_{i0} e^{-g_i t} dt \tag{3}$$

The entrepreneur then solves the following problem at each production site:

$$W_{ic\tau} = \max_T \left\{ V(T; g_i, p_{i0}) - E_c + e^{-rT} W_{ic,\tau+T} \right\} \tag{4}$$

The value of a production site does not depend on the date τ, so that $W_{ic\tau} = W(g_i, E_c, p_{i0})$ for all τ. Hence, the entrepreneurial resource allocation problem is time-invariant and, in equilibrium, $e_{ic\tau} = e_{ic}$ for all τ. In addition, firms in any given industry will have a planned lifespan that does not depend upon the age of the production site itself. Hence, entrepreneurs solve a stationary version of problem (1):

$$\max_{\substack{\{e_{ic}\}_i \geq 0 \\ s.t. \\ \sum_i e_{ic} \leq 1}} \sum_i W(g_i, E_c; p_{i0}) \, k(e_{ic}) \, . \tag{5}$$

Let $T^*(g_i, E_c; p_{i0})$ denote the optimal firm lifespan which solves problem (4).

3.3 Industry evolution

In each country, industry i is characterized by a measure of firms $\mu_{ic\tau}(S)$, defined over Borel subsets of the real line. Firms that are at the technological frontier are either at production sites that were just set up or that are the outcome of replacement. On the other hand, the measure of firms of other vintages decreases as production sites close down exogenously or as the firms that occupy them are replaced.

In an environment without replacement, the measure may be described as

$$\mu_{ic\tau}(S) = \int_{v \in S} q_{ic\tau}(v)\, dv \tag{6}$$

where

$$\begin{aligned} q_{ic\tau}(\tau) &= e_{ic} \\ q_{ic\tau}(v) &= 0 \text{ for } v > \tau \\ \dot{q}_{ic\tau}(v) &= -\zeta q_{ic\tau}(v) \text{ for } v \neq \tau \end{aligned}$$

and where $\dot{q}_{ic\tau}(v)$ is the derivative of $q_{ic\tau}(v)$ with respect to time τ. Thus, the number of firms of a given vintage of technology would decline over time as production sites shut down exogenously.

With replacement, however, the measure evolves in a more complicated fashion. At the point that $\tau - v = T^*(g_i, E_c; p_{i0})$, $\dot{q}_{ic\tau}(v) = -\infty$ as at that point the measure jumps to zero. Thus, in the case with updating, the transition function for the measure obeys:

$$\begin{aligned} q_{ic\tau}(\tau) &= e_{ic} + \int q_{ic\tau}(\tilde{v})\, I\left\{\tilde{v} = \tau - T^*(g_i, E_c; p_{i0})\right\} d\tilde{v} \qquad (7) \\ q_{ic\tau}(v) &= 0 \text{ for } v > \tau \text{ and } v < \tau - T^*(g_i, E_c; p_{i0}). \\ \dot{q}_{ic\tau}(v) &= -\zeta \mu_{ic\tau}(v) \text{ for } \tau - T^*(g_i, E_c; p_{i0}) \le v \le \tau \end{aligned}$$

Remark 1 *As defined, the measure is upper-hemicontinuous. There is a technical question concerning the treatment of firms that update* $v = \tau - T^*(g_i, E_c; p_{i0})$*: however, all treatments result in measures that are almost-everywhere equal to the current specification provided the measure has no mass-points. It is possible, though notationally cumbersome, to extend the definition to more general measures.*

4 Model Solution

4.1 Equilibrium

Definition 1 *An* entry equilibrium *is a level of entry for each industry* $\{e_{ic}\}$ *and a function* $T^*(g_i, E_c; p_{i0})$ *such that:*

(i) establishments are operated optimally, i.e. $T^*(g_i, E_c; p_{i0})$ *solves problem* (4)*;*

(ii) the entrepreneurial resource is used optimally, i.e. $\{e_{ic}\}$ *solves problem* (5)*;*

(iii) μ_{ic0} *is given and, for* $\tau > 0$, $\mu_{ic\tau}$ *is determined according to equations* (6) *and* (7).

Definition 2 *An entry equilibrium is a* steady state *if there exists a* μ_{ic}^{*} *such that* $\mu_{ic\tau} = \mu_{ic}^{*}\ \forall\tau \geq 0$.

The following condition is necessary and sufficient for there to be entry into all sectors in equilibrium.

Lemma 1 *For all* i *and* c, $e_{ic} > 0$ *if and only if* $g_i < \bar{g}\left(E_c, p_{0i}\right) = \frac{1}{E_c p_{0i}} - r$ *(or, equivalently, if and only if* $E_c < \bar{E}\left(g_i, p_{0i}\right) = \frac{1}{p_{0i}(g+r)}$*.)*

Lemma 1 may be interpreted as requiring either that entry costs are not so large in any country that profits are negative, or that the range of rates of ETC across industries is not too broad. The discount rate r also matters because profits are delivered over time, whereas entry costs must be paid up-front at least once. We will assume henceforth that $g_i < \bar{g}\left(E_c, p_{0i}\right)$ for all i and c.

Proposition 2 $T^{*}\left(g_i, E_c; p_{i0}\right) < \infty$ *exists and is unique.*

Proposition 3 *There exists a unique steady state entry equilibrium to which all equilibria converge uniformly.*

Over a given time interval $\Delta < T^* \left(g_i, E_c; p_{i0}\right)$, a proportion $\xi \left(\Delta, g_i, E_c; p_{i0}\right)$ of firms will exit either due to replacement or to the shutting down of the production site where they are located. Define the steady state *exit rate* as $X^* \left(g_i, E_c; p_{i0}\right) = \lim_{\Delta \rightarrow +0} \frac{\xi(\Delta, g_i, E_c; p_{i0})}{\Delta}$. Since the steady state measure is constant, the entry rate in a given industry will equal the exit rate.

Proposition 4 *The steady state rate of entry and exit* $X^* \left(g_i, E_c; p_{i0}\right)$ *is negatively related to* $T^* \left(g_i, E_c; p_{i0}\right)$.

What is the relationship between g_i and rate of exit? Intuition might suggest that $\frac{\partial T^*(g_i, E_c; p_{i0})}{\partial g} < 0$: if g_i is relatively high, then firms fall away from the frontier faster than otherwise and there is an incentive to close down and return to the frontier sooner. Let us term this the "catch-up" effect. However, differentiating the optimal lifespan $T^* \left(g_i, E_c; p_{i0}\right)$ with respect to g_i yields the following expression:

$$\frac{\partial T^* \left(g_i, E_c; p_{i0}\right)}{\partial g_i} = -\frac{1}{g_i} T^* \left(g_i, E_c; p_{i0}\right) - \frac{1}{g_i} . \frac{\partial W \left(g_i, E_c; p_{i0}\right)}{\partial g_i} \times \frac{1}{W \left(g_i, E_c; p_{i0}\right)}. \quad (8)$$

Equation (8) has two parts. The first is negative, representing the "catch-up" effect. However, the second has the opposite sign of $\frac{\partial W(g_i, E_c; p_{i0})}{\partial g_i}$, and it is straightforward to show that $\frac{\partial W(g_i, E_c; p_{i0})}{\partial g_i}$ is negative. This is because the benefit of starting a new firm is lower when g is high since, once created, it will become obsolete at a faster rate. Let us call this the "give-up" effect.

Since the "catch-up" and "give-up" effects counteract each other, the sign of the overall expression is not immediate. However, a closer examination of (8) suggests that the importance of the "give-up" effect may depend on whether $W(g_i, E_c; p_{i0})$ is very small – or on whether g_i is close to $\bar{g}(E_c; p_{i0})$. Indeed:

Proposition 5 *There exists a unique* $g^*(E_c; p_{i0}) > 0$ *such that* $T^*(g_i, E_c; p_{i0})$ *is decreasing in* g_i *if and only if* $g_i < g^*(E_c; p_{i0})$. *In addition,* $g^*(E_c; p_{i0}) < \bar{g}(E_c; p_{i0})$.

Corollary 6 *The exit rate* $X^*(g_i, E_c; p_{i0})$ *is increasing in* g_i *if and only if* $g_i < g^*(E_c; p_{i0})$.

Thus, if the rate of ETC is not too broad, the rate of entry and exit is highest in industries in which ETC is rapid, as in the data.

Figure 5 illustrates the firm lifecycle for two values of g_i in the interval $(0, g^*)$. In an industry in which g_i is high, the productivity of a given firm falls behind that of the frontier technology more rapidly. As a result, it is optimal to replace firms more frequently. Nonetheless, at the point at which they are replaced, firms are less productive relative to the frontier in "fast paced" industries than in industries in which the technological frontier expands slowly. In figure 5, values of g_i are chosen to represent the low and high range of the reported values by Cummins and

Violante (2002), whereas p_{i0} and E_c are set arbitrarily. The firm lifespans are not unreasonable, whereas g^* for these parameters is over 34%. This is considerably above the range of empirically reasonable values, as the maximum annual reported industry ETC growth rate is under 9% (see Appendix). This suggests that the assumption that $g_i < g^*(E,p)$ is not restrictive. Moreover, as argued in Section 2, the evidence is consistent with the condition that $g_i < \bar{g}(E_c; p_{i0})$, in that the industry entry and exit rates reported by Brandt (2004) are positively related to the industry rates of ETC found by Cummins and Violante (2002).

FIGURE 5 ABOUT HERE

4.2 Regulation of Entry

Recent work reflects an increasing interest in the regulation of entry. The detailed case study of De Soto (1990) and the cross-country analysis of Djankov et al (2002) argue that the regulation of entry is an important factor of aggregate outcomes, and that the primary difference between entry regulation regimes appears to be the extent to which they impose costs on entrepreneurs. Fonseca et al (2001) and Bertrand and Kramarz (2002) find a relationship between entry costs and employment aggregates. However, the *cross-industry* effects of institutional entry costs have only recently begun to be addressed. Fisman and Sarria-Allende (2004) do not find a clear empirical relationship between the response of sector shares to entry regulation in manufacturing data, whereas Messina (2005) finds that entry costs are negatively related to the share of the service sector. The results of Section 2 also suggest that entry costs are related to a relative absence of high-tech industries. I now ask how the level of entry costs affects sectoral composition in the model economy.

Definition 3 *A steady state equilibrium displays "technological skew" if* $\frac{\mu^*_{i'c'}}{\mu^*_{ic'}} < \frac{\mu^*_{i'c}}{\mu^*_{ic}}$ *whenever* $E_{c'} > E_c$ *and* $g_{i'} > g_i$.

Again, technological skew is the notion that industries in which technical change is rapid are relatively more common in countries in which entry costs are low, whereas countries in which the regulation of entry is costly are likely to end up with industries that are less "fast-paced." The concept is defined in terms of entry costs, but is applicable to other policies also.

Proposition 7 $\frac{\partial W(g_i,E_c;p_{i0})}{\partial E_c} < 0$. *Moreover,* $\frac{\partial^2 W(g_i,E_c;p_{i0})}{\partial E_c \partial g_i} < 0$ *if and only if* $T^*(g_i, E_c; p_{i0})$ *is decreasing in* g_i.

Proposition 8 $\frac{\partial^2 W(g_i,E_c;p_{i0})}{\partial E_c \partial g_i} < 0$ *if and only if* $g < g^*(E_c; p_{i0})$.

Proposition 9 *If* $g_i < g^* (E_c, p_{i0})$ *for all* i *and* c*, then the equilibrium displays technological skew.*

Proposition 8 finds that, as conjectured, entry costs are most detrimental to entrepreneurial activity in sectors in which the rate of ETC is high, provided the range of g_i is not too broad. Proposition 9 shows that, provided the rate of ETC is not "too broad," high entry costs lead countries to specialize in industries in which the rate of technical change is low. It is of note that, while the earlier results on the relationship between firm and plant turnover assume that prices p_{i0} are constant across industries, Proposition 9 does not depend upon the values of p_{i0}.

5 Discussion: Extensions and Implications

5.1 Technology updating

The basic model requires entrepreneurs to start a new firm in order to adopt a new technology. The model could be extended to allow firms to respond to the fact that their technology is determined by vintage by *updating* their technology periodically.

Suppose now that entrepreneurs are able to update the technology at their old firms without having to start a new one. Entrepreneurs are characterized by an idiosyncratic level of *managerial ability* $\alpha \in [0, \bar{\alpha}]$, where α is distributed over the population of entrepreneurs according to a measure A. α is an index of her ability to *preserve firm value*: it is the cost of adopting a new technology without having to build a new firm.[10]

Once more, let W equal the value of a new production site in a given industry, and let $\hat{W}$ be the value of a production site once the initial entry cost has been incurred, so that $W(g_i, E_c; p_{i0}, \alpha) = \hat{W}(g_i, E_c; p_{i0}, \alpha) - E$ where:

$$\begin{aligned} \hat{W}(g_i, E_c; p_{i0}, \alpha) &= \max_T \Big\{ V(T) + e^{-rT} \max \Big[\hat{W}(g_i, E_c; p_{i0}, \alpha) - E_c, \\ &\qquad \hat{W}(g_i, E_c; p_{i0}, \alpha) - \alpha \Big] \Big\} \end{aligned} \tag{9}$$

Clearly there will be updating iff $\alpha < E_c$. Thus, if $\bar{\alpha} > E_c$, there is a bifurcation whereby intrepid entrepreneurs always update, whereas others always replace their firms. The former only pay entry costs once, so for them $\hat{W}(g_i, E_c; p_{i0}, \alpha)$ does not depend upon E_c : $\frac{\partial W(g_i, E_c; p_{i0}, \alpha)}{\partial E} = -1$ and $\frac{\partial^2 W(g_i, E_c; p_{i0}, \alpha)}{\partial E \partial g} = 0$. For these firms, there is no systematic link between E_c and g_i of the kind in Proposition 7. However, for firms such that $\alpha > E_c$, the sectoral choice problem is the same as (4), since re-entry

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[10] Chan et al (1990) account for the structure of venture capital contracts on the basis of a model with entrepreneurial differences in managerial skill.

is more profitable than updating. Hence, Propositions $7 - 9$ apply directly to the activity of these entrepreneurs.

The empirical pattern of plant-level investment suggests that a large proportion of plants do not significantly change their technology over their lifetimes.[11] Nonetheless, this extension underlines an important aspect of the model: sectoral choice must be at least partially irreversible. To put it another way, there must be some sector-specificity to entrepreneurial activity, so that the expected returns from a unit of entrepreneurial resource are related to the fate of more than one single firm.

5.2 Other extensions

The model presented above demonstrates that the regulation of entry leads to technological skew for the case of two industries. The results of the model apply to the case in which there are $I > 2$ industries, with some caveats. A sufficient condition is that prices p_{i0} must be such that they do not overturn the result that entry costs are more detrimental to profits in industries in which g_i is high. However, this is not necessary. For example, in a model of occupational choice between entrepreneurship and labor, Veracierto (2001) assumes that entrepreneurial output is based on the

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[11] Doms and Dunne (1998) find that most plant level investment occurs in widely-spaced "lumps" that occur on average once every 6 years or more. Dunne et al (1989) find that about 40% of plants do not appear to survive for 5 years and, since their data is quinquennial, this is likely to underestimate the true hazard rate. Identifying these "lumps" with significant changes to the production technology (see Samaniego (2006b)) suggests that most plants may not reach that stage.

production function $k(e) = \bar{k}e^{\beta}$, a functional form that is particularly useful for quantitative applications. In this case, technological skew also holds for any number of industries regardless of the price indices p_{i0}.

Proposition 10 *Suppose that $k(x) = \bar{k}x^{\beta}$. Then, for any $I \geq 2$, the equilibrium is technologically skewed.*

The assumption that prices decline exponentially over time delivers a stationary environment. At the same time, the fact that sector shares may change over time has received some attention. For example, Ngai and Pissarides (2004) account for the dynamics of the service sector share on the basis of sectoral differences in productivity growth. Although it is beyond the scope of this paper, it would be interesting to develop a general equilibrium extension in which the assumption of stationarity could be relaxed, so that sector shares might display some transition dynamics. In a different context that does allow for transition dynamics on the basis of preferences (not technology, as here), Messina (2005) shows that product market regulation may account for a portion of cross-country differences in sector shares.[12] None of these papers have entry, exit nor ETC, and it would be interesting to quantitatively assess the contribution of technological factors to these cross-country differences in a

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[12] In that paper differences in sector shares are accounted for on the basis of different income elasticities across goods.

suitable extension of the current paper. As discussed below, such an extension might have significant macroeconomic implications.

5.3 Macroeconomic implications

As mentioned in Section 2, the influence of the IT sector upon macroeconomic outcomes has received a lot of interest lately. In particular, Oliner and Sichel (2000) *inter alia* argue that a substantial part of the resurgence in US economic growth in the late 1990s can be attributed to the diffusion of IT. This suggests that any policies that discourage the use of IT could have important macroeconomic consequences, and has prompted several studies to explore whether there is evidence of a link between IT and cross-country macroeconomic performance.[13]

The above results suggest that countries with low entry costs may specialize in industries in which embodied technical change is rapid, such as IT. Interestingly, this would imply that entry costs may affect not only the *level* of GDP but also its *growth rate*. To see this, define γ_τ as the growth factor of GDP at time τ, chain-weighted and measured using discrete-time data. The formula for γ_τ is:

$$\gamma_\tau = \sqrt{\frac{\sum_i p_{i\tau} q_{i\tau}}{\sum_i p_{i\tau} q_{i,\tau-1}} \times \frac{\sum_i p_{i,\tau-1} q_{i\tau}}{\sum_i p_{i,\tau-1} q_{i,\tau-1}}}$$

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[13] See for instance Bassanini et al (2000), Pilat and Lee (2001) and Colecchia and Schreyer (2002).

where $q_{i\tau}$ is output in sector i during year τ. Along a balanced growth path, $q_{i,\tau-1} = q_{i\tau}e^{-g_i}$ and $p_{i,\tau-1} = p_{i\tau}e^{g_i}$, so the aggregate growth factor becomes

$$\gamma_\tau = \sqrt{\frac{\sum_i \sigma_i e^{g_i}}{\sum_i \sigma_i e^{-g_i}}} \tag{10}$$

where σ_i is the nominal share of GDP of industry i. Technological skew implies that, in an economy with high levels of entry costs, there will be a smaller (larger) share of GDP in industries in which technical change is fast (slow). If so, the impact of firing costs upon industry composition may affect *long run growth rates in real GDP*. If the rate of technical change is a microeconomic determinant of industry location and comparative advantage, then countries might be destined to different medium- or long-run *growth rates* based on their institutions. It is unusual to have a microeconomic foundation whereby policy may have growth effects rather than just level effects. The literature on "barriers to growth" related to Parente and Prescott (2000) tends to focus on the cost of importing capital or monopoly as factors behind low growth. This paper suggests that the regulation of entry could be another factor, as well as any other policy that leads to technological skew.

5.4 Service sector data

Fisman and Sarria-Allende (2005) fail to find a relationship between industry turnover (as measured by turnover in the US) and industrial structure across countries. However, their data only includes manufacturing – the US Census of Manufacturing, and the UNIDO Industrial Statistics Size-Distribution Database database. As noted, Brandt (2004) finds that industry fixed effects for entry and exit in manufacturing industries are small and not statistically significant in most cases, whereas they *are* statistically significant for almost all service sector industries. Similarly, Cummins and Violante (2002) find that rates of ETC tend to be lower in manufacturing than in services. Hence, it may be that there is not enough variation in the determinants of entry and exit (such as the rate of ETC) across manufacturing industries to yield clear results. Service sector data on output and prices are widely regarded as suffering from measurement problems. However, the problems and virtues of data on entry and exit should not depend on whether the industries in question include services. Section 2 finds that rates of entry, exit and ETC are more limited in range in manufacturing than across all sectors, suggesting that technological skew may be most clearly visible in data that includes services. Thus, the results suggest that it may be important for comparisons of cross-country industry structure to include service sector data also, where possible.

6 Concluding remarks

The purpose of this paper is two-fold. First, it provides a survey of entry, exit and embodied technical change across industries, as well as the relationship between these factors and institutional entry costs as reflected in broad sectoral composition. Second, it shows that the observed patterns are consistent with optimal behavior in a canonical vintage capital model with entrepreneurial choice. The paper shows that the rate of ETC change may interact with entry costs, causing countries in which entry is heavily regulated to specialize in industries in which the rate of firm-ETC is low. The mechanism involves higher rates of firm obsolescence in industries in which the rate of ETC is high, *caeteris paribus.*

More broadly, the paper articulates the notion of *technological skew*, whereby a policy may cause countries to specialize in this manner. Although it has been found to account for several features of industry dynamics, the usefulness of the concept of embodied technical change for policy analysis has long been debated – see for example Denison (1964) and Hulten (1992). This paper shows that, through its relationship with establishment dynamics, the costs imposed by the regulation of entry can affect the distribution of industries across countries in a systematic way. Having identified a new channel through which policy might have macroeconomic effects – and possibly growth effects – it would contribute to this debate to explore what other policies could have this effect. For example, a general equilibrium extension of the model, possibly in a multi-country setting, would be useful for addressing the long term effects of industrial policy that targets particular industries, as well as broad forms of regulation such as those that impose institutional entry costs.

A Data

A.1 The concept of embodiment

The concept of embodiment used here in is that of *firm*-embodied technical change, the rate at which *firms* become obsolete. Cummins and Violante (2002) provide industry indices of *capital*-embodied technical change for the United States.[14] However, the evidence suggests that capital-ETC and firm-ETC are related, however. For example, in a study of the aerospace industry, Ramey and Shapiro (2001) find that the value of used capital indicates the existence of large industry- and firm-specific components.[15] For the case of IT capital, Milgrom and Roberts (1990), Brynjolfsson and Hitt (2000) and Brynjolfsson et al (2002) find that the adoption of certain changes to business organization, such as increased decentralization and the use of self-managing teams, are central to whether IT investments result in productivity

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[14] I am grateful to Gianluca Violante for providing me with data on embodied technical change.

[15] The authors argue is an industry in which these components are likely to be relatively small.

improvements at the plant level. In a calibrated model of establishment dynamics, Samaniego (2006b) finds that about 60% of economic growth can be attributed to firm-embodied technical change, which is close to the value attributed to capital-ETC in Greenwood et al (1997) and Cummins and Violante (2002). As a result, the paper adopts the measure of Cummins and Violante (2002) as an indicator of firm-ETC.

A.2 Entry costs and policy

Cross-country data on entry costs and policy are available for the following countries: Austria (AUT), Australia (AUS), Belgium, Canada, Denmark, Finland, France, Germany, Ireland, Italy, Japan, Netherlands, New Zealand, Norway, Portugal, Spain, Sweden, Switzerland, the UK and the US. :Including GDP per capita in the regressions did not affect results.

Aside from ENT, EPL and PUB, the following additional policies were included. Samaniego (2006a) argues that most industrial support consists of transfers to failing establishments, so the presence of such subsides could constitute a potentially important determinant of the decision to retire obsolete firms. Hence, I also consider the proportion of GDP spent on industrial subsidies as reported in Ford and Suyker (1989) – denoted IND. I also include two further variables from the Nicoletti et al (2000) data set: the extent of public ownership (PUB), and barriers to trade (TRA). I include PUB for two reasons. First, Ford and Suyker (1989) and Leonard and Van Audenrode (1997) point out that much industrial support may be implicit through, for example, government ownership of establishments. Hence, national accounts data may miss certain forms of industrial support that could impact resource reallocation. PUB may be an indicator of omitted industrial support, and is the only policy variable that has a strong correlation with industrial subsidies (see below). Second, PUB may correlate with state investment in IT infrastructure, given that IT has been the object of public attention in recent years. As a result, it is *a priori* unclear whether one might expect PUB to be positively or negatively related to IT use. As for trade barriers, they may matter because most of the countries in the data set can be reasonably regarded as small open economies, and the layers of the IT industry are distributed globally.

A.3 Summary statistics

Tables $6A-6C$ report the correlations between the different policy and sectoral indicators used in Section 2. The main observations are that (a) The sectoral indicators are positively related amongst themselves; (b) the policy indicators are positively related amongst themselves; and (c) for the most part, the policy indicators are negatively related to the sectoral indicators (the exceptions are ITEMP and TRA).

TABLES $6A - 6C$ ABOUT HERE

B Proofs

Proof of Lemma 1. Notice that $\lim_{T\to\infty} V(T) - E > 0$ iff $g_i < \bar{g}(E_c, p_{0i})$, since

$$V(T) = \frac{p_{i0}}{r+g_i}\left[1 - e^{-(r+g_i)T}\right]. \tag{11}$$

Otherwise, for all T, $V(T) - E < 0$ and hence $W < 0$. The Inada conditions imply that there will always be entry when $W > 0$. ■

Proof of Proposition 2. In most of the proofs below, I suppress the dependence of W and V upon parameters for simplicity. In addition, observe that $W(g, E; p) = pW\left(g, \frac{E}{p}; 1\right)$, so for the current proof assuming that $p = 1$ is without loss of generality, since what follows depends upon the signs of derivatives only. It essentially re-normalizes the units in which E is measured. Assuming an interior solution ($T \in \mathbf{R}_+$), the first order condition to (4) is

$$V'(T(W)) = rWe^{-rT(W)} \Rightarrow e^{-gT} = rW \tag{12}$$

so, given $W > 0$, the argmax is $T(W) = -\frac{1}{g}\log rW$. The result follows provided it is shown that there exists a unique $W > 0$ such that $W = V(T(W)) - E + e^{-rT(W)}W$, or that there is a unique zero of the function $Q(W)$, where $Q(W) = W\left(1 - e^{-rT(W)}\right)$ $-V(T(W)) + E$. It is straightforward to show that $T(0) = \infty$, so $Q(0) = E - (r+g) < 0$. Moreover, by the envelope theorem, $Q'(W) = 1 - e^{-rT(W)} > 0$, so there is at most one $W : Q(W) = 0$. Moreover, $T\left(\frac{1}{r}\right) = 0$, so $Q\left(\frac{1}{r}\right) = E > 0$. Hence such a $W \in \left(0, \frac{1}{r}\right)$ exists and is unique. ■

Proof of Proposition 3. Before anything else, it is useful to note that $W(g_i, E_c; p_{0i})$ $= p_{0i}W\left(g_i, \frac{E_c}{p_{0i}}; 1\right)$. Hence, entry will be set so that $p_{0i}W\left(g_i, \frac{E_c}{p_{0i}}; 1\right)k'(e_{ic}) = \tilde{M}_c \forall i$ where M_c is the (endogenous) value of entry in country c, and which will be determined by market clearing. Consider $d : E_d > E_c$. We know that in country c, $p_{0i}W\left(g_i, \frac{E_c}{p_{0i}}; 1\right)k'(e_{ic}) = \tilde{M}_c$. Since e_{ic} is not optimal in country d, Proposition 7 implies that $p_{0i}W\left(g_i, \frac{E_d}{p_{0i}}; 1\right)k'(e_{ic}) < \tilde{M}_d$. Moreover, let the interval $U = \left(p_{01}W\left(g_1, \frac{E_d}{p_{01}}; 1\right)k'(e_{1c}),\ p_{0I}W\left(g_I, \frac{E_d}{p_{0I}}; 1\right)k'(e_{Ic})\right)$. It has to be that $\tilde{M}_d \in U$. Consider any $u \in U$, and pick e_{id} such that $p_{0i}W\left(g_i, \frac{E_d}{p_{0i}}; 1\right)k'(e_{id}) = u$. For any given u, it may not be the case that $\sum_i e_{id} = 1$ – however, there is one and only one such u for which this is the case, as $\sum_i e_{id}$ will be decreasing in u.

As for the steady state measure, consider an economy in which $\mu_{icv}(S) = 0 \forall S, v <$

τ_0. At this point, e_{ic} firms are born of vintage τ each period $\tau \geq \tau_0$, so that

$$\mu_{ic\tau}(S) = \int_{\substack{\tilde{v} \operatorname{mod}(T^*(g_i, E_c; p_{i0})) \in S \\ \tilde{v} \geq \tau_0}} e^{-\zeta(\tau - \tilde{v})} e_{ic} d\tilde{v} \tag{13}$$

Define this measure as $\tilde{\mu}$. Observe that $\tilde{\mu}$ converges uniformly towards a distribution that is exponential over the interval $[\tau - T^*(g_i, E_c; p_{i0}), \tau]$ and has mass $\int_{-\infty}^{\tau} e_{ic} e^{-\zeta(\tau - v)} dv = \frac{e_{ic}}{\zeta}$ (the number of production sites). Denote this measure μ_{ic}^*.

Now without loss of generality[16] consider another economy with arbitrary continuous measure $\mu_{ic\tau_0}$ such that $\mu_{ic\tau}(S) = 0$ for any $S \leq \tau - T^*(g_i, E_c; p_{i0})$. Each period $\tau \geq \tau_0$, the measure μ will be

$$\mu_{ic\tau}(S) = \tilde{\mu}_{ic\tau}(S) + e^{-\zeta(\tau - \tau_0)} F\left(\mu_{ic\tau_0}, S\right). \tag{14}$$

Thus $\tilde{\mu}_{ic\tau}(S)$ represents what happens to firms at production sites born after τ_0, whereas $F\left(\mu_{ic\tau_0}, S\right)$ represents the influence of firms born before, which wanes as their production sites close as $F\left(\mu_{ic\tau_0}, S\right) \leq \mu_{ic\tau_0}(\mathbb{R})$ for any S. Thus, the measure converges uniformly towards $\tilde{\mu}_{ic\tau}$, and hence towards μ_{ic}^*. ■

Proof of Proposition 4. The exit rate $X^*(g_i, E_c; p_{i0}) = \zeta + \lim_{\Delta \to {}_+0} \tilde{\xi}(\Delta)/\Delta$,

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[16] If this condition were violated by any firms, they would update immediately so at time $\tau_0 + \varepsilon$ the condition would be satisfied.

where the first element accounts for exogenous exit and

$$\tilde{\xi}(\Delta) = \frac{e_{ic}\int_{T^*(g_i,E_c;p_{i0})-\Delta}^{T^*(g_i,E_c;p_{i0})} e^{-\zeta T^*(g_i,E_c;p_{i0})}dt}{\frac{e_{ic}}{\zeta}} \tag{15}$$

$$\Rightarrow \lim_{\Delta\to_{+}0}\frac{\tilde{\xi}(\Delta)}{\Delta} = \zeta e^{-\zeta T^*(g_i,E_c;p_{i0})}. \tag{16}$$

■

Proof of Proposition 5. Again without loss of generality I assume that $p = 1$ for this proof. Rearranging (8), $\frac{\partial T^*}{\partial g} < 0$ if and only if $-T^* < \frac{\partial W}{\partial g}\cdot\frac{1}{W}$. It is simple to show that $W = (V - E)/\left(1 - e^{-rT}\right)$, so that

$$-T^*\left(V\left(T^*\right) - E\right) < \frac{\partial V\left(T^*\right)}{\partial g}. \tag{17}$$

In turn,

$$\frac{\partial V\left(T^*\right)}{\partial g} = -\frac{1}{(r+g)}V(T) + T^*\left[\frac{1}{(r+g)} - V\left(T^*\right)\right]. \tag{18}$$

Combining (17) with equations (11) and (18) yields the inequality $V\left(T^*\right) < T^*\left[1 - E(r+g)\right]$ where the right hand side of the equation is positive by assumption. Expanding yields

$$\frac{1}{r+g}\left[1 - e^{-(r+g)T^*}\right] < T^*\left[1 - E(r+g)\right]. \tag{19}$$

Define $\tau^*(g)$ as

$$\tau^*(g) = \left\{ \tau : \frac{1}{r+g}\left[1 - e^{-(r+g)\tau}\right] = \tau\left[1 - E(r+g)\right] \right\}, \tag{20}$$

which is the value of T^* such that this expression (19) holds with equality. Thus, $\frac{\partial T^*}{\partial g} < 0$ if and only if $T^* > \tau^*(g)$.

At $g = 0$, $T^* = \infty$ so this expression holds. On the other hand, as $g \to \frac{1}{E} - r$ (the boundary beyond which positive entry is not profitable), $\tau^* \to \infty$ as the left hand side of the expression in (20) is positive and finite, whereas $\lim_{g \to \frac{1}{E} - r}\left[1 - E(r+g)\right] = 0$. Consequently, there must be at least one intermediate value such that $T^* = \tau^*$. Call the lowest such value g^*, and suppose there is another denoted g^{**}. At both g^* and g^{**}, by definition, $\frac{\partial T^*}{\partial g} = 0$. At g^{**}, the derivative of T^* would have to be zero by the definition of τ^*. At g^{**}, $\frac{\partial \tau^*}{\partial g}$ would have to be less than or equal to zero, however, since on the interval (g^*, g^{**}) it is the case that $\frac{\partial T^*}{\partial g} > 0$ and that $T^* < \tau^*$. This is a contradiction as, over the relevant range, $\frac{\partial \tau^*}{\partial g} = \frac{1 - E(r+g)}{e^{-(r+g)\tau}} > 0$. ■

Proof of Proposition 7. Consider any ε such that $0 < \varepsilon < T^*(g, E; p)$. Define the following Bellman equation:

$$Bv = \max_{T \geq \varepsilon}\left\{V(T) - E + e^{-rT}v\right\}. \tag{21}$$

where v is a continuous and bounded function of parameters and B is the Bellman operator. B satisfies Blackwell's sufficiency conditions for a contraction mapping – see Theorem 3.3 from Stokey et al (1989). This implies that standard discrete time recursive methods can be applied directly to characterize the solution to problem (21), something that is not the case with the unrestricted problem (4). Hence, there exists a unique $W : BW = W$. Clearly, the solution to problems (4) and to the fixed point of the Bellman operator in (21) will be the same, as the latter is a restriction on the former that does not rule out the unrestricted optimum.

Suppose that $\frac{\partial^2 v}{\partial E \partial g} < 0$. From equation (21), $\frac{\partial Bv}{\partial E} = -1 + e^{-rT^*} \frac{\partial v}{\partial E}$, and $\frac{\partial^2 Bv}{\partial E \partial g} = e^{-rT^*} \frac{\partial^2 v}{\partial E \partial g} - \frac{\partial T^*}{\partial g} r e^{-rT^*} \frac{\partial v}{\partial E}$. Corollary 1 from Stokey et al (1989) then implies that, at the fixed point, $\frac{\partial^2 W}{\partial E \partial g} \left(1 - e^{-rT^*}\right) = -\frac{\partial T^*}{\partial g} r e^{-rT^*} \frac{\partial W}{\partial E}$. Since $\frac{\partial W}{\partial E} < 0$, the sign of $\frac{\partial^2 W}{\partial E \partial g}$ is the same as the sign of $\frac{\partial T^*}{\partial g}$. ■

Proof of Proposition 8. Corollary of Propositions 5 and 7. ■

Proof of Proposition 9. Label the two industries l and h such that $g_h > g_l$. Also, pick two countries r and u such that $E_r > E_u$ (r is for "regulated" and u is for "unregulated"). In equilibrium, entry in either industry should yield the same marginal return, so that $p_h W_{hu} \left(g_h, \frac{E_u}{p_{0h}}; 1 \right) k' \left(e_{hu} \right) = p_l W_{lu} \left(g_l, \frac{E_u}{p_{0l}}; 1 \right) k' \left(e_{lu} \right)$ and

$p_h W_{hr}\left(g_h, \frac{E_r}{p_{0h}}; 1\right) k'\left(e_{hr}\right) = p_l W_{lr}\left(g_l, \frac{E_r}{p_{0l}}; 1\right) k'\left(e_{lr}\right)$. Rearranging, we have that

$$\frac{p_h W_{hu}\left(g_h, \frac{E_u}{p_{0h}}\right)}{p_l W_{lu}\left(g_l, \frac{E_u}{p_{0l}}\right)} = \frac{k'\left(e_{lu}\right)}{k'\left(e_{hu}\right)}, \tag{22}$$

$$\frac{p_h W_{hr}\left(g_h, \frac{E_r}{p_{0h}}\right)}{p_l W_{lr}\left(g_l, \frac{E_r}{p_{0l}}\right)} = \frac{k'\left(e_{lr}\right)}{k'\left(e_{hr}\right)}. \tag{23}$$

First note that $W_{hj}\left(g_h, \frac{E_j}{p_{0h}}\right) < W_{lj}\left(g_l, \frac{E_j}{p_{0l}}\right)$ for any country j, so that $\frac{W_{hj}\left(g_h, \frac{E_j}{p_{0h}}\right)}{W_{lj}\left(g_l, \frac{E_j}{p_{0l}}\right)} < 1$. Furthermore, that $\frac{\partial^2 V}{\partial E \partial g} < 0$ implies $\frac{W_{hr}\left(g_h, \frac{E_r}{p_{0h}}\right)}{W_{lr}\left(g_l, \frac{E_r}{p_{0l}}\right)} < \frac{W_{hu}\left(g_h, \frac{E_{uh}}{p_{0h}}\right)}{W_{lu}\left(g_l, \frac{E_u}{p_{0l}}\right)}$. This, along with (22) and (23), implies $\frac{k'(e_{lr})}{k'(e_{hr})} < \frac{k'(e_{lu})}{k'(e_{hu})}$.Finally,$e_{lj} = 1 - e_{hj}$ in any country j, so that $\frac{k'(1-e_{hr})}{k'(e_{hr})} < \frac{k'(1-e_{hu})}{k'(e_{hu})}$. Using the product rule, $\frac{d\frac{k'(1-e)}{k'(e)}}{de} = \frac{-k''(1-e)k'(e) - k''(e)k'(1-e)}{k'(e)^2} > 0$. Consequently, $e_{hu} > e_{hr}$ and $e_{lu} < e_{lr}$. ■

Proof of Proposition 10. Optimal use of the entrepreneurial resource implies

$$\frac{p_h W_{hu}\left(g_h, \frac{E_u}{p_{0h}}\right)}{p_l W_{lu}\left(g_l, \frac{E_u}{p_{0l}}\right)} = \frac{e_{lu}^{\beta-1}}{e_{hu}^{\beta-1}}, \frac{p_h W_{hr}\left(g_h, \frac{E_r}{p_{0h}}\right)}{p_l W_{lr}\left(g_l, \frac{E_r}{p_{0l}}\right)} = \frac{e_{lr}^{\beta-1}}{e_{hr}^{\beta-1}}.$$

Again, note that $W_{hj}\left(g_h, \frac{E_j}{p_{0h}}\right) < W_{lj}\left(g_l, \frac{E_j}{p_{0l}}\right)$ for any country j, so that $\frac{W_{hj}\left(g_h, \frac{E_j}{p_{0h}}\right)}{W_{lj}\left(g_l, \frac{E_j}{p_{0l}}\right)} < 1$. Furthermore, that $\frac{\partial^2 V}{\partial E \partial g} < 0$ implies $\frac{W_{hr}\left(g_h, \frac{E_r}{p_{0h}}\right)}{W_{lr}\left(g_l, \frac{E_r}{p_{0l}}\right)} < \frac{W_{hu}\left(g_h, \frac{E_{uh}}{p_{0h}}\right)}{W_{lu}\left(g_l, \frac{E_u}{p_{0l}}\right)}$. This, along with (22) and (23), implies $\frac{e_{lr}^{\beta-1}}{e_{hr}^{\beta-1}} < \frac{e_{lu}^{\beta-1}}{e_{hu}^{\beta-1}} \Rightarrow \frac{e_{lr}}{e_{hr}} > \frac{e_{lu}}{e_{hu}}$. Since $\mu_{ic}^* = \frac{e_{ic}}{\zeta}$, the result follows. ■

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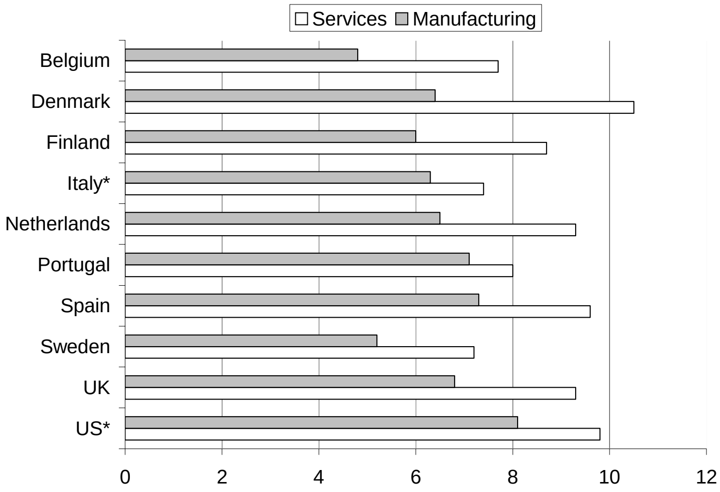

Figure 1: Rates of Entry across the OECD 1997-2000, for Services and Manufacturing (%). Source: Brandt (2004). *Data are from Eurostat, except for Italian and US data which are from the OECD.

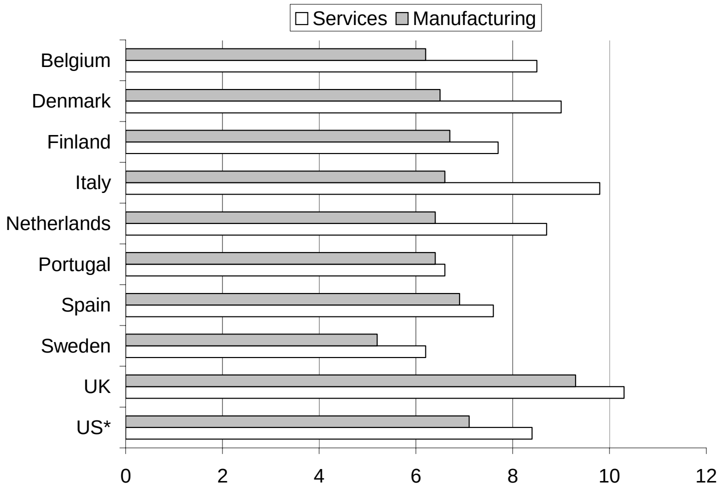

Figure 2: Rates of Exit across the OECD 1997-2000, for Services and Manufacturing (%). Source: Brandt (2004). *Data are from Eurostat, except for US data which are from the OECD.

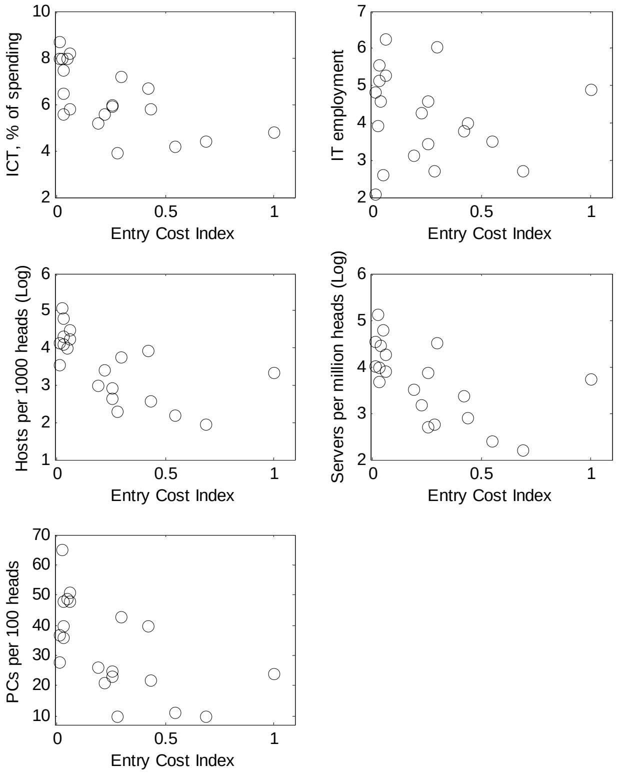

Figure 3: Entry costs and Information Technology in the OECD.

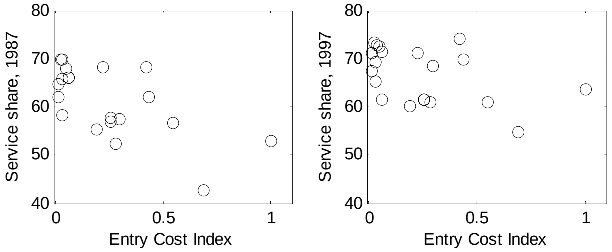

Figure 4: Entry costs and the Service Share in the OECD.

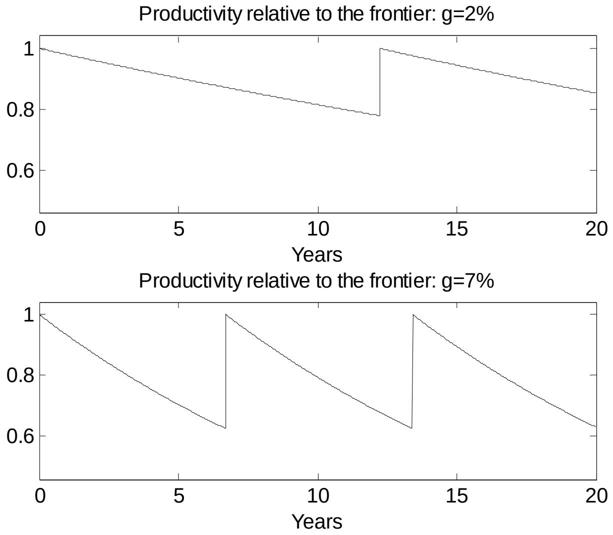

Figure 5: Equilibrium behavior at a production site, for different values of g the rate of embodied technical change. A production site is created at time zero, and the firm that occupies the site falls steadily behind the frontier until it becomes optimal to replace it. At this point, a new firm is established with the frontier technology, and the cycle is repeated. $r = 7\%, p = 1, E = 1$. As for the values of g, 2% and 7% correspond to the lowest and highest industry rates of ETC found by Cummins and Violante (2002) in US data for 1947-2000 (for Agriculture and Communications, respectively).

ETC measure	ENTRY	EXIT
ETC, Imputed	53.5%*** (0.11)	47.3%*** (0.12)
ETC, Not imputed	44.7%*** (0.15)	45.7%*** (0.15)

Table 1 – Correlation of embodied technical change with rates of entry and exit. Numbers in brackets are standard errors. An asterisk (*) denotes significance at the 10% level, whereas two and three asterisks denote significance at the 5% and 1% levels respectively.

Name	**Variable**
ITSP	Share of IT spending in GDP, 1992-1999.
ITEMP	Share of IT in private sector employment, 1998.
PCS	PC base: Average number of PCs per 100 people, 1999.
HOST	Internet size: Log Internet hosts per 1000 people, 1999.
SERV	E-commerce: Log Secure servers per million people, 2000.
S87	Service sector share, 1987.
S97	Service sector share, 1997.

Table 2 – Indicators of technological skew. Sources: OECD (2000), Coppel (2000) and Pilat and Lee(2001).

	ITSP	ITEMP	HOST	SERV	PCS	S87	S97
Correlation	-0.64***	-0.13	-0.63***	-0.58***	-0.60***	-0.64***	-0.45**
S.E.	(0.18)	(0.23)	(0.18)	(0.19)	(0.18)	(0.18)	(0.20)

Table 3 - Correlations between entry costs and sectoral indices.

Name	**Variable**
ENT	Entry costs
EPL	Employment protection measure
IND	Industrial Subsidy rates[1]
PUB	Extent of public ownership
PRO	Product market regulation
TRA	Barriers to International Trade and Investment

Table 4 – Policy indices.

Dependent	Policy	Index					#Obs	Adj R^2
Variable	ENT	EPL	IND	PUB	PRO	TRA		
HOST	-0.56***	-0.55**	-0.38*	0.76***	-0.13	0.00	20	0.61
	(0.17)	(0.24)	(0.19)	(0.24)	(0.28)	(0.19)		
SERV	-0.30*	-0.74***	-0.23	0.51**	-0.22	0.02	20	0.71
	(0.15)	(0.21)	(0.16)	(0.21)	(0.24)	(0.16)		
PCS	-0.50**	-0.44	-0.31	0.63**	-0.24	0.07	20	0.44
	(0.20)	(0.29)	(0.22)	(0.29)	(0.33)	(0.22)		
ITSP	-0.39**	-0.47*	-0.27	0.31	-0.30	0.09	20	0.61
	(0.17)	(0.23)	(0.18)	(0.24)	(0.28)	(0.19)		
ITEMP	-0.23	-0.53	-0.02	0.92**	-0.01	-0.14	20	0.32
	(0.22)	(0.32)	(0.24)	(0.32)	(0.36)	(0.24)		
S87	-0.52**	-0.58*	-0.10	0.15	0.32	-0.12	20	0.34
	(0.22)	(0.31)	(0.24)	(0.31)	(0.36)	(0.24)		
S97	-0.22	-0.90***	-0.22	0.24	0.43	0.10	20	0.39
	(0.21)	(0.30)	(0.23)	(0.30)	(0.35)	(0.23)		

Table 5 – Sectoral composition and policy. Each row corresponds to a regression, with dependent variables on the left-most column. Variables are normalized by their means and standard deviations.

Variable	ITSP	ITEMP	HOST	SERV	PCS	S87
ITSP	1.00	-	-	-	-	-
ITEMP	0.17	1.00	-	-	-	-
HOST	0.69	0.43	1.00	-	-	-
SERV	0.81	0.31	0.82	1.00	-	-
PCS	0.76	0.39	0.90	0.84	1.00	-
S87	0.72	0.26	0.72	0.60	0.69	1.00
S97	0.63	0.20	0.67	0.58	0.59	0.87

Table 6A - Correlations among sectoral indices.

Variable	ENT	EPL	IND	PUB	PRO
ENT	1.00	-	-	-	-
EPL	0.51	1.00	-	-	-
IND	0.06	0.20	1.00	-	-
PUB	0.37	0.53	0.54	1.00	-
PRO	0.31	0.68	0.10	0.63	1.00
TRA	-0.18	-0.06	0.13	0.30	0.41

Table 6B - Correlations among policy variables.

Variable	ITSP	ITEMP	HOST	SERV	PCS	S87	S97
ENT	-0.64	-0.13	-0.63	-0.58	-0.60	-0.64	-0.45
EPL	-0.78	-0.16	-0.60	-0.82	-0.59	-0.55	-0.62
IND	-0.24	0.34	-0.12	-0.14	-0.10	-0.15	-0.25
PUB	-0.41	0.50	-0.03	-0.26	-0.09	-0.24	-0.19
PRO	-0.54	0.80	-0.23	-0.51	-0.29	-0.20	-0.15
TRA	0.11	0.20	0.26	0.15	0.24	0.17	0.22

Table 6C - Correlations among ETC indices and policy variables.