Contribuição especial

Saturation in Autoregressive Models

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resumo

Neste artigo estendemos a ideia base do algorítmo de saturação de modelos com variáveis indicadores a um tipo particular de modelos dinâmicos. Demonstra-se que o procedimento mantém o nível de significância real correcto para processos AR(1) estacionários, independentemente do número de partições da amostra usado. Derivamos a potência teórica em face de um *outlier* de tipo aditivo e apresentamos evidência de Monte Carlo que demonstra uma boa taxa de rejeição empírica da hipótese nula nesse caso. É apresentado um conjunto extenso de simulações de Monte Carlo que evidenciam que o procedimento tem uma potência apreciável quando existe quebra na média condicional do processo nas últimas *rT%* observações da amostra. Este resultado não depende do nível de autocorrelação das observações, nem da utilização de um mal especificado modelo do tipo *location-scale*, abrindo assim as portas a uma nova classe de testes automáticos de quebras de estrutura que poderão revelar-se melhores que testes do tipo de Bai-Perron em pequenas amostras.

résumé / abstract

In this paper, we extend the impulse saturation algorithm to a class of dynamic models. We show that the procedure is still correctly sized for stationary AR(1) processes, independently of the number of splits used for sample partitions. We derive theoretical power when there is an additive outlier in the data, and present simulation evidence showing good empirical rejection frequencies against such an alternative. Extensive Monte Carlo evidence is presented to document that the procedure has good power against a level shift in the last *rT%* of the sample observations. This result does not depend on the level of serial correlation of the data and does not require the use of a (mis-specified) location-scale model, thus opening the door to an automatic class of break tests that could outperform those of the Bai-Perron type.

JEL Codes: C22; C51

1. Introduction

A key recent development in testing for parameter non-constancy is doing so by adding a complete set of indicators to a model (see Hendry, Johansen and Santos, 2005). This new technique came to be known as impulse or indicator saturation. Using general-to-specific (GETS) procedures, the authors establish the null distribution of the mean and variance estimators in a location-scale model, after adding T impulses, when T is the sample size, and retaining the relevant ones. A two-fold process is investigated whereby half the indicators are added and the significant ones recorded. Then, the other half is examined, and finally the two are combined in a union model. Under the null hypothesis that no indicator matters, the average retention rate of indicators is αT, matching the binomial result exactly, and showing that there is no overfitting[3]. Moreover, Hendry at al. (2005) show that other splits (such as T/3, T/4, etc) do not affect the retention rate of the model under the null.

Hendry and Santos (2006) extend this procedure to break testing in location-scale models. What under the null was a model selection problem, under the alternative becomes a test for breaks at unknown dates, since an indicator is tested for every observation. Theoretical power of the impulse saturation break test is derived, both for the case of a mean shift and for the case of a variance shift. Results are shown to be remarkably close to Monte Carlo outcomes.

Previous results on GETS model selection where there are more candidate indicator variables than indicators are given in Hendry and Krolzig (2003). Notwithstanding, the theoretical analysis for the general case treated there is hardly as developed as the analysis in Hendry et al. (2005) for the case of a complete set of indicators. Clearly, the reason for this is that impulse dummies are perfectly orthogonal to each others, so we do not have to cope with the problems of collinearity faced in more general settings (see Hendry and Krolzig (2003), and Hendry and Castle (2005)). Hendry (2000) advises orthogonalization of the regressors prior to model selection as a way to reduce model uncertainty.

The objective of this paper is to extend the baseline impulse saturation results to a class of dynamic models, namely that of stationary autoregressive models. We provide Monte Carlo evidence that there are no size distortions in impulse saturating stationary autoregressive processes, and that the procedure has good power properties in this class of models both to detect additive outliers (AO) and to detect level shifts at unknown dates.

The paper is organized as follows. Section 2 presents Monte Carlo evidence of the null rejection frequencies (NRFs) of indicators in saturated stationary AR(1) models. A pilot extension to a unit root process is also documented. Section 3 derives analytical power of the procedure for the additive outlier case, and compares such results with Monte Carlo evidence. Section 4 provides simulation results for rejection frequencies of the null when there is a level shift on the last of the sample observations. Section 5 concludes.

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2 This research was conducted while the first author was a doctoral student at the University of Oxford, UK, and is a part of his doctoral dissertation. Both authors acknowledge the invaluable contributions of Soren Johansen and Bent Nielsen in several discussions. Several participants at the Royal Economic Society Annual Conference 2006 provided useful comments and suggestions. James Reade provided invaluable research assistance. The authors are also most grateful for comments by the Editor and an anonymous referee. The usual disclaimer applies. Financial Support from the Fundação para a Ciência e a Tecnologia, Lisbon, and from the ESRC under a Professorial Fellowship, RES051270035, are acknowledged by the first and second authors respectively.
3 Hendry, Leamer and Poirier (1990) conclude that the tests have the same properties at each reduction stage as when applied in the General Unrestricted Model. Hence, there is no need to adjust critical values for testing in the union model. White (1991) and Mayo (1980) corroborate this. In particular Mayo (1980) argues that test information is independent from sufficient statistics from which parameter estimates are derived.

2. Null Rejection Frequencies in the Impulse Saturated Stationary AR(1) Process[4]

We consider the stationary AR (1) process with zero mean as the Data Generating Process (DGP):

$$y_t = \rho y_{t-1} + \varepsilon_t \qquad (1)$$

We assume that $\varepsilon_t \sim IN(0;1)$ and that $|\rho| < 1$. We consider adding T impulses in partitions of $T/2$ and $T/3$ to (1). Hence, the two General Unrestricted Models (GUMs) would be the DGP augmented by $T/2$ indicators, in the first case studied. In the second case, the three GUMs would match (1) augmented with $T/3$ indicators.

That is, for *T/2* we consider the intermediate econometric models:

$$y_t = \rho y_{t-1} + \sum_{s=1}^{T/2} \varphi_s 1_{\{s=t\}} + v_t$$

and

$$y_t = \rho y_{t-1} + \sum_{s=T/2+1}^{T} \varphi_s 1_{\{s=t\}} + \omega_t$$

A partition of *T/3* would naturally imply three intermediate regressions.

We allow ρ to vary across the Monte Carlo experiments, taking values from 0.1 to 0.9. The objective of considering this range for the autoregressive parameter is to check if the null properties of the model depend on the degree of first order serial correlation in the sample.

The sample sizes considered are $T = 100$, $T = 200$ and $T = 300$[5]. Individual significance tests on the impulse indicators are conducted for a range of significance levels α, taking values from the set {0.1; 0.05; 0.025; 0.01}[6].

It should be noticed that the computed t-ratios are constructed using the standard normal approximation to the distribution of the individual significance test statistics. $M = 10000$ replications are conducted in each experiment and the empirical rejection frequency is the average across all experiments of the ratio of indicators retained in the union model to the sample size. Table 1 reports the results for $T = 300$ and a split of $T/2$.

Table 1 – Null Rejection Frequencies, *T* = 300, *T/2*

$\alpha \setminus \rho$	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
0.1	0.101	0.109	0.101	0.101	0.101	0.101	0.101	0.101	0.101
0.05	0.051	0.051	0.051	0.051	0.051	0.051	0.051	0.051	0.051
0.025	0.026	0.026	0.026	0.026	0.026	0.026	0.026	0.0257	0.026
0.01	0.01	0.01	0.01	0.010	0.01	0.01	0.01	0.011	0.011

4 All the Monte Carlo simulations conducted in this paper were written using Ox 3.4 (Doornik, 2001). In particular, autoregressive series were generated using the armagen function within the ARMA package. All codes written for this paper are available from the authors on request.
5 In practice we have generated samples of sizes 120, 220 and 320 and we have disregarded the first 20 observations in each case, in order to eliminate dependence on the initial values.
6 Santos (2006) shows the results are not sensitive to changes to in the innovation variance.

Table 1 shows that for such a sample size, the nominal significance level is close to the empirical rejection frequency: the two are never apart by more than two tenths of a percentage point. Table 2 refers to the $T = 200$ case. Again the split considered is $T/2$. In spite of the reduction in the sample size, the empirical rejection frequency is still close to the nominal significance. Table 3 reports the results for the case $T = 100$. Nominal and real significance levels diverge as the sample size decreases, as was to be expected given the asymptotic approximation used. Nonetheless, for $T = 100$, such a divergence is still small: in nearly all cases never greater than four tenths of a percentage point.

Table 2 – Null Rejection Frequencies, $T = 200$, $T/2$

$\alpha \setminus \rho$	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
0.1	0.10168	0.10164	0.10167	0.10171	0.10171	0.10169	0.10179	0.10195	0.10227
0.05	0.051341	0.051351	0.051349	0.051385	0.051438	0.051471	0.05147	0.051535	0.051742
0.025	0.026	0.026	0.026	0.026	0.026	0.026031	0.2601	0.0261	0.0262
0.01	0.011	0.011	0.011	0.011	0.011	0.011	0.011	0.011	0.011

Table 3 – Null Rejection Frequencies, $T = 100$, $T/2$

$\alpha \setminus \rho$	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
0.1	0.103564	0.103651	0.10369	0.10373	0.10375	0.103926	0.10404	0.10445	0.10532
0.05	0.052848	0.052858	0.052987	0.053026	0.053085	0.053176	0.053321	0.053539	0.054259
0.025	0.027064	0.027092	0.027159	0.027163	0.027212	0.027237	0.027297	0.027487	0.02799
0.01	0.011362	0.011374	0.01378	0.011419	0.011439	0.011491	0.011553	0.011606	0.011871

Tables 1, 2 and 3 also confirm that divergence between nominal and real significance levels are slightly more pronounced as ρ becomes closer to unity. In any case, the fundamental conclusion from the three tables is that nominal and real significance levels are close, overcoming most of the effects introduced by dynamics.

We now turn to investigate the impact of a different sample split on the empirical rejection frequency, under the null. The same defaults apply. Table 4 refers to the $T = 300$ case and table (5) to the $T = 100$.

Table 4 – Null Rejection Frequencies, $T = 300$, $T/3$

$\alpha \setminus \rho$	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
0.1	0.10072	0.10073	0.10074	0.10076	0.10082	0.10081	0.10085	0.10092	0.10091
0.05	0.050676	0.050676	0.050671	0.050691	0.050697	0.050694	0.050716	0.050746	0.050789
0.025	0.0255	0.025487	0.025474	0.025465	0.025454	0.025447	0.025439	0.025439	0.025537
0.01	0.010299	0.010295	0.010306	0.010291	0.010295	0.010308	0.01029	0.0103	0.010347

Table 5 – Null Rejection Frequencies, $T = 200$, $T/3$

$\alpha \setminus \rho$	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
0.1	0.10118	0.10123	0.010114	0.10117	0.010119	0.10119	0.10127	0.10134	0.10157
0.05	0.05096	0.050947	0.051013	0.051028	0.051061	0.051083	0.051092	0.051124	0.05117
0.025	0.025689	0.025725	0.025726	0.025726	0.025698	0.025726	0.025748	0.025781	0.025885
0.01	0.010533	0.01053	0.010533	0.010554	0.010552	0.010537	0.010537	0.010562	0.01059

As was already the case with the Monte Carlo evidence in the IID location-scale model, the change in the split from *T*/2 to *T*/3 does not alter the main result that nominal and real significance levels are close for the sample sizes considered.

In conclusion, the Monte Carlo analysis conducted suggests that it is possible to implement impulse saturation algorithm in a stationary AR(1) model, under the null hypothesis of no indicators in the DGP. NRFs distortions are, for the sample sizes considered, very small.

2.1. Rejection Frequency under the null: Unit Root Case

We have also run a pilot experiment to check whether there would be any significant NRFs problems in a random walk model. We considered the DGP:

$$y_t = y_{t-1} + \varepsilon_t \tag{2}$$

We assume that ε_t ~ IN(0;1). Hence there are no dummies in the DGP, but there is a unit root. We consider the average across the Monte Carlo replications of the ratio of retained indicators to the sample size, at each replication as our measure of empirical NRFs. Results are reported on table 6 and confirm closeness of nominal and empirical NRFs. *T*/2 is used.

Table 6 – Null Rejection Frequencies Unit Root Case, *T/2*

$\alpha \setminus T$	$T = 300$	$T = 200$	$T = 100$
0.1	0.10402	0.106	0.11056
0.05	0.052895	0.054478	0.058025
0.025	0.027025	0.028076	0.030874
0.01	0.011227	0.011949	0.0113675

Although there is a slight increase in the discrepancy between real and nominal sizes, at all significance levels, it is our view that these are not sufficient to preclude the saturation of a unit root model like (2). Nonetheless, the analysis of the unit root case would require considerable more evidence, whilst all we are doing here is to suggest that it would be possible to use dummy saturation in such models as well.

3. The additive outlier case

3.1 Monte Carlo evidence on power

In order to evaluate the use of a GETS modelling strategy for the inclusion of indicators in a stationary AR(1), we shall look at the problem under H_1, that is when the indicator's coefficient of some impulse is not zero. We shall do this by imposing an additive outlier in the DGP, that is now given by:

$$y_t = \begin{Bmatrix} \rho y_{t-1} + \varepsilon_t \Leftarrow t \neq t^* \\ y_t^* \Leftarrow t = t^* \end{Bmatrix} \tag{3}$$

where we assume that ε_t ~ IN(0;1) and that $|\rho| < 1$. Hence, at $t = t^*$ there is an additive outlier. We assume that this is an exogenous shock to y_{t^*} such that,

$$y_t^* = \rho y_{t^*-1} + \delta \tag{4}$$

In our Monte Carlo experiments, we allow to take values from the set {2; 2.5; 3; 4; 5}. Furthermore, it is known that the additive outlier has an effect in two periods in the residuals of the stationary AR(1) model: t^* and t^*+1. If the effect of the additive outlier at the time when it occurs is δ, on the following period it has an effect $\rho\delta$. Hence, for the relevant impulse indicators' coefficients estimators to be unbiased they should have expectations equal to δ and $-\rho\delta$. For $|\rho|<1$, this means that the second coefficient is smaller than the first in absolute value: the individual significance test statistics will have lower non-centralities implying lower power (see the analysis of theoretical power in the next subsection).

Table 7 reports the empirical rejection frequencies of the null, for the indicator at t^*, when the sample size is $T=100$, and an additive outlier occurs at $T=80$. A significance level of 0.025 is used for impulse saturation, and the split is $T/2$. Table 8 refers to the t^*+1 indicator.

Table 7 – AO: Empirical Rejection Frequencies for the indicator at t^*, $T=100$, $T/2$

$\delta \backslash \rho$	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
$\delta=2$	0.4063	0.4057	0.4065	0.4066	0.4069	0.4055	0.4056	0.4041	0.4031
$\delta=2.5$	0.6013	0.6017	0.6014	0.6009	0.6011	0.6012	0.6005	0.6013	0.6001
$\delta=3$	0.7729	0.7721	0.7726	0.7726	0.7728	0.7729	0.7748	0.7741	0.771
$\delta=4$	0.9574	0.9578	0.958	0.9577	0.9571	0.9564	0.9559	0.9562	0.9556

Table 8 – AO: Empirical Rejection Frequencies for the indicator at t^*+1, $T=100$, $T/2$

$\delta \backslash \rho$	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
$\delta=2$	0.033	0.0432	0.0574	0.0782	0.1067	0.1429	0.1902	0.2464	0.3079
$\delta=2.5$	0.0375	0.0489	0.0732	0.1069	0.1532	0.2128	0.2879	0.3691	0.4616
$\delta=3$	0.0418	0.0597	0.0943	0.1419	0.211	0.2996	0.3985	0.5086	0.6207
$\delta=4$	0.0507	0.0848	0.1419	0.232	0.3526	0.4853	0.6238	0.754	0.8589

The method appears to have good power to detect the moment at which the AO occurs. Power at that moment does not depend on the autoregressive coefficient, as was expected. Also, we confirm that the second indicator will be retained less often, with the autoregressive coefficient playing a role here[7].

3.2. Theoretical power derivation for the Additive Outlier case

We shall proceed with the analysis of theoretical power separating conclusions for the indicator at time t^* and at time t^*+1. Consider the DGP defined by (3) and (4), where $|\rho|<1$, $\varepsilon_t \sim IN(0;1)$. Consider the econometric model:

$$y_t = \rho y_{t-1} + \psi D_t + \phi d_t + v_t \tag{5}$$

D_t is a single impulse indicator such that $D_{t^*}=1$. d_t is another single impulse indicator such that $d_{t^*+1}=1$.

Suppose we wish to test the null hypothesis:

$$H_0: \psi = 0$$

7 Additional evidence as to the unbiasedness of the indicators' coefficients in the two periods and as to the positive effect from impulse saturation, reducing the bias of $\hat{\beta}$, could also be given and is available upon request.

in a model that differs from (5) because it does not contain the lagged dummy (for simplicity). We make use of the test statistic:

$$t = \frac{\hat{\psi}}{\sqrt{\hat{V}(\hat{\psi})}} \xrightarrow[\mathrm{H}_0]{} \mathrm{N}(0;1)$$

(see Hendry and Santos, 2005). Hence,

$$t^2 = \frac{\hat{\psi}^2}{\hat{V}(\hat{\psi})} \xrightarrow[\mathrm{H}_0]{} \chi^2_{(1)}$$

Notice that:

$$\mathrm{E}\begin{bmatrix}\hat{\rho}\\ \hat{\psi}\end{bmatrix} \cong \begin{pmatrix} T^{-1}\sum_{t=1}^{T}\mathrm{E}\left(y_{t-1}^2\right) & T^{-1}\mathrm{E}\left(y_{t^*-1}\right) \\ T^{-1}\mathrm{E}\left(y_{t^*-1}\right) & T^{-1} \end{pmatrix}^{-1} \begin{pmatrix} T^{-1}\sum_{t=1}^{T}\mathrm{E}\left(y_t y_{t-1}\right) \\ T^{-1}\mathrm{E}\left(y_{t^*}\right) \end{pmatrix}$$

Since,

$$\mathrm{E}\left(y_{t^*-1}\right) = 0$$

and

$$\mathrm{E}\left(y_{t^*}\right) = \delta$$

we obtain,

$$E[\hat{\psi}] \cong \frac{-T^{-2}E\left(y_{t^*-1}\right)\sum_{t=1}^{T}\mathrm{E}\left(y_t\, y_{t-1}\right) + T^{-2}E\left(y_{t^*}\right)\sum_{t=1}^{T}\mathrm{E}\left(y_{t-1}^2\right)}{T^{-2}\sum_{t=1}^{T}\mathrm{E}\left(y_{t-1}^2\right) - T^{-2}\left[E\left(y_{t^*-1}\right)\right]^2}$$

which simplifies to:

$$\mathrm{E}(\hat{\psi}) \cong \frac{T^{-2}\delta\sum_{t=1}^{T}\mathrm{E}\left(y_{t-1}^2\right)}{T^{-2}\sum_{t=1}^{T}\mathrm{E}\left(y_{t-1}^2\right)} = \delta$$

Notice also that,

$$E\left(\hat{V}\begin{bmatrix}\hat{\rho}\\ \hat{\psi}\end{bmatrix}\right) \cong \sigma^2 \begin{bmatrix}\frac{1-\rho^2}{\sigma^2} & 0\\ 0 & 1\end{bmatrix} \Rightarrow E\left(\hat{V}\left[\hat{\psi}\right]\right) = \sigma^2$$

Under the alternative,

$$t^2(\delta) \sim \chi^2\left(1;\delta^2\right)$$

where $\chi^2(1;\delta^2)$ is a non-central χ^2 distribution with 1 degree of freedom and non-centrality parameter δ^2 (see Johnson, Kotz and Balakrishnan, 1995).

Bearing in mind that the relationship, between a non-central and a central χ^2 with m degrees of freedom is given by:

$$\chi^2_{(1)}\left(\delta^2\right) = h\chi^2_{(m)}$$

(see Hendy, 1995), where,

$$h = \frac{1+2\delta^2}{1+\delta^2}$$

and

$$m = \frac{1+\delta^2}{h}$$

for a significance level of 0.025, we can compute the probability of rejecting the null when indeed that is false as:

$$\Pr\left(\chi^2_{(1)}\left(\delta^2\right) > 3.84\right) = \Pr\left(\chi^2_{(m)} > 3.84h^{-1}\right) \qquad (6)$$

The noticeable conclusion is that the non-centrality depends only on δ, and not on the sample size T nor on the autoregressive coefficient ρ. This is line with our findings in table 7. Hence, for $\delta \in \{2; 2.5; 3; 4\}$ the values for theoretical power are

$$p_\delta = \Pr\left[t^2_\alpha\left(\delta^2\right) > c_\alpha\right] \cong \begin{cases} 0.50 & \delta = 2 \\ 0.71 & \delta = 2.5 \\ 0.86 & \delta = 3 \\ 0.99 & \delta = 4 \end{cases} \qquad (7)$$

The Monte Carlo evidence reported on the relevant table of the previous subsection suggests that empirical power is always below theoretical power, but that the difference is never too big: about 0.1 for $2 \le \delta \le 3$, and vanishing rapidly for $\delta > 3$.

3.3 Dummy at t + 1 when AO *is at t*

In this case,

$$E\left(t^2\right) = \rho^2 \delta^2 \tag{8}$$

Hence, the noncentrality, and therefore power, will now depend both on δ and on ρ. Suppose $\rho = 0.9$ and $\delta \in \{2; 2.5; 3; 4\}$. Then, for a similar critical value as above,

$$p_\delta = \Pr\left[t_\alpha^2\left(\delta^2\right) > c_\alpha\right] \cong \begin{cases} 0.46 & \delta = 2 \\ 0.67 & \delta = 2.5 \\ 0.8 & \delta = 3 \\ 0.98 & \delta = 4 \end{cases} \tag{9}$$

Results should be compared with those in table 9. Again empirical power converges to theoretical power as δ increases.

Table 9 – Theoretical power at time *t* + 1

$\delta \setminus \rho$	**0.9**
$\delta = 2$	0.3079
$\delta = 2.5$	0.4616
$\delta = 3$	0.6207
$\delta = 4$	0.8589

4. Level shifts in stationary AR(1) processes

Any reference to the power properties of impulse saturation algorithm in stationary autoregressions, under the alternative, would have to contemplate both outliers and level shifts. In a sense, however, the analysis is not all that different, since level shifts are sequences of additive outliers (see Peña, 2001). Hence, we expect the impulse saturation algorithm to have power against level shifts in this class of models.

For the purpose of the Monte Carlo analysis we postulate a DGP where, for $T \leq T^*$:

$$y_t = \rho y_{t-1} + \varepsilon_t \tag{10}$$

and for $T > T^*$,

$$y_t = \delta + \rho y_{t-1} + \varepsilon_t \tag{11}$$

where $\varepsilon_t \sim IN(0;1)$ and $|\rho| < 1$. By assumption, $\frac{T - T^*}{T} = r = 0.2$. That is, the break occurs for the last 20% sample observations. In the first set of Monte Carlo results reported in tables 10-12, we assume that $\rho = 0.5$. Keeping ρ and r fixed, we allow for different significance levels and break magnitudes. Tables 10-12 report the empirical null rejection frequencies for the indicators covering those last observations. The entire break period is comprised within a single partition. *T/2* is used.

Results reported in tables 10-12 are encouraging: empirical null rejection frequencies for the indicators in the break period indicate useful power for $\delta \geq 2.5$, and $\alpha \geq 0.025$. The sample size is

not playing a relevant role here. A complete study should also allow *r* to vary. Nonetheless, this is not the main effect we are interested in studying here.

Table 10 – Level Shift – Empirical rejection frequencies, r = 0.2, *T* = 100

$\alpha \setminus \delta$	$\delta = 1$	$\delta = 2$	$\delta = 2.5$	$\delta = 3$	$\delta = 4$
$\alpha = 0.1$	0.2973	0.6573	0.7923	0.88175	0.9644
$\alpha = 0.05$	0.2004	0.5429	0.6991	0.8145	0.9369
$\alpha = 0.025$	0.1334	0.4382	0.6037	0.7376	0.8995
$\alpha = 0.01$	0.077	0.3202	0.4823	0.6315	0.8363

Table 11 – Level Shift – Empirical rejection frequencies, r = 0.2, *T* = 200

$\alpha \setminus \delta$	$\delta = 1$	$\delta = 2$	$\delta = 2.5$	$\delta = 3$	$\delta = 4$
$\alpha = 0.1$	0.2803	0.6471	0.7955	0.8927	0.9761
$\alpha = 0.05$	0.185	0.5284	0.6998	0.8274	0.9543
$\alpha = 0.025$	0.1203	0.4205	0.5997	0.7506	0.9234
$\alpha = 0.01$	0.0664	0.3001	0.4733	0.6405	0.8692

Table 12 – Level Shift – Empirical rejection frequencies, r = 0.2, *T* = 300

$\alpha \setminus \delta$	$\delta = 1$	$\delta = 2$	$\delta = 2.5$	$\delta = 3$	$\delta = 4$
$\alpha = 0.1$	0.2757	0.6462	0.7984	0.89891	0.981
$\alpha = 0.05$	0.181	0.527	0.7022	0.8835	0.9624
$\alpha = 0.025$	0.1171	0.418	0.6027	0.7588	0.935
$\alpha = 0.01$	0.0641	0.2971	0.4747	0.6488	0.8848

Rather we investigate whether the impulse saturation procedure is sensitive to the degree of serial correlation in the series. That is, instead of $\rho = 0.5$, as in the previous example, we shall be considering empirical power when $\rho = 0.9$. Therefore, we considered the following DGP:

$$y_t = \begin{cases} 0.9y_{t-1} + \varepsilon_t \Leftarrow t \leq T^* \\ \delta + 0.9y_{t-1} + \varepsilon_t \Leftarrow t > T^* \end{cases} \tag{12}$$

where ε_t is a Gaussian white noise process with unit variance, and $\delta \in \{1; 2; 2.5; 3; 4\}$. Table 13 reports results for a sample size of $T = 300$ and table 14 reports results for $T = 100$. Other defaults apply.

Table 13 – Level Shift – Empirical rejection frequencies, r = 0.2, *T* = 300, $\rho = 0.9$

$\alpha \setminus \delta$	$\delta = 1$	$\delta = 2$	$\delta = 2.5$	$\delta = 3$	$\delta = 4$
$\alpha = 0.1$	0.093	0.364	0.512	0.65	0.829
$\alpha = 0.05$	0.157	0.4825	0.6343	0.7524	0.892
$\alpha = 0.025$	0.23	0.585	0.725	0.825	0.931
$\alpha = 0.01$	0.3324	0.693	0.811	0.888	0.961

Table 14 – Level Shift – Empirical rejection frequencies, r = 0.2, *T* = 100, ρ = 0.9

$\alpha \setminus \delta$	δ = 1	δ = 2	δ = 2.5	δ = 3	δ = 4
α = 0.1	0.147	0.465	0.604	0.717	0.858
α = 0.05	0.227	0.574	0.708	0.83	0.909
α = 0.025	0.309	0.665	0.784	0.8623	0.941
α = 0.01	0.413	0.759	0.8553	0.913	0.966

Comparing with the corresponding tables for ρ = 0.5, it is clear that there is no significant dominating power loss when ρ is increased to 0.9. Indeed, in some cases power is even increased. This is an important result as it suggests power of this procedure does not depend on degree of serial correlation of the data.

5. Conclusions

In this paper we have established that the impulse saturation method can also be applied to stationary AR(1) models. Monte Carlo evidence has shown that nominal and real size are close for this type of model. There are some indications that the magnitude of the autoregressive coefficient and that the sample size might cause some deviations but these are, in any case, always very slight. A pilot extension to a unit root process suggests the process could be applied there as well.

On the other hand, impulse saturation tests are shown to have power (in the AR(1) framework) against additive outliers and level shifts. Theoretical power is studied for the AO case, whilst results for the level shift case are entirely simulation-based. In any event, the empirical rejection frequencies for the indicators at the AO date, or covering the shift period, indicate the procedure has good power against these alternatives.

A most relevant conclusion of this paper is that the impulse saturation test for level shifts in dynamic models does not depend on the degree of serial correlation of the sample, nor does it seem to demand that the test is conducted in a (mis-specified) location scale model. Hence there appears to be some advantages of using this procedure over the Bai and Perron test (1998, 2003). Santos (2006) explores this issue further.

The analysis developed here has already proven to be useful for the development of new super exogeneity tests (see Hendry and Santos, 2006a), and follows from the preliminary papers by Hendry, Johansen and Santos (2005) where the properties of the impulse saturation algorithm under the null that no indicators matter were studied in detail in a location-scale model, and Hendry and Santos (2006b) where it the power properties of the procedure in location-scale models were studied. Santos and Oliveira (2006) and Santos (2006) have developed empirical applications of these procedures.

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What type of firm forges closer innovation linkages with Portuguese Universities?

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resumo

Utilizando dados baseados num inquérito extensivo às empresas localizadas em Portugal, analisamos quais as características das empresas que estão associadas ao estabelecimento de contactos com as universidades. Embora cerca de metade das empresas inquiridas afirmem que terão mantido algum tipo de contacto com as universidades no período 2001-2003, poucas (22%) consideraram as universidades como uma fonte importante de conhecimento e informação para as suas actividades de inovação. A nossa análise indica que a propensão das empresas em manterem ligações com as universidades é explicada pelas respectivas características, padrões regionais e sectoriais. Um resultado não ambíguo e estatisticamente robusto é que a proximidade é importante nas ligações entre empresa e universidade – as nossas estimativas revelam que as empresas têm maior probabilidade de contactar as universidades localizadas na sua vizinhança.

résumé / abstract

En utilisant des données d'une enquête aux entreprises localisées au Portugal, nous analysons les relations entreprises/université pour identifier les caractéristiques des sociétés qui maintiennent des relations avec l'université. Quoique presque la moitié des entreprises enquêtées affirment qu'elles ont eu des contacts avec les universités dans la période 2001-2003, seulement 22% considèrent les universités comme une source importante de connaissance et d'informations pour leurs activités d'innovation.

Notre analyse indique que la propension des entreprises au maintien de liaisons avec les universités est expliquée par les caractéristiques des sociétés et par des facteurs régionaux et sectoriels. Un résultat non ambigu et statistiquement robuste de notre analyse est que la proximité est importante pour les relations entreprises/université – nos estimations révèlent que les sociétés ont une plus grande probabilité de contacter les universités localisées dans leur voisinage.

Using large-scale survey data for firms located in Portugal, we analyze which firm characteristics are conducive to establishing contacts with universities. Although almost half of the firms surveyed stated they had established some contacts with universities in the period 2001-2003, only a few (22%) consider universities an important source of knowledge and information for their innovation activities. Our analysis indicates that the firms' propensity to draw on each of the Portuguese universities is explained by the characteristics of the different firms and their regional and industrial patterns. An unambiguous and statistically robust finding is that proximity matters highly in firms-universities linkages – our estimations reveal that firms are more likely to contacts universities located nearby.

JEL Codes: O38; C25

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1. Introduction

The importance of the traditional university is well documented in the literature (Geiger, 1993; Bok, 2003). Their primary mission is to engage in research and disseminate knowledge across both academic and student communities. They also contribute indirectly to technology transfer activities by providing highly educated and qualified personnel to industry (Carayannis *et al.*, 1998). According to Segal (1986), these universities not only provide a source of technical expertise for faculty members, but their students also acquire a wealth of codified and tacit knowledge through learning and living at the university.

While universities have a long-standing role in the system of innovation, it has nevertheless changed. The new role of universities as engines of local economic development (Feller, 1990) or magic beanstalks of invention and research (Miner *et al.*, 2001) places new demands on universities and raises question about the role of research universities in advanced economies. Many universities have restructured their research capabilities to be more responsive to local industry (Bercovitz and Feldmann, 2006) by, for example, setting up specialized research units, joint cooperative ventures or interdisciplinary projects that are more receptive to industrial needs. These specialized units may focus on revitalizing existing industries. In transferring technology, universities contribute to the stock of technologies that firms may draw on for innovation and economic growth.

Some however have raised the concern that universities are being asked to deviate from an historically successful role and that increased commercial influences may destroy the norms of open science that have promoted the national interest (Nelson, 2001). These same concerns may be raised at the regional level. Universities certainly add more to their local economies than the metrics of technology transfer are able to capture (Huffman and Quigley, 2002; Feldman and Desrochers, 2003). There are certainly many different modes of how universities interact with and enrich their local economies than by simply counting technology transfer indicators (LERU, 2006).

Firms should therefore be interested in forging links, perhaps even in collaborating with universities in order to capture timely new technological opportunities stemming from basic research (Mohnen and Hoareauc, 2003). Indeed, proximity to basic science is reported by Cohen (1995) to be one of the main determinants of innovation. Governments in their quest to maximize the social return of innovation should also be concerned with fostering such links between private firms and universities. Not all firms, though, are ready to seek such links and to be able to benefit from them (Veugelers and Cassiman, 2005). It would be interesting to know what profile of firm it takes, for instance, size, age, export and R&D intensity, foreign ownership, human capital (skill and education intensity), openness behaviour, region and industry, to seek close contacts and collaborate with centers of basic research.

The discussion of university-industry relationships, which entered the policy arena in the early 1980s, has become the property of both academics and the general public. An enormous number of contributions to academic writings and articles in the business and public press have come from policy makers in the last few years in a bid to explain, justify and regulate the interactions between universities and firms (Fontana *et al.*, 2004). At the European level, very few of these works have been supported by systematic data analysis. A large number of works have studied university-industry relationships from a qualitative point of view or by relying on a case study of a single university (Faulkner and Senker, 1995; Geuna *et al.*, 2004).

Using a large-scale database of firms located in Portugal, we aim to contribute to a better understanding of the quality and extent of firm-university links by examining the firms' propensity to establish (formal) contacts with universities. Similar studies in terms of the scope of analysis (e.g. Mohnen and Hoareauc, 2003) focus on the linkages between firms and universities considering this latter as an aggregate, homogenous entity. The present study overcomes such

limitation by econometrically evaluating the quality and extension of firm-university contacts with *all* and *each* of the Portuguese universities.

The paper is structured as follows. In the next section, a systematisation of the importance of Universities for firms learning and innovation is undertaken. In Section 3, we present some descriptive results regarding the contacts between firms located in Portugal and Universities. In the following section, the determinants of the firms' propensity to contact all and each of the Portuguese Universities is assessed using logit estimations. Finally, in Section 5 we conclude the study by highlighting the main results.

2. The importance of Universities in learning and innovation in firms

While universities have long served as a source of technological advances for industry, university-industry collaboration has intensified in recent years due to four interrelated factors (Bercovitz and Feldmann, 2006): the development of new, high-opportunity technology platforms such as computer science, molecular biology and material science; the more general growing scientific and technical content of all types of industrial production; the need for new sources of funding for academic research brought on by severe budgetary restrictions; and the prominence of government policies aimed at raising the economic returns of publicly funded research by stimulating university technology-transfer (Geuna, 1998).

However, technology-transfer is challenging as private firms and research universities have profoundly different missions and often display mutual distrust (Slaughter and Leslie, 1997). While universities are often regarded as holding important assets that could be leveraged for economic development, the presence of a local university may be necessary, but not sufficient, to guarantee that knowledge-based economic development takes place (Bercovitz and Feldmann, 2006).

Universities themselves are complex bureaucracies with their own rules, rewards and incentive structures (Clark, 2003). Moreover, in contrast to commercial firms with a relatively simple profit motive, universities have complex objective functions that involve a variety of educational and societal objectives as well as the interests of faculty members and the broader scientific community (Etzkowitz *et al*., 2000).

The universities' relationships with firms are formed through a series of sequential transactions such as sponsored research and licenses (Mowery and Ziedonis, 1999; Siegel *et al*., 1999; Feldman *et al*., 2002; Thursby and Kemp, 2002), spin-off firms and the hiring of students. The core elements in university-industry relationships are transactions that occur through the mechanisms of sponsored research support (including participation and sponsorship of research centres), agreements to license university intellectual property, the hiring of research students, and new start-up firms.

Several macro-economic studies have indicated the importance of basic, scientific, research for technology, innovation and economic growth of nations (e.g. Griliches, 1998; Jaffe, 1989; Adams, 1990; Rosenberg and Nelson, 1994; Mansfield, 1995; Cohen *et al*., 2002). At the micro level the technology management literature documents, mainly on the basis of specific case studies and detailed surveys at the firm-level, how scientific knowledge feeds into successful innovations (e.g. Allen, 1977; Tushman and Katz, 1980). Linking scientific knowledge is especially important for firms innovating in the fast developing technologies like biotechnology, information technology and new materials (Mowery, 1998; Zucker *et al*., 1998; Cockburn and Henderson, 2000; Costa and Teixeira, 2005).

Especially in Europe, there seems to be a gap between high scientific performance on the one hand and industrial competitiveness on the other hand. This gap, mainly attributed to low levels of Industry Science Links, is known as the "European paradox" (EC, 2000). The evidence from the Community Innovation Survey for the EU shows that only a small fraction of innovative enterprises use science, i.e. universities and public research laboratories, as an important

information source in their innovation process – in the latest Eurostat-Community Innovation Survey CIS-III (1999-2000), of all reporting innovative EU firms (excl UK) 4.5% rated universities as important sources of information, while 68% indicated universities as not important at all (Veugelers and Cassiman, 2005). Furthermore, the survey shows that in 2000 less than 10% of innovative firms had cooperative agreements with universities. Similarly, Hall *et al.* (2001) report that in the United States the vast majority of research partnerships registered under the National Cooperative Research and Production Act do not include a university. Although the trend is increasing, only a modest 15% of all research partnerships involved a university.

There are few studies that consider the firm, rather than the university, as the focal actor. Prior research demonstrates significant variation in the firms' use of external resources (Laursen and Salter, 2004), organization of inter-firm R&D activity, and objectives in inter-firm R&D strategic partnerships (Sakakibara, 1997). Although the broad literature on strategic R&D alliances (e.g., Narula, 1999; Hagedoorn *et al.*, 2000; Caloghirou *et al.*, 2003; Elmuti *et al.*, 2005) mentions the importance of firm – university alliances, it does not specifically focus on the unique aspects of universities as research partners. As such, we have only a limited understanding of how university interactions fit within the firm's broader R&D strategy — and how firm strategy and organizational structure influence both the technology-transfer mechanisms employed by the firm and the relationship the firm ultimately maintains with the university.

Previous research has shown, however, that linking with external entities is a key element in successfully exploring strategies that emphasize the search for, discovery and development of new knowledge (March, 1991; Cockburn and Henderson, 1994; Von Hippel, 1998; Rosenkopf and Nerkar, 2001). Specifically, such interactions give the firm access to knowledge that differs from, but can complement, the firm's existing technology portfolio. It is the integration of this new knowledge that leads to path-breaking innovation. Academic researchers perform a great deal of cutting-edge research and universities are known sources of new knowledge (Rosenberg and Nelson, 1994). As such, we expect that pursuing university interactions to tap into such expertise is likely to be more highly valued by firms with innovation strategies that emphasize exploration rather than exploitation — the refinement, extension, and intelligent use of existing competencies (March, 1991; Levinthal and March, 1993).

What increases the propensity of firms to draw upon public research in general and universities in particular? In a regression analysis, Cohen *et al.* (2002) take size and age of the firm as the two explanatory variables. Larger firms and start-ups have a higher probability of benefiting from academic research.

Other studies (Schartinger *et al.*, 2001; Arundel and Geuna 2004) incorporate additional explanatory variables, such as level of R&D expenditure, degree of firms' innovativeness. A more recent study (Laursen and Salter, 2004) introduced the concept of 'open' search strategies of firms into this literature. Accordingly, search strategies play a central role in determining innovative performance (e.g., Katila and Ahuja, 2002). Laursen and Salter (2004) provide a proxy for assessing the degree to which the firm seeks to draw in new knowledge and to re-use that is, openness of a firm's search activities. The constructed variable is based on the number of different sources of external knowledge (e.g., clients, suppliers) that each firm draws upon in its innovative activities. Implicitly, it is assumed that the higher the number of external knowledge sources that a firm draws upon the more "open" it is its search strategy. With this variable the authors seek to introduce a degree of managerial choice into the debate about university–industry links. In this context, it is hypothesised that firms that adopt open search strategies have a higher probability of considering the knowledge produced by universities as important for their innovation activities.

As referred in the introductory part of the present paper, very few studies within firm-university linkages have been supported by systematic data analysis. The vast majority have studied such linkages from a qualitative point of view or by relying on case studies. Additionally, these studies tend to consider all universities in aggregate without distinguish the different type of universities

that exist in a given country, namely those that are more 'entrepreneurial led' from those more 'classical'.

In the next section we present descriptive and econometric analysis which permit to evaluate the quality and extension of firm-university contacts with *all* and *each* of the Portuguese universities. Moreover, we introduce in the econometric specification additional variables likely to explain the propensity of firms contacting universities, namely human capital and R&D intensity, which tend to reflect firms' absorption capabilities, and other firm structural variables, in concrete export intensity and foreign ownership. It is important to note that although in the descriptive part (Section 3.2) we refer to *all types* of contacts, including both formal and informal, in the estimation part (Section 4) only *formal* contacts (Protocols, partnerships, and projects; Consulting activities; Training provision for final year undergraduates; Seminars, conferences, publication, and alike) are taken into account as a non-negligible amount of firms could not precise the amount of informal contacts established with universities for the period in analysis. Informal contacts tend to be especially relevant when firms seek to access local tacit knowledge as they are based on personal contacts where social factors probably matter (Kallsen and Tornquist, 1994; Arundel and Geuna, 2004).

3. Contacts between firms located in Portugal and Universities. Some descriptive results

3.1 Methodology and the representativeness of the data

The empirical analysis is based on a direct survey to all (2852) firms located in Portugal listed in 24 Portuguese entrepreneurial associations covering all economic activities[1].

The questionnaire was implemented through telephone and fax contacts to all firms from the above mentioned list. The results provided in the present paper are based on the amount (1538) of valid questionnaires gathered from October 2004 up to the end of December 2005, reflecting a remarkable response rate (53.9%), well above several firm related surveys, some of which are compulsory – for instance, in the CIS III, the response rate was 45.8% in the case of Portugal (Bóia, 2003), and 41.7% for the U.K. (Stockdale, 2002).

When compared to the population, our respondent sample presents a relative bias towards manufacturing industry, particularly in industries such as 'Food products, beverage and tobacco' (7.9% of total respondents versus 1.6% of the total population), 'Textiles and leather' (8.6% versus 3.7%), and 'Coke and chemicals' (4.2% versus 0.2%). It is underrepresented in 'Electricity, gas and water supply, construction' (4.9% of total respondents versus 17.0% of the total population) and 'Wholesale and retail' (33.8% versus 52.1%).

In regional terms, our sample has a bias towards the Northern (37.2% of total respondents versus 31.3% of the total population) and the Lisbon and Tagus Valley (38.1% of total respondents versus 28.9% of the total population) regions, and presents a relatively poor coverage for regions such as the Alentejo, Algarve and Islands.

1 AECOPS – Assoc. Emp. Const. Civil e Obras Públicas; AEP – Associação Empresarial de Portugal – Indústria; comércio por grosso e a retalho; AFIA – Assoc. dos Fabricantes p/ a Ind. Automóvel; AIC – Assoc. Industrial de Cristalaria; AIMC – Assocação dos Industriais de Madeira do Centro; AIVE – Assoc. dos Industriais de Vidro para Embalagem; ANETIE – Assoc. Nac. das Emp. das Tecnologias de Informação e Electrónica; ANICP – Assoc. Nacional das Indústrias de Conservas de Peixe; ANIL – Assoc. Nac. Ind. de Lanifícios; ANIL – Assoc. Nacional dos Industriais de Lacticínios; ANIMEE – Assoc. Nac. dos Ind. de Material Eléctrico e Electrónico; ANIVE. – Associação Nacional das Ind. de Vestuário e Confecção; APCOR – Assoc. Port. dos Ind. de Cortiça; APIAM – Associação Port. dos Industriais de Águas Minerais Naturais e de Nascente; APIC – Assoc. Port. Ind. de Cortumes; APIEE – Asso. Port. dos Ind. de Engenharia Energética; APIFARMA – Associação Portuguesa da Indústria Farmacêutica; APIP – Assoc. Portuguesa da Indústria de Plásticos; Associação dos Industriais de Colas; Associação dos Indust. Port. de Iluminação; CEFAMOL – Associação Nacional da Ind. de Moldes; CELPA – Assoc. da Indústria Papeleira; TAGUSPARK; Markelink.

Table 1 – Characteristics of the respondent firms located in Portugal – industrial and regional distribution (%) compared to the population

	Population (INE, 2003)	Respondent sample (n=1538)
Industry		
Mining and quarrying	0.2	0.8
Food products, beverage and tobacco	1.6	7.9
Textiles and leather	3.7	8.6
Wood, pulp and publishing	2.4	3.0
Coke and chemicals	0.2	4.2
Rubber and other non-metallic	1.1	3.9
Basic metals and fabricated metal products	2.6	4.3
Machinery and equipment NEC	0.7	2.7
Electrical and optical equipment	0.3	3.4
Transport equipment	0.1	2.2
Manufacturing NEC and recycling	1.7	4.0
Electricity, gas and water supply, construction	17.0	4.9
Wholesale and retail	52.1	33.8
Transport and storage	4.3	4.1
Post and telecommunications, financial intermediation	2.7	1.8
Computer and related activities	0.5	3.6
Research and development & eng services	8.0	4.7
Social services and non-profit associations	0.9	2.0
Regions (NUTs II)		
North	31.3	37.2
Centre	22.5	19.5
Lisbon and Tagus Valley	28.9	38.1
Alentejo	7.9	2.3
Algarve	5.4	1.6
Islands (Madeira and the Azores)	4.0	1.3

Source: Authors' computation based on direct survey, October 2004-December 2005.

3.2. Database general description – firms' structural characteristics

Respondent firms have reasonable experience in business (on average, they have been in activity for 25.9 years), are of medium-to-small sized, employ on average 139 workers, are in their majority (87.3%) nationally owned and relatively inward oriented (they export on average 17.3% of their sales). Around 21.9% of the firms' total workforce has 12 or more years of

education and the percentage of engineers in the total workforce is 7.9%; the ratio of R&D on sales reaches a figure of 2.2%.

Similarly to Laursen and Salter (2004), the information and knowledge sources for innovation activities were assembly into six different items – internal, institutional, market – business networks, sector information, specialized information and other. In a Likert-scale, 0-1-2-3-4-5 (with 0 indicating that the firm does not used the listed source), firms indicated the degree of importance (1: low; 5: extremely important) of the listed source for their innovation activities. The distribution of firms (in percentage of the total number), according to the importance that they attributed to the listed sources is presented in Table 2. Following 'Internal', with 89.1%, 'Specialized information' includes the sources, namely 'Health and hygiene legislation' and 'Environmental norms and legislation', considered as highly important for more than eighty per cent of the respondent firms.

The number of firms which claim to draw from Universities in their innovative activities is quite high (75.4%). Nevertheless, it is still well below the scores for "business-networks" (88.7%) and "specialized information" (95.2%) sources. Despite this high percentage of firms, 'only' 21.5% of the firms indicate that the knowledge they draw from Universities is highly important – recall that this percentage is well below the figure (42.8%) that technology-based firms located in Portugal indicated (Costa and Teixeira, 2005). Nevertheless, among 'Institutional Sources', Universities are the most highly ranked source for the firms' innovation activities.

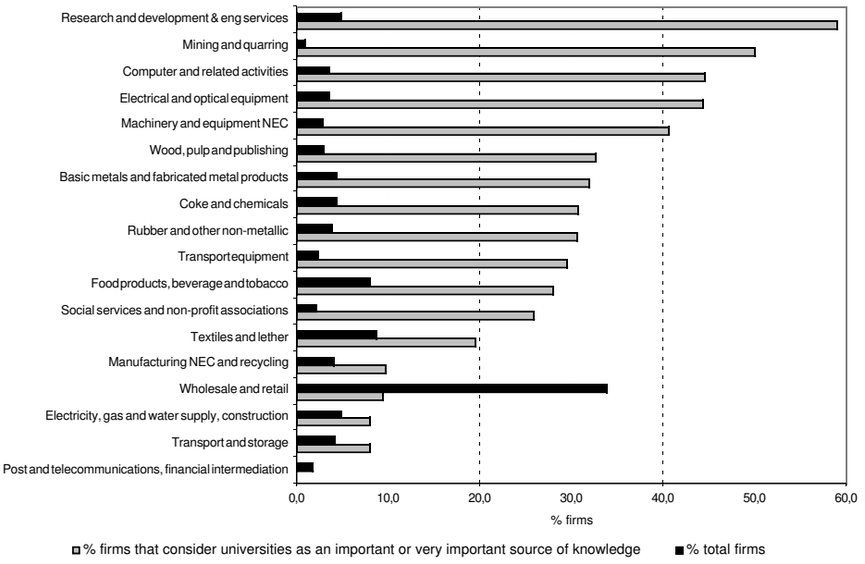
Table 2 – Characteristics of the respondent firms located in Portugal – industrial and regional distribution (%) compared to the population

Type	Source	% of firms			
		Not used	Low or very low	Medium	High and very high
Internal	Within the firm	0.1	0.5	10.3	89.1
Institutional	**Universities**	**24.6**	**37.9**	**16.0**	**21.5**
	Public R&D institutes	19.4	50.4	21.0	9.2
	Other governmental entities	19.7	59.2	15.2	5.9
	Private R&D institutes	25.4	33.6	24.8	16.1
Business networks	Clients	0.6	15.3	36.3	47.8
	Equipment suppliers	7.5	42.2	25.7	24.6
	Competitors	1.7	17.1	38.9	42.3
	Consultants	14.4	26.2	23.4	36.0
	R&D labs and firms	32.3	23.6	26.6	17.4
Sector information	Sector conferences and meetings	12.2	42.9	28.7	16.2
	Trade associations	6.3	51.0	31.6	11.1
	Technical and sector literature	18.0	26.3	18.5	37.2
	Fairs and events	7.2	17.1	21.6	54.2
Specialized information	Technical standards and norms	12.8	14.3	11.7	61.3
	Health and hygiene legislation	0.8	3.5	11.1	84.6
	Environment norms and legislation	0.7	3.4	9.6	86.3

Source: Authors' computation based on direct survey, October 2004-December 2005.

The importance attributed to universities as a source of knowledge and information for innovation activities varies considerably according to the industry. As we can see from Figure 1, in industries such as 'Research and Development & Engineering Services', and 'Mining and Quarrying', more than half of firms consider universities as a very important source for innovation-related activities. In contrast, over three quarters of the respondent firms belonging to industries such as 'Transport and Storage', 'Post and Telecommunications, Financial Intermediation', 'Manufacturing NEC and Recycling', and 'Electricity, Gas and Water Supply, Construction' claimed they did not use universities, or that they were not important, as a source of information and knowledge in innovation activities.

Figure 1 – Importance of Universities for innovation-related information and knowledge sources for firms located in Portugal by industry



Source: Authors' computation based on direct survey, October 2004-December 2005.

Through a simple descriptive analysis we find that both large and very large firm categories (employing 250 or more employees) are those that encompass a larger percentage of firms attributing high importance to universities as a source of innovation-related information and knowledge. Moreover, start-up (firms with 10 or less years in business) and non start-up firms seem to value universities similarly. In comparison to foreign-owned firms, the nationally-owned seem to draw much less on universities for their innovative activities (73.2% versus 90.7%, respectively, claim to use universities as sources of information for their innovation activities). Foreign-owned firms seem to attribute more importance to universities in this regard. Finally, around one quarter of firms located in the Northern and Central regions claimed that universities are an important or very important source of information and knowledge for their innovation-related activities. This contrast with the small importance attributed by firms located in the Alentejo and Islands.

Table 3 – Importance of Universities as a source of innovation-related information and knowledge for firms located in Portugal according to firm traits

	% of firms				
	Not used	Low or very low	Medium	High and very high	No. Firms (%Total)
Size (no. employees)					
Micro [1,10[	41,8	32,2	11,4	14,7	273 (17.8%)
Small [10, 50[	27,3	35,4	15,7	21,7	466 (30.4%)
Medium [50, 250[	19,1	41,8	17,7	21,4	593 (38.6%)
Large [250, 500[	11,2	37,3	17,9	33,6	134 (8.7%)
Very Large [500, …[	11,6	44,9	18,8	24,6	69 (4.5%)
Age (years in business)					
Start-ups (10 or less years)	27,5	34,1	16,8	21,6	334 (21.8%)
Non-start-ups	23,7	39,0	15,8	21,5	1201 (78.2%)
Capital ownership					
Nationally-owned	26,8	37,6	14,6	21,0	1341 (87.4%)
Foreign- owned	9,3	40,2	25,8	24,7	194 (12.6%)
Region					
North	24,5	37,8	14,7	23,1	572 (37.3%)
Centre	24,0	38,3	15,3	22,3	300 (19.5%)
Lisbon and Tagus Valley	24,0	36,9	18,7	20,4	583 (38.0%)
Alentejo	34,3	51,4	0,0	14,3	35 (2.3%)
Algarve	28,0	40,0	16,0	16,0	25 (1.6%)
Islands (Azores and Madeira)	29,8	40,1	14,7	15,4	20 (1.3%)
Total firms (average, %)	**24,6**	**37,9**	**16,0**	**21,5**	**100**
No. Firms	377	582	246	330	1535

Source: Authors' computation based on direct survey, October 2004-December 2005.

3.3. Database general description – contacts with universities

The oldest university, Universidade Coimbra, was created in the thirteen century receiving, with the implementation of the Republic in 1911, new legal status. Universidade de Lisboa and Universidade do Porto date back to the Republic period (1911). These three institutions are the most traditional and largest Portuguese universities (see Table 4). Although Porto university have always had a more technical and artistic tendency, the three mentioned universities are often regarded as the *'classical'* universities (Torgal, 2000).

During the late 1970s and the mid 1980s Portugal pursued a process of convergence that aimed at expanding and diversifying the tertiary system[2], especially by implementing the binary system (Universities and Polytechnics), promoting the private university system, and encouraging

2 Tertiary system includes all post-secondary education provided by universities, polytechnics, post-secondary colleges and other institutes.

institutional autonomy in the public sector (OECD, 2006). In the binary system the activities of universities would be teaching longer degrees, research and postgraduate education whereas the polytechnics would be devoted to shorter vocational degrees and professional training. This was regarded as a step towards more responsive higher education (Teixeira *et al.*, 2003).

With the Veiga Simão's reform (and the publication of the DL nº 402/73), the universities of Aveiro, Minho and Nova were created. Later, new public universities were established namely Algarve (1979), Açores (1980), and in the mid-eighties, Beira Interior (UBI), Madeira and Trás-os-Montes e Alto Douro (UTAD).

The Education System Act (Law 46/86) implemented in the mid-eighties defined the main objectives of higher education as teaching and research, cultural production and the development of entrepreneurial and scientific spirit and reflective thought (OECD, 1995). Here, the role of higher education institutions, namely universities, as providers of services to the outside community, particularly to industry was not however mentioned (OECD, 2006). Even though, within Portuguese public universities, Aveiro, Minho and Técnica Lisboa present a more industry-oriented perspective, with their 'mission statements' explicitly mentioning the aim of

Table 4 – Public Portuguese Universities plus Universidade Católica Portuguesa – students enrolled and year of foundation

University Profile	University	Student Enrolled 2005/2006	Year of foundation
	Universidade Aveiro	8902	1973
Entrepreneurial-led	Universidade Católica Portuguesa – Porto (1)	4200	1978
	Universidade Minho	15130	1973
	Universidade Técnica Lisboa	21708	1930
Classical	Universidade Coimbra	19890	1290 (1911*)
	Universidade Lisboa	18147	1911
	Universidade Porto	25370	1911
Research-led	Universidade Católica Portuguesa – Lisboa (1)	5354	1967 (1971*)
	Universidade Nova Lisboa	14677	1973
Regional-led	Universidade Algarve	3818	1979
	Universidade Beira Interior	5350	1986
	Universidade Évora	7500	1537
Not discriminated (included in 'others')	Universidade Aberta (2)	9171	1988
	Universidade Açores	2520	1980
	ISCTE – Instituto Superior Ciências Trabalho e Empresa	6000(3)	1972 (1990(4))
	Universidade Madeira	2551	1986
	Universidade de Trás-os-Montes e Alto Douro	6599	1986

Source: OCES (2006), Alunos inscritos no ano lectivo de 2005-2006, OCES/MCTES in http://www.oces.mctes.pt/?id_categoria=21&id_item=149810&pasta=23; year of foundation gathered from universities web page.
Note: (1) Private University classified as an institution of public interest – the total students enrolled in its four centres (Braga, Lisboa, Porto and Viseu) is 10102; (2) Distance learning public university; (3) approximate value; (4) Public non-integrated university; * Legal status.

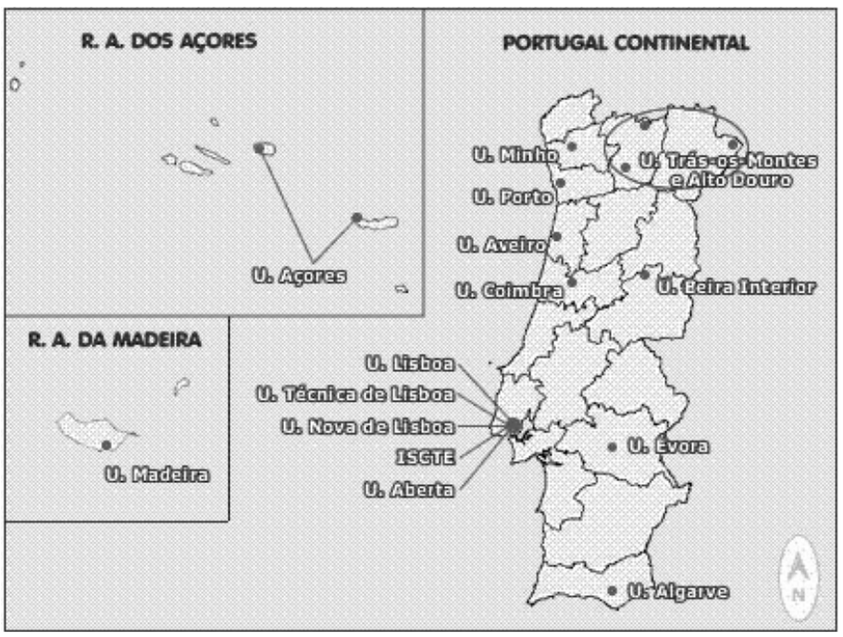
promoting university-firms linkages (Amorim, 2001). Etzkowitz (1983) has coined the phrase 'entrepreneurial universities' to describe the series of changes that reflect the more active role universities have taken in promoting direct and active transfer of academic research. In this vein, we might group these universities plus Universidade Católica Portuguesa (UCP) – Porto as *entrepreneurial-led universities*. This latter, one of the four regional centres of UCP, a private university with a public interest legal status, combines its educational function with a reasonable focus on business cooperation projects and services provision.

Universidade Nova Lisboa and (to a lesser extent) UCP-Lisboa are self-assumed[3] and increasingly acknowledged as *scientific-led* institutions. They put substantial emphasis on international scientific publication performance, being considerably oriented towards scientific knowledge development (Teixeira, 2006).

The youngest public universities – Algarve, Açores, UBI, Madeira, and UTAD – were created with an explicit government aim of promoting *regional development* (Torgal, 2002).

The next figure depicts the geographical distribution of the Portuguese public universities. Five out of the 15 public universities (including here also ISCTE) locate in the Lisbon area. Three universities, Minho, Porto and UTAD, belong to the North region sited respectively in the cities of Braga-Guimarães, Porto and Vila Real. In the Centre region are situated the universities of

Figure 2 – The location of Portuguese public universities



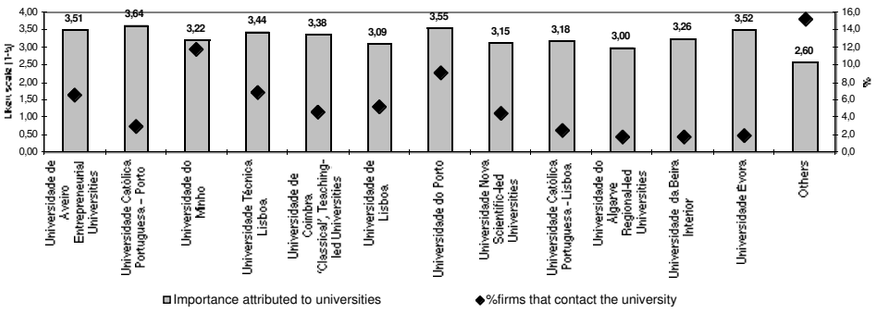
Source: Direcção Geral do Ensino Superior in http://www.pedagogicosensinosuperior.pt/PEDAGOGICO/REDE/Criação+de+Instituições/

3 See institutional presentation at these universities web pages (www.unl.pt/unl/nova and www.ucp.pt).

Aveiro, Coimbra and Beira Interior (Covilhã). University of Évora is situated in Alentejo whereas further south is located University of Algarve (Faro). Universidade Católica Portuguesa is geographically decentralized with two main sites, Porto and Lisbon. Finally, the universities of Açores and Madeira are situated in the islands, being the smallest (in terms of students enrolled) of the Portuguese public universities.

The University of Minho and University of Porto are the Portuguese universities with the highest amount of firms that claimed to have established some sort of contact (both informal and formal) with them during the period of 2001-2003, encompassing respectively 11.8% and 9.1% of total respondents. It is interesting to note that those firms that established some sort of contact with the University of Minho do not attribute as much importance to universities as a source of information and knowledge as those that established contacts with the University of Porto or that small minority which states to have contacts with the University of Algarve. Indeed, in a Likert scale (1- no or low importance … 5- extremely important), the University of Minho's corresponding average is 3.22 whereas the Universities of Porto's and Católica do Porto's are, respectively 3.55 and 3.64 (cf. Figure 3).

Figure 3 – Total contacts by university and the average relative importance attributed to universities as a source of information and knowledge by the corresponding firms



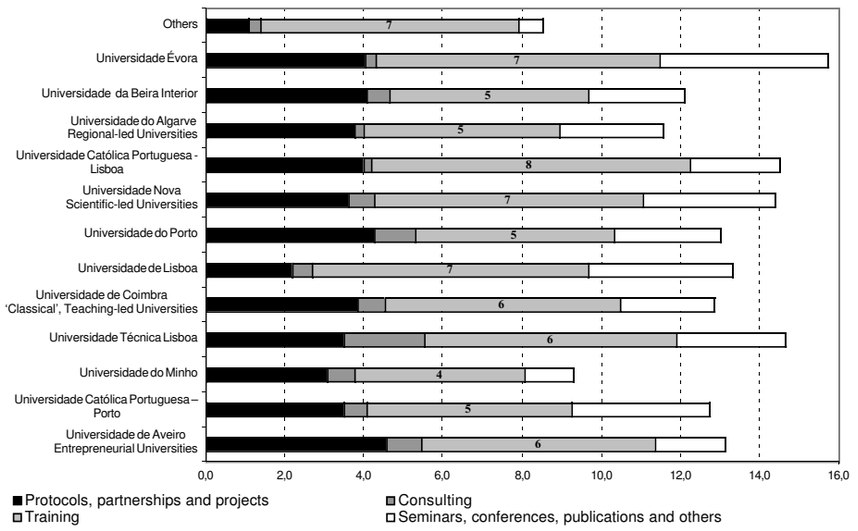
Source: Authors' computation based on direct survey, October 2004-December 2005.

Beside having been asked whether they had contacts with Universities, the firms were further inquired on the number and types – informal versus formal – of contacts that they had established with Universities in the three-year period in analysis (2001-2003). In relation to formal contacts, we divide them into four main groups (by decreasing order of commitment and knowledge content between firms and universities): Group 1 – Protocols, partnerships, and projects; Group 2 – Consulting activities; Group 3 – Training provision for final year undergraduates; Group 4 – Seminars, conferences, publication, and others.

Consulting activities are the least frequent type of formal contact (Figure 4). On average, firms that contacted in the period 2001-2003 the universities in analysis established 2 contacts of this type with the Técnica de Lisboa, and 1 with the Universities of Porto and Aveiro. This latter university is at the forefront of contacts involving Protocols, partnerships and projects with an average of almost five in the period under study. Summing up the most demanding type of contacts in terms of competencies and knowledge involved, that is, 'Protocols, partnerships, and projects' and 'Consulting', the Técnica de Lisboa, University of Aveiro, and University of Porto are the better positioned with an average of around five contacts per firm in the 2001-2003 period. We could thus assume that firms seem to recognize in these universities valid competencies, seeing them as important sources of knowledge for their innovative activities.

The most frequent type of contacts between firms located in Portugal and universities is training of final year undergraduates. To a great extent, firms located in Portugal are used as a locus for the first job market experience of future graduates – several even acknowledge that this type of contact is a one-way relation where universities/students have a more active role in searching for and maintaining this type of contact. The Católica (Lisboa), Évora, Lisboa, and Nova Universities seem to be the most active ones with an average of 7-8 training contacts from firms in 2001-2003.

Figure 4 – Type of formal contacts (average number) by university



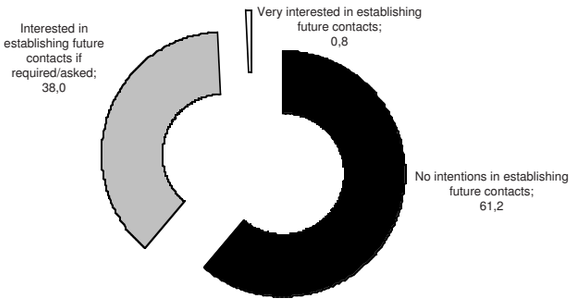
Source: Authors' computation based on direct survey, October 2004-December 2005.

In the least demanding type of contacts – attending seminars, conferences or reading/consulting publications – the Évora, Lisboa and Católica (Porto) Universities present the highest average, with approximately 4 contacts per firm in the period 2001-2003.

A truly disturbing finding is that although around 47% of the respondent firms state they had established (formal and informal) contacts with universities in the period 2001-2003, when asked whether they would be interested in establishing future contacts with these institutions, 61.2% claimed that they have no intentions in this respect and 38.0% revealed a moderate interest as they declared that they would establish contacts only if requested. Only 12 firms out of the 1521 that answered this question maintained they were highly interested in establishing future contacts with universities.

Such a disheartened scenario may reflect several issues. First, that firms located in Portugal do not consider (as expressed in Table 2) universities as critical sources of knowledge and information for their innovative activities, so they do not contact them at the outset. Second, having contacted universities, firms became disappointed with the outcomes of this relationship and realized that contacts were fruitless. Third, this situation may indicate relatively low innovative dynamics in firms located in Portugal, or at least some shortage of innovative dynamics requiring more fundamental and basic scientific knowledge.

Figure 5 – Interest in future contacts with universities (% total respondent firms)



Source: Authors' computation based on direct survey, October 2004-December 2005.

4. Determinants of the firms' propensity to contact *all* and *each* of the Portuguese Universities. An econometric analysis

4.1. Econometric specification and description of the variables

The aim here is to assess which are the main determinants of the firms' propensity to contact universities. The nature of the data observed relative to the dependent variable [Have contacted? (1) Yes; (0) No] dictates the choice of the estimation model. Conventional estimation techniques (e.g., multiple regression analysis), in the context of a discrete dependent variable, are not a valid option. First, the assumptions needed for hypothesis testing in conventional regression analysis are necessarily violated – it is unreasonable to assume, for instance, that the distribution of errors is normal. Second, in multiple regression analysis predicted values cannot be interpreted as probabilities – they are not constrained to fall in the interval between 0 and 1[4]. The approach used, therefore, will be to analyze each situation in the general framework of probabilistic models.

Prob (event j occurs) = Prob (Y = j) = F[relevant effects: parameters].

According to the literature (*cf.* Section 2) there are a set of factors, such as the firm's structural characteristics (age, size, export and R&D intensity, and foreign ownership), human capital intensity (firms' average skills and education), strategic firm traits such as openness to drawing on different sources of knowledge and information in their innovation activities, regional location and industry, gathered on a vector *X*, which might potentially explain the outcome, so that

$$\Pr ob(Y=1) = F(X,\beta) \quad and \quad \Pr ob(Y=0) = 1 - F(X,\beta).$$

The set of β parameters reflects the impact of changes in *X* on the likelihood of 'contacting'. The problem at this point is to devise a suitable model for the right-hand side of the equation. The requirement is for a model that will produce predictions that are consistent with the underlying theory. For a given vector of regressors, one would expect

$$\lim_{\beta' X \to +\infty} \Pr ob(Y=1) = 1 \quad and \quad \lim_{\beta' X \to +\infty} \Pr ob(Y=1) = 0.$$

4 The logistic regression model is also preferred to another conventional estimation technique, discriminant analysis. According to Hosmer and Lemeshow (1989), even when the assumptions required for discriminant analysis are satisfied, logistic regression still performs well.

Partly because of its mathematical convenience, the logistic distribution, $\Pr ob(Y=1) = \frac{1}{1+e^{-\beta' X}}$, has been used in many applications (Greene, 2000). Rearranged in terms of the log odds[5], this expression is the so-called *logit* model.
The probability model is a regression of the following kind:

$$E(Y \backslash X) = 0[1 - F(\beta' X)] + 1[F(\beta' X)] = F(\beta' X).$$

Whatever distribution is used, it is important to note that parameters of the model, like those of any non-linear regression model, are not necessarily the marginal effects.

In general, $\frac{\partial E(Y \backslash X)}{\partial X} = \frac{dF(\beta' X)}{d(\beta' X)} \beta = f(\beta' X)\beta$, where $f(.)$ is the density function that corresponds to the cumulative distribution, $F(.)$.

For the logistic distribution, $\frac{d\Lambda(\beta' X)}{d(\beta' X)} = \frac{e^{\beta' X}}{(1+e^{\beta' X})^2} = \Lambda(\beta' X)[1 - \Lambda(\beta' X)]$

Thus, in the *logit* model, $\frac{\partial E[Y \ X]}{\partial X} = \Lambda(\beta' X)[1 - \Lambda(\beta' X)]\beta$.

It is obvious that these values will vary with the values of X. In interpreting the estimated model, it would be useful to calculate this value at, say, the means of the regressors and, where necessary, other pertinent values. In the logistic regression, the parameters of the model are estimated using the maximum-likelihood method (ML). That is, the coefficients that make observed results most "likely" are selected, given the assumptions made about the error distribution.

The empirical assessment of the propensity to contact is based on the estimation of the following general logistic regression:

$$P(ContactUniv) = \frac{1}{1+e^{-Z}}; \text{ with } Z = \underbrace{\beta_0 + \beta_1 Age + \beta_2 Size + \beta_3 ExpInt + \beta_4 R\&DInt + \beta_5 FOwnership}_{} + \underbrace{\beta_6 SkillInt + \beta_7 EducInt}_{} + \beta_8 Openness + \beta_4 \textbf{Region} + \beta_{10} \textbf{Industry} + \varepsilon_i$$

In order to have a more straightforward interpretation of the logistic coefficients, it is convenient to consider a rearrangement of the equation for the logistic model, in which the logistic model is rewritten in terms of the odds of an event occurring.

Writing the logistic model in terms of the odds, we obtain the *logit* model

$$\log\left(\frac{\Pr ob(ContactUniv)}{\Pr ob(Not\ ContactUniv)}\right) = \underbrace{\beta_0 + \beta_1 Age + \beta_2 Size + \beta_3 ExpInt + \beta_4 R\&DInt + \beta_5 FOwnership}_{} + \underbrace{\beta_6 SkillInt + \beta_7 EducInt}_{} + \beta_8 Openness + \beta_4 \textbf{Region} + \beta_{10} \textbf{Industry} + \varepsilon_i$$

The logistic coefficient can be interpreted as the change in the log odds associated with a one-unit change in the independent variable. Then, e raised to the power β_i is the factor by which the odds change when the ith independent variable increases by one unit. If b_i is positive, this factor

5 The odds of an event occurring are defined as the ratio of the probability that it will occur to the probability that it will not.

will be greater than 1, which means that the odds are increased; if β_i is negative, the factor will be less than one, which means that the odds are decreased. When β_i is 0, the factor equals 1, which leaves the odds unchanged. In the case where the estimate of β_1 emerges as positive and significant for the conventional levels of statistical significance (that is, 1%, 5% or 10%), this means that, on average, all other factors being held constant, firms that are in business for a longer time have higher (log) odds of contacting universities.

The estimates of the βs are given in Table 6 below. In this table we present 13 different models. The first model ('All Univ') illustrates the estimated econometric specification relative to the firms' propensity to establish formal contacts with (*all*) universities. The remaining 12 models pertain to the propensity of firms located in Portugal to establish formal contacts with *each* Portuguese university.

In Table 5 some descriptive statistics of the variables involved in the estimation procedure as well their bivariate linear correlations estimates are presented. Around 46% of the firms surveyed claimed to have had formal contacts with universities in the period 2001-2003. These firms present an average age of approximately 26 years and an average size of 139 workers. Note that the youngest firm has been in business for one year whereas the oldest has been in business for almost three centuries (276 years). In terms of size, the smallest employs one worker whereas the

Table 5 – Descriptive statistics

		Mean	σ	Min	Max	1	2	3
	Formal contacts	0.458	0.498	0	1.00	0.089***	0.133***	0.219***
Structural firm characteristics	(1) Age	25.9	21.12	1	276	1	0.142***	0.079***
	(2) Size	139.1	360.65	1	6582		1	0.136***
	(3) Export Intensity	0.173	0.304	0	1.00			1
	(4) R&D Intensity	0.022	0.075	0	1.00			
	(5) Foreign ownership	0.127	0.334	0	1.00			
Human Capital	(6) Skill intensity	0.079	0.162	0	1.00			
	(7) Education intensity	0.219	0.256	0	1.00			
Strategic firm trait	(8) Openness (ln)	2.629	0.248	0	2.77			

Table 5 – Descriptive statistics (cont.)

		4	5	6	7	8
	Formal contacts	0.193***	0.193***	0.062**	0.151***	0.313***
Structural firm characteristics	(1) Age	-0.100***	-0.100***	0.014	-0.129***	0.042
	(2) Size	-0.059**	-0.059**	0.124***	-0.041	0.104***
	(3) Export Intensity	-0.058**	-0.058**	0.067***	-0.065**	0.221***
	(4) R&D Intensity	1	1	-0.056**	0.168***	0.070***
	(5) Foreign ownership			1	0.268***	0.128***
Human Capital	(6) Skill intensity				0.122***	0.156***
	(7) Education intensity				1	0.237***
Strategic firm trait	(8) Openness (ln)					1

Table 6 – Determinants of the firms' propensity to establish (formal) contacts with Portuguese Universities (ML estimation)

		All Univ.	U. Algarve	U. Aveiro	UBI
Structural firm characteristics	Age (ln)	0,08	-0,31	0,10	0,14
	Size (ln)	0,55***	0,48***	0,42***	0,38*
	Export Intensity	0,49*	0,38	-0,10	-0,95
	R&D Intensity	7,95***	2,32	2,64***	1,26
	Foreign ownership	-0,49***	-0,67	0,14	1,37**
Human Capital	Skill intensity	3,47***	1,80	3,26***	2,31
	Education intensity	1,27***	0,28	0,48	0,44
Strategic firm trait	Openness (ln)	1.81***	2,19	0.93	-0.19
Region	North	0,22	-0,61	0,93***	0,81
	Centre	0,53***	-0,33	2,31***	2,76***
	Alentejo	0.63	1,18	0,76	-15,87
	Algarve	1,78***	5,24***	-16,70	-14,65
	Islands	0,44	1,33	0,80	2,38
Industry	Mining and quarrying	1,09	-17,32	0,00	-16,36
	Food products, beverage and tobacco	0,60***	-0,05	-0,34	1,61**
	Textiles and leather	0,11	-17,26	-0,37	2,25**
	Wood, pulp and publishing	0,19	-17,16	1,36**	-15,97
	Coke and chemicals	0,71**	-0,04	0,08	1,77*
	Rubber and other non-metallic	0,85***	-0,58	-0,09	-17,01
	Basic metals and fabricated metal products	0,93***	-18,31	1,28***	0,07
	Machinery and equipment NEC	1,39***	0,52	1,05*	-16,45
	Electrical and optical equipment	0,46	-17,36	-0,22	-16,02
	Transport equipment	0,64	-17,68	0,36	-16,34
	Manufacturing NEC and recycling	-0,28	-16,98	0,02	-16,32
	Electricity, gas and water supply, construction	-0,56*	-0,54	-0,25	-16,20
	Transport and storage	-0,62	-17,67	0,07	-15,52
	Post and telecommunications, financial intermediation	-0,61	-17,23	-17,55	-15,67
	Computer and related activities	0,00	-18,79	0,11	0,65
	Research and development & eng services	1,37***	0,19	1,16**	2,77***
	Social services and non-profit associations	0,00	0,79	0,09	1,90
	Constant	-8,58***	-11,31***	-9,08***	-8,21***
	N	1528	1528	1528	1528
	Contacted	698	28	101	27
	Not contacted	830	1500	1427	1501
	Goodness of fit				
	Nagelkerke R Square	0.402	0.444	0.267	0.316
	% Corrected	73.9	98.6	93.6	98.2
	Hosmers and Lameshow Test	11.305	3.906	4.475	2.880
	(p-value)	(0.185)	(0.865)	(0.812)	(0.942)

U. Cat. Lisboa	U. Cat. Porto	U. Coimbra	U. Évora	U. Lisboa	U. Minho	U. Nova	U. Porto	U. Técnica Lisboa
-0,14	0,33	0,17	-0,34	0,38	0,02	0,25	-0,06	0,01
0,72***	0,34***	0,55***	0,69***	0,38***	0,36***	0,33***	0,49***	0,39***
-0,14	1,19*	0,43	-0,49	-0,03	0,17	0,71	0,86**	-0,13
0,83	1,41	2,15*	2,98*	2,35**	1,73	2,86***	1,03	1,30
0,35	-0,24	-1,22**	-0,73	-0,13	-0,14	0,43	-0,28	0,27
1,69	2,24*	4,18***	1,80	1,92***	3,28***	2,64***	3,69***	2,87***
1,14***	1,73**	1,41**	1,60*	2,43***	1,11**	1,21**	1,43***	0,12
0.91	-0.74	0.60	0.28	0.06	0.23	-0.60	0.77	-0.40
-2,27***	1,58***	-0,37	-0,67	-1,88***	2,91***	-1,47***	2,83***	-2,07***
-1,45*	0,39	2,69***	-0,74	-0,91**	1,10***	-1,70***	1,15***	-0,78**
-17,40	-16,50	0,15	3,79***	-0,78	-17,48	-0,87	-0,09	-1,33
-17,43	1,82	1,41	-16,06	-17,89	1,53	-17,88	-16,44	-18,25
0,27	0,62	0,33	0,30	-0,99	1,24	-0,92	0,64	-0,81
-16,60	2,16*	-0,21	1,26	0,91	-17,77	-17,57	-17,87	3,25***
0,00	2,18***	-0,89	2,23***	0,17	0,05	0,78	0,19	0,79
0,14	-18,33	-1,37	0,40	-1,00	1,54***	-0,48	-0,89*	-0,47
0,94	0,31	0,07	1,70	-0,11	0,36	0,84	-0,10	2,28***
-0,75	-0,13	1,73***	1,31	0,60	1,78***	0,28	1,24**	1,71***
-17,13	0,28	-0,33	-15,49	-17,74	2,74***	0,80	-0,09	0,56
-17,69	0,16	-0,23	-15,90	-0,46	1,38***	-17,86	1,20**	1,44***
0,41	-0,34	-1,22	2,11	-0,34	1,46***	0,52	0,84	2,05***
-17,66	-17,72	0,53	1,62	-1,15	0,35	-1,08	0,76	1,38**
-0,76	-17,93	-1,48	0,11	0,16	1,37***	-0,73	0,36	1,09
-16,78	-0,20	-1,54	-15,96	-0,44	-0,74	1,13	-0,30	0,02
-18,08	-0,01	0,74	0,37	-0,75	0,22	-0,90	0,85	0,25
-0,13	-16,79	-0,87	-15,56	-1,13	-0,93	-17,75	-17,83	-17,42
-18,13	-16,62	-17,41	-16,41	-18,43	-17,60	-17,88	-17,56	0,12
-0,45	0,50	0,51	0,21	0,22	0,41	0,79	1,34**	1,20**
0,42	1,98***	0,18	1,40	0,62	0,82	0,42	1,44***	1,66***
1,35	0,65	0,60	2,03*	0,60	0,72	0,89	0,31	1,25
-8,52***	-6,27***	-9,26***	-8,25***	-6,22***	-7,54***	-4,12***	-9,27***	-3,91***
1528	1528	1528	1528	1527	1528	1528	1528	1528
40	45	72	29	79	179	68	138	105
1488	1483	1456	1499	1448	1349	1460	1390	1423
0.305	0.302	0.344	0.337	0.297	0.412	0.258	0.349	0.316
97.4	97.1	95.9	98.4	94.8	89.3	95.4	92.1	93.1
1.836	6.035	7.439	3.127	2.607	10.396	6.893	9.525	8.209
(0.986)	(0.643)	(0.490)	(0.926)	(0.957)	(0.238)	(0.548)	(0.300)	(0.413)

largest employs 6582 workers. On average, the firms in the analysis export less than 20% of their total sales and 12.7% are majority-owned foreign affiliates. In our sample, workers with 12 or more years of schooling sum up to 40664, representing 19% of these firms' total workforce, which is below the percentage (26.8%) obtained in the *Quadros de Pessoal* referring to the year 2002 (DGEEP-MTSS, 2005). However, on average, in our sample, the ratio of 'top educated' workers to total workers amounts to 21.9%. As for 'top skills', that is engineers, our percentage is likely to be closer to the figure presented in the 2002 *Quadros de Pessoal* data. In our respondent sample, engineers totaled 11745 individuals, which represent 5.5% of the total workers employed by these same firms. In *Quadros de Pessoal* the corresponding percentage is 6.8% but it not only encompasses engineers but also other university graduates. On average, a respondent firm presents a ratio of engineers to total workers of 7.9%. In terms of R&D intensity, the firms under study stated that 2.2% of the total sales were expended in R&D related activities, which is well below the figure (5.1%) obtained for technology-intensive firms (Costa and Teixeira, 2005). Finally, the firms have relatively 'open' strategic behaviours in terms of searching for knowledge and information for their innovative activities – on average, a firm draws on 13 out of 15 external sources of knowledge and information.

In bivariate terms, estimates of the linear correlation coefficients indicate that firms that are in business for a longer time, are larger, more export, R&D and human capital intensive, and are (majority) foreign-owned tend to establish more formal contacts with universities.

4.2. Estimation results

The quality of adjustment of all models estimated is quite acceptable. According to Hosmer and Lemeshow's test, all specifications reveal a good fit[6]. Moreover, the percentage of correct predictions ranges between 73.9% ('All Univ') and 98.6% ('Algarve').

In line with previous studies (e.g. Veugelers and Cassiman, 2005), our results for all the universities as a whole ('All Univ') confirm the strong industry effect in industry science links, which tend to be agglomerated in specific science-based industries, most notably in 'Research and Development and Engineering Services'. Notwithstanding, industries such as 'Food, beverage and tobacco', 'Rubber and other non-metallic' and 'Basic and fabricated metal products', tends, in average, to present higher propensity for contacting universities than the default category ('Wholesale and retail'). In contrast, 'Electricity, gas and water supply, and construction' reveal a low propensity for drawing on universities as source of information and knowledge for their innovation activities.

Not surprisingly, we also find large firms to be more likely to have contacts with universities. Firm size may be related to the presence of the necessary resources to efficiently implement contacts with scientific institutions as part of the innovation strategy of the firm. In fact, the positive and significant estimates for human capital related variables and R&D intensity reflect the critical role of absorptive capacity in firm-university links. Indeed, firms possessing higher levels of absorptive capabilities (that is, higher human capital and R&D intensities), are, all other factors being held constant, more likely to contact universities.

Furthermore, although in the descriptive and exploratory analysis, foreign owned firms were more associated with higher levels of university contacts, controlling for industry, region and other firm structural and strategic variables likely to influence the propensity of contacts, reveal lower likelihood for being actively involved in industry science links in Portugal.

In regional terms, firms located in Central and, somehow surprisingly, Algarve regions, *ceteris paribus* disclose higher propensities for contacting universities.

6 This test null hypothesis refers that the predicted values by the model are not significantly different from the observed values. Given that the p-value is not significant for standard values, this hypothesis is not rejected, leading us to the conclusion that the first model foresees the reality reasonably well.

The following table summarises the main characteristics of the firms that contact all and each of the Portuguese universities.

Universities that reveal to have the most demanding linkages with firms (i.e., consulting and project related contacts) – Técnica de Lisboa , Aveiro and Porto – are in average contacted by large and skill intensive firms belonging to industries such as 'R&D & Engineering service' and 'Basic and fabricated metal products'. Universities of Porto and Técnica are also contacted by firms from 'Coke and chemicals' and 'Computer and related activities'.

Table 7 – Characteristics of the firms that contact all and each of the Portuguese universities – overview of the main results obtained through the econometric specifications (continua)

University Profile	University	Structural traits	Human capital	Region	Industry
Entrepreneurial Universities	Universidade de Aveiro	Larger R&D intensive	Skill intensive	North Centre	Wood, pulp and publishing Basic and fabricated metal products Machinery and equipment nec R&D & Engineering services
	Universidade Católica Portuguesa – Porto	Larger Exporters	Skill intensive Education intensive	North	Mining and quarrying Food, beverage and tobacco R&D & Engineering services
	Universidade do Minho	Larger	Skill intensive Education intensive	North Centre	Textiles and leather Coke and chemicals Rubber and other non-metallic Basic and fabricated metal products Machinery and equipment nec Transport equipment
	Universidade Técnica Lisboa	Larger	Skill intensive	Lisbon and Tagus Valley	Mining and quarrying Wood, pulp and publishing Coke and chemicals Basic and fabricated metal products Machinery and equipment nec Electrical and optical equipment Computer and related activities R&D & Engineering services
'Classical', Teaching-led Universities	Universidade de Coimbra	Larger R&D intensive Nationally owned	Skill intensive Education intensive	Centre	Coke and chemicals
	Universidade de Lisboa	Larger R&D intensive	Skill intensive Education intensive	Lisbon and Tagus Valley	
	Universidade do Porto	Larger Exporters	Skill intensive Education intensive	North Centre	Coke and chemicals Basic and fabricated metal products Computer and related activities R&D & Engineering services

Table 7 – Characteristics of the firms that contact all and each of the Portuguese universities – overview of the main results obtained through the econometric specifications (continuação)

University Profile	University	Structural traits	Human capital	Region	Industry
Scientific-led Universities	Universidade Nova	Larger R&D intensive	Skill intensive Education intensive	Lisbon and Tagus Valley	
	Universidade Católica Portuguesa – Lisboa	Larger	Education intensive	Lisbon and Tagus Valley	
Regional-led	Universidade do Algarve	Larger		Algarve	
	Universidade da Beira Interior	Larger Foreign owned		Centre	Food, beverage and tobacco Textiles and leather Coke and chemicals R&D & Engineering services
	Universidade Évora	Larger R&D intensive	Education intensive	Alentejo	Food, beverage and tobacco Social services and non-profit associations

A clear-cut and statistically strong finding is that proximity matters a lot in firms-universities contacts. In fact, as we may observe in Tables 6 and 7, our results that everything remaining constant, in average, firms are more likely to contacts universities located nearby. For instance firms located in Algarve tend to contact to a larger extent the University of Algarve, whereas mostly firms from the Alentejo contact the University of Évora. Nova (Lisboa) and Técnica de Lisboa are contacted especially by firms from Lisbon and Tagus Valley. One interesting result is that Aveiro, Minho and Porto are those universities which have a broader spatially range being contacted by both Centre and North regions' firms.

The importance of proximity is thus highlighted in our results. Such fact may result from what the extensive literature on proximity related issues documents as the positive externalities associated with the spatial proximity to universities, which can be accessed by the firm through the spillover mechanism of human capital. As Varga (2000) shows, university graduates may be one of the most important channels for disseminating knowledge from academia to the local high-technology industry. In addition, other related externalities may result from close geographic proximity. For example, local proximity lowers the search costs for both firms and students. This may lead to some competitive advantage over similar firms, which are not located close to universities, especially when high skilled labor is a scarce resource and there is intense competition about high potentials.

5. Conclusions

It has been clear over the last decades that the innovation process is not the result of isolated agents. Interactions among various agents of the economy have been acknowledged to be at the core of the process (Monjonand and Waelbroeck, 2003). Rosenberg and Nelson (1994) argue that universities, and more generally science and academic research are an important factor in the development of major innovations. This view is confirmed by several empirical studies that reveal the importance of universities in the innovation process (Jaffe, 1989; Berman, 1990; Mansfield, 1995). For instance, Mansfield (1995) finds that 10% of the innovations under study could not have been developed without academic research, while Berman (1990) finds that direct industry funding of university research can be associated with subsequent increases in industry R&D expenditure.

Thus, in an innovation setting where 'no firm is an island', successful innovation partly depends on the ability of firms to acquire technical knowledge from external sources (Arundel and Geuna, 2004) and effectively include this knowledge in their innovation activities (Kline and Rosenberg, 1986; Freeman, 1987). Where firms go to obtain technical knowledge and how they obtain it will be influenced by firm-specific characteristics, such as their internal competences and sector of activity, and by the national and regional innovation system of the country in which they are located (Lundvall, 1992; Nelson, 1993). The latter includes the availability and quality of knowledge produced by other private firms and by the 'public science' infrastructure, namely universities.

Our results show that in Portugal, on the overall, the links between firms and the universities are weak, occasional and lack of sustainability. The universities in general do not seem to have innovation strategies and the local institutional – organizational representation of innovation support at the universities seems to be inadequate (LERU, 2006; OECD, 2006). Moreover, the interactive skills of the firms seems to be extremely weak, only large (whichever the university), R&D and human capital intensive firms systematically evidence higher propensity for drawing on universities as sources of information and knowledge for their innovation activities. This aspect might be to some extent related with the fact that universities pursue mainly fundamental research (Motohashi, 2005). Due to their mission, they do not supply industry with readymade new product technologies. University-firms linkages involve much more than technology purchases, typically requiring significant development activity on the firm side; for this reason, they tend to concentrate in large firms with their own adequate R&D resources. Overall the results seem to suggest that the low frequency of contacts with universities in Portugal may be related to an industry structure that is focused on non-science based industries, characterized by a high share of small and medium sized firms, whose portfolio of R&D strategies is limited.

Furthermore the results of this analysis support the view that relationships between firms and universities are characterized by a high degree of heterogeneity. To speak about university-industry relationships in a general way and develop policies on the basis of such generalization will lead to unintended intersectoral differences. Indeed, the various actors will react to these policies in different ways depending on their specific characteristics. In addition, it is extremely important to take into account that policies in support of collaboration between universities and firms should create incentives for both sets of actors to cooperate. Current policies are mainly directed to forcing universities into these types of relationships with no acknowledgement that without appropriate 'demand' little will be achieved. This paper provides strong evidence that, after controlling for firm size and other firm structural and strategic factors, the openness of firms to the external environment (and therefore their willingness to interact with it) is very important in explaining their probability of contacting with universities. Without willing partners satisfaction will not be achieved.

It is important to highlight here that, as in the case of India, documented by Bhattacharya and Arora (2004), firms and universities in Portugal seem to have different norms, and have different levels of evaluation criteria. Expectations from each other are also not clear in many cases resulting in linkages not translating into deeper levels. Firms located in Portugal tend to be skeptical of the research done in the university. Further, even if the technology they have felt is promising the resultant transfer has not taken place in many cases. In general, collaboration with industry is still only a peripheral concern of the university. Universities seem to be more comfortable with their role of knowledge generating institution. Indeed, despite recent research underscores the importance of universities in contributing to local economic development, leading edge research, high value jobs and innovation (Etzkowitz, 2002), as O'Shea *et al.* (2005: 1005) recognize in the case of the USA, "…unfortunately, for many institutions, efforts to make universities more entrepreneurial have not had sufficient impact". The present study reveals that this is also the case for Portugal…

A challenging and interesting pathway for further research in this area would be to investigate why some universities maintain and sustain closer links with firms, which might be the institutional-organizational factors that promote more entrepreneurial-led behaviours on behalf of universities. Such endeavour would obviously require a more in-depth study of each university.

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The evolutionary model of entrepreneurial firms' dependence on networks: going beyond the start-up stage

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resumo

Neste artigo propomos um modelo dinâmico da dependência das empresas empreendedoras nas suas redes relacionais. Primeiro, argumentamos que cinco características das empresas empreendedoras induzem a sua elevada dependência nas redes. Estas características incluem a orientação empreendedora, o papel central do empreendedor, limitações nos recursos, procura de flexibilidade e enfoque num nicho de mercado. Em seguida, examinamos como o crescimento das empresas empreendedoras é acompanhado pela evolução destas cinco características conduzindo a uma alteração da forma como estas constroem e usam as suas redes. Em particular, examinamos a composição e a estabilidade das redes relacionais das empresas empreendedoras. Este artigo contribui para a construção de uma teoria mais integrativa de empreendedorismo.

résumé / abstract

Dans cet article on propose un modèle dynamique de la dépendance des entreprises entreprenantes dans leurs réseaux relationnels. Premièrement nous faisons valoir que cinq caractéristiques des entreprises entreprenantes induisent à leur élevée dépendance dans les réseaux. Ces caractéristiques incluent l'orientation entreprenante, le rôle central de l'entrepreneur, les limitations dans les ressources, la recherche de flexibilité et l'approchement dans un créneau de marché. Ensuite, on examine comment est-ce que la croissance de la société entreprenante est accompagnée par l'évolution dans les cinq caractéristiques, en conduisant à une modification de la forme suivie par les entreprises entreprenantes pour construire et utiliser leurs réseaux. En particulier, on examine la composition et la stabilité des réseaux relationnels des entreprises entreprenantes. Cet article contribue à une construction plus integrative d'une théorie de l'esprit entreprenant.

In this paper, we propose a dynamic model of entrepreneurial firms' dependence on networks. First we argue that five characteristics of entrepreneurial firms result in their high dependence on networks; these five characteristics include entrepreneurial orientation, central role of the entrepreneur, resource constraints, pursuit of flexibility, and niche market focus. We then examine how entrepreneurial firms' growth is accompanied by the evolution of these five characteristics leading to a shift in the mode through which entrepreneurial firms construct and deploy their networks. In particular, we examine the composition and the stability of entrepreneurial firms' networks. This paper contributes to building a more integrative theory of entrepreneurship.

JEL Codes: M13; M14

1. Introduction*

It has been widely accepted in the entrepreneurship research that networks of relationships play a crucial role in the entrepreneurial processes (Birley, 1985; Aldrich and Zimmer, 1986; Jarillo, 1988; Dubini and Aldrich, 1991; Larson, 1992; Jack and Anderson, 2002). Departing from the notion that the dependence on networks is intrinsic to entrepreneurial firms (Low and MacMillan, 1988; Minguzzi and Passaro, 2000), prior studies have documented how entrepreneurial firms employ family ties, friendships, strategic alliances, and other types of social connections (Birley, 1985; Ramschandran and Ramnarayan, 1993; Coviello and Munro, 1995; Hite and Hesterly, 2001) to obtain resources (Lipparini and Sobrero, 1994), gain legitimacy (Stuart *et al.*, 1999; Human and Provan, 2000), enhance organizational learning (Minguzzi and Passaro, 2000), and collaborate on new product development (Deeds and Hill, 1996). Because entrepreneurial firms experience more and faster changes than established mature firms, it is likely that the composition of their networks has to reflect these changes. However, few studies have theorized or documented empirically how network dependence evolves over the firms' life cycle and particularly from the start-up to the maturity stage.

Despite the rich evidence of the importance of network ties, existing entrepreneurship research focused on either describing these ties or on examining the functions of the ties and has less often focused on two other important and related issues. First, a systematic examination of the antecedents of entrepreneurial firms' dependence on networks. It is often taken for granted that the dependence on networks is an intrinsic response of entrepreneurial firms (Jack and Anderson, 2002) to overcome resource dependencies, and thus the search of antecedents has seldom moved beyond resource constraints (Stinchcomb, 1965). However, it is likely that entrepreneurial firms' dependence on networks is not limited to resource dependence arguments and may be complemented with the examination of other firm attributes (e.g., organizational structure, strategy, and market focus). In particular, based on extant research we identify five fundamental characteristics of entrepreneurial firms: entrepreneurial orientation, central role of entrepreneurs, small size, pursuit of flexibility, and niche market focus, that explain their dependence on networks. As entrepreneurial firms grow the relative and absolute importance of these characteristics changes, which requires adjustments in the entrepreneurial firms' network - as different components of organizational systems should be aligned with each other (Tushman and Romanelli, 1985). Thus, to address this issue, an integration of these attributes is formulated in the first part of the paper.

Second, the understanding of the dynamics of entrepreneurial firms' networks has also been overlooked. This is partially because the lack of a comprehensive understanding of the antecedents of entrepreneurial firms' dependence on networks has somewhat limited scholars' exploration of the dynamism of entrepreneurial firms' networks (Human and Provan, 2000). Notwithstanding, entrepreneurial firms' networks are strategically constructed and employed, and the network ties may have different roles along the firms' life cycle, as argued by Baum, Clabrese and Silverman (2000) and Hite and Hesterly (2001). In this regard, Minguzzi and Passaro (2000: 182) argued that «the learning processes that induce the growth and retention of entrepreneurial and managerial culture in the firm and changes in entrepreneurial behavior can deeply influence the networks of external relations of the firm». These aspects were brought to the fore also by Hite and Hesterly's (2001) conceptual investigation of the evolution of firms network from emergence to early growth, and by Larson's (1992) examination of the dynamics of dyadic strategic alliances between entrepreneurial firms over the span of several years. Extant research

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permits only a partial understanding of the evolutionary pattern(s) of entrepreneurial firms' networks, the evolution of entrepreneurial firms network composition (i.e., the types of ties that the firm carries), the structural positions occupied, and the stability of the network (Aldrich and Whetten, 1981). The second part of this paper permits a better understanding of the varied requirements in terms of composition and stability of the focal firms' networks over the firms' life cycles (i.e., as the firms grow).

Combining these two issues, we propose an evolutionary model of entrepreneurial firms' dependence on networks. The mode in which entrepreneurial firms construct and utilize their business networks changes along the firms' growth (Hite and Hesterly, 2001), although the dependence on networks may not necessarily decrease. On one hand, their networks might need to be more stable to provide a foundation for a quickly changing firm. On the other hand, if the firms are changing quickly, then the network might be changing just as quickly. In alternative, entrepreneurial firms may seek to develop more diverse and perhaps fluid networks that permit adaptations to these changes. In this case it is reasonable, for example, that some of the old network ties may be discarded and other are moved to a latent stage, to possibly be recovered later on when, and if, needed.

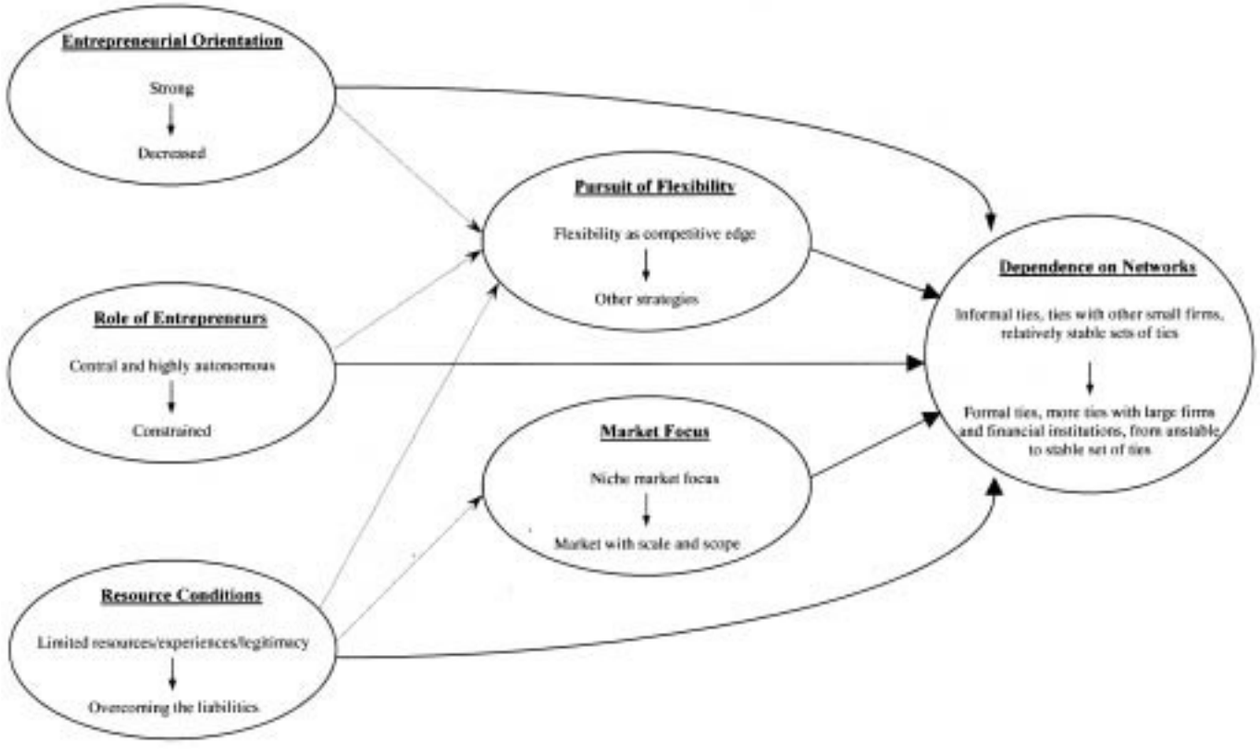
In this paper, we focus on the entrepreneurial firms' ego network and analyze the dynamism of the network from an evolutionary perspective. An ego network is composed of actors that directly connect with the focal entrepreneurial firm (Wasserman and Faust, 1994). Building upon Hite and Hesterly (2001), who examined characteristics of ties (i.e., embedded vs. arm-length ties, path-dependent vs. intentionally managed ties) to propose a change in the proportion of embedded ties, we concentrate on the configurational characteristics of firms networks and advance a change in the proportion of both formal and informal ties. Specifically, we investigate the dynamism of entrepreneurial firms' networks by comparing network *composition* and *stability* between the start-up and the established stage. Hence, we also contribute for a better understanding of how firms' networks are configured and reconfigured to respond to changes internal to the firms.

In the remainder of this paper we first identify five antecedents of entrepreneurial firms' dependence on social networks dependence from prior entrepreneurial studies and explain why they are related to firms' dependence on social networks. In the second part, we examine how firms' growth causes an alteration in these antecedents, resulting in the evolution of the entrepreneurial firms' network. At closing, we discuss our theoretical contributions and implications for future research.

Antecedents of entrepreneurial firms' dependence on social networks

The conceptual model, shown in Figure 1, conveys two main ideas that preside over this paper. First, we discuss how five main characteristics of entrepreneurial firms determine entrepreneurial firms' dependence on social networks. These characteristics are: entrepreneurial orientation, central role of entrepreneur, resource constraints, pursuit of flexibility, and niche market focus. Second, we discuss how as entrepreneurial firms evolve from the start-up to the established stage, their business networks evolve in response to changed internal, but possibly also external, conditions namely changes in the five characteristics mentioned above. Below, we explain how these five factors are antecedents of entrepreneurial firms' dependence on social networks. However, it is important to explain at the outset that the entrepreneur is embedded in a social network that plays a critical role in the entrepreneurial process (Aldrich and Zimmer, 1986). Social networks are broadly defined by a set of actors (individuals or organizations) and a set of linkages between the actors (Brass, 1992). For the entrepreneurs, these linkages, or relationships, to others provide various types of resources (Larson, 1991).

Figure 1 – The Evolutionary Model of Entrepreneurial Firms' Dependency on Social Networks



Note: The arrows inside the ovals denote the change of entrepreneurial firm's characteristics from the 'start-up' to the "established' stage

Entrepreneurial orientation

Entrepreneurial firms generally have a strong entrepreneurial orientation (Lumpkin and Dess, 1996), which manifests itself in three dimensions: innovation, risk-taking, and proactiveness (Miller, 1983). *Innovativeness* refers to an entrepreneurial firm's tendency to engage in and support new ideas, novelty, experimentation, and creative processes that may lead to new products, services, processes or technologies (Lumpkin and Dess, 1996). To be innovative entrepreneurial firms depend on their networks to (1) access information about customer demand, market conditions, technology, and potential collaborators to discover and explore innovative opportunities (Pineda *et al*., 1998), and (2) to access needed financing and identify human talents to carry out innovative ideas (Lipparini and Sobrero, 1994; Jack and Anderson, 2002). The network ties assist entrepreneurial firms identify possible sources of know-how and information and obtain physical and financial resources (Jarillo, 1988; Ramachandran and Ramnarayan, 1993) that will help them being more active than large firms in developing new products (Carrier, 1994; Deeds and Hill, 1996).

Risk taking is another dimension of entrepreneurial orientation. Risk taking refers to the extent to which entrepreneurs are willing to make risky resource commitments (Miller and Friesen, 1978). For instance, Brockhaus (1980) found that entrepreneurs are keen on exploiting emerging opportunities despite being attentive to the risks involved in these opportunities. Entrepreneurial firms are particularly subject to the costs and risks of new market entry and new product development (Lu and Beaminsh, 2001). Entrepreneurial firms depend on the network to govern, limit and share with partners potential risks (Kogut, 1988), and rely on their ties to obtain accurate information on potential risks (Birley, 1985).

Finally, *proactiveness* emphasizes that entrepreneurial firms take initiative in pursuing new opportunities and entering emerging markets (Miller and Friensen, 1978). To be more proactive, and hence be capable of taking stock of emerging opportunities, entrepreneurial firms may strategically construct networks of relations to firms that permit broader search opportunities in- and out-side their market and technological landscape. The fabrics of entrepreneurial firms' informal and formal relationships nurture proactiveness through information advantages (Dubini and Aldrich, 1991; Ostaard and Birley, 1994). The entrepreneurs learn through their social contacts (Carpenter and Westphal, 2000), or from what Powell (1990) designated as «networks of learning».

Central role of the entrepreneur

The entrepreneur plays a fundamental role in entrepreneurial new ventures. Since Schumpeter (1934) that the entrepreneurship literature has been emphasizing the central role of the entrepreneurs in entrepreneurial firms (Palmer, 1971; Low and MacMillan, 1988). At the start-up stage, entrepreneurs are the primary sources of ideas, innovation and technological expertise (Birley, 1985). Entrepreneurs have enormous discretionary power and autonomy (Lumpkin and Dess, 1996) in the absence of formalized internal structures and external stakeholders, and consequently they have great freedom in conducting business. A reasonable explanation for different management practices between large and entrepreneurial firms is that entrepreneurs enjoy much more power and discretion than their counterparts in large established firms. Moreover, at the start-up stage, entrepreneurial firms lack formalized internal control systems and their internal structure is overseen by the entrepreneurs' direct control and by loose hierarchical constraints (Mintzberg, 1979).

The central role of entrepreneurs contributes to the entrepreneurial firms' dependence on the social networks and particularly the network of the entrepreneur her/himself. Ostgaard and Birley (1994), for instance, noted a strong correlation between the characteristics of the entrepreneurs' personal network and the firms' strategy. The owner-managers of entrepreneurial firms tend to rely on their memberships in various associations (Aldrich and Zimmer, 1986). Oviatt and McDougall (1995) described how the network of the International Investment Group (IIG), an Atlanta-based business consulting venture, is composed of personal, as opposed to business,

relationships among highly successful individuals. IIG conducts most of its business with other members of the network.

Resource constraints

The entrepreneurial firms' dependence on the network for resources seems to be an intrinsic response to overcome a limited resource endowment and enhance the likelihood of success (Birley, 1985; Lorenzoni and Ornati, 1988; Jack and Anderson, 2002). Entrepreneurial firms depend on the social and business networks to complement their activities or compensate for deficiencies (e.g., use local intermediaries or develop ties with larger firms) (Fontes and Coombs, 1997), to access information and other resources (Holmlund and Kock, 1998), to identify export opportunities (Ellis, 2000), and to identify appropriate entry modes and marketing strategies into foreign markets (Coviello and Munro, 1995, 1997). In sum, the dependence of entrepreneurial firms on networks is an outcome of their attempt to overcome resource constraints (Jarillo, 1989).

Entrepreneurial firms are usually conceptualized as being small, and new, and as having a limited pool of resources (e.g., managerial, financial, informational, human) (Stinchcombe, 1965; Beamish, 1999) that limit their operations and increase their likelihood of failure - being subject to a 'liability of smallness' (Aldrich and Auster 1986; Stinchcombe 1965). This liability refers to the hazards, stereotypically based on internal resource limitations, that small firms incur, but that may be overcome, at least partly, by establishing resource-rich ties to other firms (Gulati, 1998).

Pursuit of flexibility

To achieve flexibility in design, manufacturing, workforce size, employee skills, and cost structure, entrepreneurial firms benefit from joining networks of firms. As Jarillo (1989: 133) noted «one of the most efficient weapons used by entrepreneurial firms to gain market share from larger, more powerful corporations is their flexibility». Teece *et al.* (1997: 520) referred to highly flexible firms as those with a capability to «scan the environment, evaluate markets and competitors, and to quickly accomplish reconfiguration and transformation ahead of competition». If entrepreneurial firms had to 'do it alone' (Baum *et al.*, 2000) the financial investments incurred and the commitment of physical and human resources would reduce their ability to explore novel opportunities due to switching costs, asset specific commitments, and/or other resource limitations. The membership in a network with other firms also facilitates entrepreneurial activities because partners provide easier and more abundant access to information (Dyer and Singh, 1998), reduce the need to carry out investments in fixed assets specific to a certain activity, and ease a possible shift to an emerging business.

The pursuit of flexibility is likely contingent upon the three characteristics examined above: entrepreneurial orientation, role of the entrepreneur, and resource constraints. First, an entrepreneurial oriented culture requires entrepreneurial firms to be flexible to explore emerging, related and unrelated business opportunities (Birch, 1987). Second, the salience of the entrepreneur, and corresponding firms' power and decision making structure, facilitates the pursuit of flexibility because autonomous entrepreneurs can make strategic decisions and respond swiftly to the opportunities identified (Palmer, 1971; Lumpkin and Dess, 1996). Third, flexibility can also compensate for the disadvantages of limited resources. Hence, flexibility is not only a possibly intrinsic characteristic but more importantly it is likely a planned strategic choice of entrepreneurial firms.

Niche market focus

Besides maintaining flexibility, focusing on market niches is another strategic choice for entrepreneurial firms given resource constraints (Ensley, Pearson and Amason, 2002). Chaganti and Mahajan (1989) found that, because of the lack of economies of scale, new entrepreneurial

firms have more difficulties in competing on price against large established firms. In addition, despite entrepreneurial firms' relative competitive disadvantage, large firms still seek to raise entry barriers (of different forms) to edge against new entries (Porter, 1980). Thus, to preempt direct confrontation with large firms, entrepreneurial firms may tend to seek market segments with unique characteristics (Davis and Austerberry, 1999).

A niche market strategy requires entrepreneurial firms' dependence on networks. A market niche is narrowly circumscribed in terms of customers, services, and funding sources (Hannan and Freeman, 1977). As a result, information about niche markets is usually hideous, tacit, and hard to obtain (Schwart *et al*., 2000). Acquiring information about niche markets requires information channels closer to customers, and therefore, networking with customers, suppliers, families, and friends are essential «bridges» to new markets (Sharma and Johanson, 1987). In addition, entrepreneurial firms have to learn how to explore niche opportunities despite the lack of prior experience from which to draw (Ensley *et al*., 2002). Instead of learning by their own, entrepreneurs often rely on vicarious learning through external contacts for advice and necessary information. Therefore, ties to other firms facilitate entrepreneurial firms' learning (Minguzzi and Passaro, 2000) and access to market niches.

In summary, the preceding discussion illustrates that entrepreneurial firms' dependence on networks is the strategic manifestation of their own characteristics and also of strategic choices. Such dependence is causal rather than coincidental.

Proposition 1*: Entrepreneurial orientation, central role of entrepreneur, resource constraints, pursuance of flexibility, and niche-market focus jointly induce entrepreneurial firms' high dependence on networks for survival and growth.*

The evolution of entrepreneurial firms' networks

Entrepreneurial firms' dependence on networks is not static, rather, the evolution of these firms alters the mode in which they construct and utilize their networks. However, the changing patterns of entrepreneurial firms' networks have received limited attention in entrepreneurship literature in spite of its acknowledged importance (Human and Provan, 2000; Hite and Hesterly, 2001). As suggested previously, as firms evolve through their life cycles so do their networks (Hite and Hesterly, 2001). In this section, we focus on the changes of the entrepreneurial firms' networks along their life cycles in terms of composition (e.g., Baum *et al*., 2000; Gulati *et al*., 2002) and stability (e.g., Aldrich and Whetten, 1981).

Network composition

The network composition may be examined in terms of the types of ties – formal and informal – and the types of firms that compose the network at any given moment.

Type of ties. The distinction between formal and informal ties has been frequently used to reflect different governance mechanisms. The *informal ties*, which have also been referred to as personal or non-contractual relationships (Macaulay, 1963), include family ties, friendship ties, affiliation ties, community ties, and so forth (Galaskiewicz, 1979; Grannovetter, 1985; Larson, 1992). The *formal ties*, in contrast, are frequently bound by a contract or other governance forms such as strategic alliances and interlocking directorates (Gulati, 1995).

Entrepreneurial firms are likely to depend on informal ties for economic transactions at an early stage but gradually adopt more formal ties as they become more established in the market (Hite and Hesterly, 2001). In other words, the networks of entrepreneurial firms are likely to be dominantly composed of the entrepreneurs' personal and informal ties (Hite and Hesterly, 2001), which provide access to information, resources, and local markets and bring benefits of reputation, advice and serve as referrals (Dubini and Aldrich, 1991; Ramachandran and Ramnarayan, 1993; Ostgaad and Birldy, 1994). As the entrepreneurial firms grow from the start-up to the established stage they often require additional resources. The existing informal ties

may not suffice for added tangible and intangible resource and strategic requirements, and thus need to be gradually replaced by formal ties. For instance, entrepreneurial firms will seek other external agents such as financial institutions that have the capacity to meet the added resource requirements. Alternatively, the firm may go public (Aggarwal and Rivol, 1991), with the corresponding implications of the change in ownership structure, and the added monitoring of external institutional investors, and financial regulation institutions (e.g. SEC). Under the pressure of external monitoring, entrepreneurs need to justify their decisions to other parties (Ross and Staw, 1993), and are likely to avoid making decisions on the basis of «intuition» or prior experiences, which are not easily justifiable. Therefore, driven by increasing resource needs, entrepreneurs may seek to develop formal and easily justifiable external relationships with other partners (DiMaggio and Powell, 1983), such as contracts and strategic alliances. Consequently, entrepreneurs' power and autonomy decrease with their firms' growth and their risk-taking and innovative behaviors are likely to be considerably constrained. Notwithstanding, we suggest that informal ties are likely to persist, even if they become relatively less predominant, due to the complementarity between formal and informal relationships, especially between firms with recurrent transactions (Gulati, 1995).

In addition to the change in entrepreneurial orientation and organizational structure necessary to develop these formal relationships, the change in entrepreneurial firms' resource endowment facilitates the establishment of these formal ties. New entrepreneurial firms are generally perceived riskier than established firms (Baum and Oliver, 1991), and are stereotypically characterized by their lack of a broad base of influence and endorsement, perception of quality, reliability, reputation, and low legitimacy (Larson, 1992). Hence, other organizations may hesitate to develop formal relationships with entrepreneurial firms (Stuart *et al.*, 1999). However, as the entrepreneurial firm demonstrates it is viable[1] and establishes a track record of success (Bantel, 1998; Stuart *et al.*, 1999) - that is, as they become established firms – it becomes progressively easier to develop formal alliances with other established firms. Moreover, it seems reasonable to suggest that this is a positively self-reinforcing process because established formal ties with large and prestigious firms further heightens the likelihood of forming additional formal ties in the future (Gulati, 1995).

We may thus reach a similar proposition to that of Hite and Hesterly (2001) whereby we advance that at the start-up stage firms' networks are socially embedded (identity-based), and evolve to ties based on a calculation of economic costs and benefits, as firms become more established.

Proposition 2a*: An entrepreneurial firm's growth from the 'start-up' stage to the 'established' stage is likely to be accompanied by an increase in the proportion of formal ties relative to informal ties in its network.*

Type of organizations. As suggested by institutional theory (DiMaggio and Powell, 1983), resource dependence theory (Pfeffer and Salancik, 1978), and social networks literature (Galaskiewicz, 1979), different firms have different institutional power, resources, positions, and relationships in a network. These are important because the organizations to which the entrepreneurial firms are tied matter in determining the access to additional resources, social status, and markets (Stuart et al., 1999). According to prior studies, two types of organizations, namely financial firms and large firms, are of particular importance to entrepreneurial firms (Stevenson et al., 1985).

As entrepreneurial firms grow they become more likely to have ties to financial providers. At the start-up stage entrepreneurial firms will have difficulty accessing financial resources from external sources due to entrepreneurial firms perceived high risks and the high costs involved in public offerings (Aggarwal and Rivol, 1991). As entrepreneurial firms mature, accumulate experience, build a track record of successes, construct their internal structure, build transparent internal decision-making processes, and established legitimacy, the credit ratings improve and boost

1 A new venture is usually considered viable after surviving a start-up period of high mortality (Brush, 1995).

financial providers' expectations. Financial firms are more likely to get involved with large established firms. Therefore, expanding entrepreneurial firms are likely to intentionally establish ties to co-opt financial institutions, and alleviate financial resources dependence (Pfeffer, 1983).

As entrepreneurial firms grow they are also more likely to have ties to established *large firms* that can provide a range of benefits, such as legitimacy, novel knowledge and social endorsement (Stuart et al. 1999). However, at the start-up stage, entrepreneurial firms are perceived risky and thus large firms may not foresee the benefits of cooperating. Stuart et al. (1999: 316) suggested that this could be due to potential hazards «because young and small companies encounter so many potential hazards and because they have short track records by which outsiders can evaluate their quality, there is considerable uncertainty about the value of new ventures». Changes along firms' growth such as increased internal formalization of decision-making enhance large firms' confidence on partnering with these firms. Indeed, extant empirical findings suggest that established large firms tend to network with multiple entrepreneurial firms to gain access to path-breaking technologies, state-of-the-art engineering talents, or seize the control of potential markets (Alvarez and Barney, 2001). These entrepreneurial firms are likely to be more advanced in their life cycle and have already developed a track record of performance and may be relatively more 'established' entrepreneurial firms. Thus, established entrepreneurial firms are more capable of having ties with large firms than when they are at the 'start-up' stage.

Proposition 2b*: An entrepreneurial firm's growth from the 'start-up' stage to the relatively 'established' stage is likely to be accompanied by an increasing proportion of ties to large firms and financial institutions in its network.*

It is worth pointing out that our proposition 2b above does not invalidate that many new firms (especially high-tech firms) start out with close ties to very large firms, as lead investors and customers (Venkatraman, Van de Ven, Buckeye and Hudson, 1990; Baum et al., 2000). However, this is not likely to be a general case given the already noted hazards associated to entrepreneurial firms that increase the perceived risks of investing or partnering with these firms.

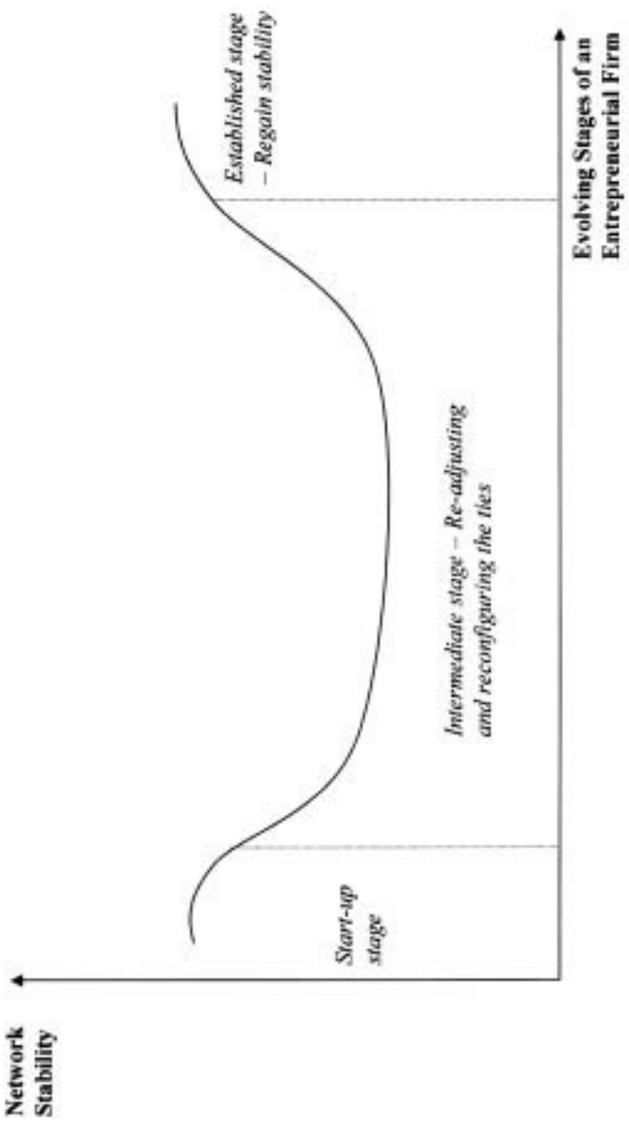
Network stability

Network stability was defined by Aldrich and Whetten (1981: 391) as «a situation in which relations between organizations within a bounded population remain the same over time.» Aldrich and Whetten (1981) further suggested that the structural characteristics of the network, the behaviors of dominant organizations, the dependence relations, and the environmental dynamics jointly influence the stability of the network. Therefore, the stability of entrepreneurial firms' network is likely to reflect the status quo of their resources, legitimacy, and strategy (Human and Provan, 2000) and stability is likely to change as these conditions change. In other words, entrepreneurial firms' growth is accompanied by changes in resources, reputation, strategies, and legitimacy that both require and induce modifications in the network. The period of instability accrues from the need to reconfigure a network that changes from cohesive to calculative-based ties (Hite and Hesterly, 2001).

As entrepreneurial firms develop from 'start-up' to 'established', their networks may first experience high instability and then progressively re-gain stability. From the 'start-up' to the 'established' stage, the stability of entrepreneurial firms' networks seems to follow a curvilinear general pattern as indicated in Figure 2. At the 'start-up' stage we expect the entrepreneurial firms' network to be relatively stable. The perceived risk and uncertainty of entrepreneurial firms are a barrier to the development of collaborations (Stuart et al., 1999), and hence the network of ties at this stage is likely to be based on informal, cohesive and personal ties of the entrepreneur, as predicted by Hite and Hesterly (2001). In addition, networking with other firms is not cost-free, and it is sometimes prohibitive for entrepreneurial firms with very limited resources because it requires large investments, continuous maintenance, and carries the risks associated to potential opportunistic behaviors of partners or even absorption (Williamson, 1985; Alvarez and Barney, 2001). That is, the entrepreneurial firm network is stable because the addition of new ties is not

possible. Hence, entrepreneurial firms tend to rely on path-dependent or existing ties, and these ties are essentially the entrepreneurs' ties. Ferreira (2002), for example, suggested a motherhood model whereby new entrepreneurial firms exploit existing ties of an umbilical nature instead of exploring new ties with firms outside the parental network of relationships.

Figure 2 – Evolution of Entrepreneurial Firms and Network Stability



During the maturation stage, as entrepreneurial firms gradually build up reliability, legitimacy and an observable track record of performance they become more likely to define new relationships. During this phase, entrepreneurial firms maintain a strong entrepreneurial orientation (Schumpeter, 1934; Miller, 1952) and are still active in exploring new opportunities while seeking to remain flexible. The combination of higher attractiveness to potential business partners, stronger capabilities, richer experiences of managing relationships, and strong entrepreneur orientation will probably lead to very high levels of instability in the entrepreneurial firms' network.

The entrepreneurial firms' network seems to regain stability as formal ties and ties to large firms and financial institutions are consolidated. As firms expand, they settle down on some opportunities with long-term prospects, instead of continuously taking risks or exploring the landscape (Jarillo, 1989; March, 1991). Moreover, with large resource and experience accumulated, expanding firms thrive for scale and scope economies, shifting away from appropriating profits and maintaining competitive advantages through strategic flexibility. This process may represent what Stevenson and Jarillo (1986) called the loss of entrepreneurial flair. This may signify the affiliation with established large firms that provide endorsement, enhance the likelihood of developing future ties with other organizations that rely on the observation of entrepreneurial firms' performance and reputation, and provide stable access to more demanding resource needs. In addition, the ties to large firms and financial institutions may tend to induce some inertia against the development of new ties (Larson and Starr, 1993; Baum and Singh, 1994) because of the benefits accruing from these relationships, and potentially high switching costs involved. Furthermore, the volume and the recurrence of transactions between partners increase as the entrepreneurial firms expand and with the longevity of relationship, resulting in increased stability of the relationships (Gulati, 1995a). We may thus advance the following proposition:

Proposition 3*: The stability of the entrepreneurial firm's network is likely to display a curvilinear relationship as it grows from the 'start-up' to the 'established' stage. Specifically, an entrepreneurial firm's network is likely to remain stable at the very initial stage of its life cycle; in the transition from the initial to the established stages, its network is likely to experience high instability; the network regains stability when the entrepreneurial firm becomes well established.*

Discussion and conclusion

This paper contributes to the entrepreneurship and small business literature by addressing why and how entrepreneurial firms rely on networks for survival and growth. We specified some network dynamics that accompany entrepreneurial firms' growth. We integrated existing research to explain why entrepreneurial firms are highly dependent on networks. From a strategy standpoint, for entrepreneurial firms, networking is almost the only, or often the best, organizing form to conduct economic transactions and explore market opportunities in conditions of resource, capability, and informational constraints. In stark contrast, networking with other organizations is not the only possible option for large established firms because they possess abundant resources, large manufacturing capacity, and intelligence systems (Ensley *et al.*, 2002). Furthermore, we examined the impact of changes in the entrepreneurial firms' characteristics on the evolution of entrepreneurial firms' networks. The dynamism of entrepreneurial firms' networks can be predicted examining changes in firms' organizational attributes. Hence, this paper contributes to a better understanding of entrepreneurial firms' networks by directing our attention to the underlying forces that cause alterations in the network.

This paper integrates the study of entrepreneurial firms' networks with approaches that examine entrepreneurs' traits (Low and McMillan, 1988), entrepreneurial orientations (Lumpkin and Dess, 1996), entrepreneurial firms' environments (Lorenzoni and Ornati, 1988), and entrepreneurial firms' growth (Churchill and Lewis, 1983; Hite and Hesterly, 2001). Our theorizing indicates that networking activities of entrepreneurial firms, along with other five characteristics, should be considered as building blocks in building a comprehensive model of entrepreneurship theory.

We highlighted some avenues for theoretical development and empirical testing in future research on entrepreneurship. First, given the focus of this paper, we did not consider the effects of contextual factors on the evolution of entrepreneurial firms' networks. Moreover, although our discussion of entrepreneurial firms' network composition was made at a high level, we may seek to deepen our understanding of the context-specificity that may be involved in firms networks. For instance, our arguments and propositions may, to some extent, be affected by firm-related contingent factors such as whether there is the possibility of venture capital funding, the positioning of the firm, and so forth. A future model may take these issues into account.

Much of our arguments, namely those related to the stability of the entrepreneurial firms' network, seem to suggest that all entrepreneurial firms follow a common pattern in their networking. That is not our contention, and Covin, Slevin and Covin (1990) already found that small firms in high- and low- technology industries emphasize different strategies. Baum *et al.* (2000) found that entrepreneurial firms in biotechnology tend to form partnership with large firms from the start-up stage. Accordingly, it is probable that the dynamic patterns suggested in this study may vary across industries. Future research may seek whether industry characteristics moderate the relationships proposed due to, for example, different requirements (e.g., capital intensity, technology intensity, labor intensity) in varied industries. This avenue may run away from the typical studies on entrepreneurial firms sampling from either high technology or service industries for generalizability.

We focused on ego networks and hence we explored a limited set of network characteristics. Social network research suggests a number of network characteristics that depict both relationships and structural positions (Wasserman and Faust, 1994) that may have important implications. While examining these characteristics in a complete network may enrich our understanding of entrepreneurial firms' networks, it also imposes challenges on our theory. This is partly because the dynamics of a complete network in which an entrepreneurial firm is located is not only influenced by the focal firm but most important by the collective characteristics of the network.

Future research could be particularly interesting in exploring how culture, and particularly national culture, moderates the effects of international entrepreneurial firms' characteristics on their dependence on and the evolution of networks? For example, in China, family businesses are very popular and different forms of informal ties exist among organizations and play important roles (Peng and Luo, 2000). Similar pattern may be seen in Italy. If culture is a moderator, we may expect international entrepreneurial firms operating in China to have a higher proportion of informal ties in their networks than those in other countries (e.g., in the US) even if they grow to be large established firms. Also, governmental influences, regulatory, legal policies and other institutional factors are possible contextual factors for these firms that warrant empirical and conceptual research.

To conclude, the specific characteristics of entrepreneurial firms largely convey their dependence on social networks. While at the 'start-up' stage of the entrepreneurial firms' life cycle it is likely that their ties are essentially informal, as the firms grow their ties are likely to become increasingly populated by formal relationships and ties to large corporations and financial firms.

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Círculo FEUC

Innovation-by-Agreement: Activating the Lisbon Agenda[1]

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Introduction

The Lisbon Agenda of 2000 confidently assumed that Europe could combine competitiveness with reinforced employee rights. When it was re-launched in 2005, convinced believers in the former EU-15 were hard to find. Globalisation and enlargement had hollowed it out. Besides which, different actors with different interests saw it differently. Some saw it as a call for more flexible production with reinforced rights, or flexibility-by-consent, notably, the ETUC, whose general secretary John Monks, forwarded a proposal on these lines to the employers' federation UNICE in 2004[2]. Others took it as a call for more flexible labour markets and reduced employee rights, or flexibility-by-constraint. The 'consent' view focussed on promoting innovation by reinforcing rights; the 'constraint' view focussed on cutting costs and reducing them. Given the choice, most management preferred the constraint option.

The Lisbon Agenda has been more cited than read, especially by much of the European press. In fact it called for:

> 'giving higher priority to lifelong learning as a basic component of the European social model, including encouraging agreements between the social partners on innovation and lifelong learning; by exploiting the complementarity between lifelong learning and adaptability through flexible management of working time and job rotation (and) furthering all aspects of equal opportunities, including reducing occupational segregation, and making it easier to reconcile working life and family life (European Council, 2000).

Lisbon, in these senses, was a call less for reform of labour markets than for a renewal of the European social model based on both economic efficiency and social consent (EU Commission, 1993). The background case behind this call was for innovation-by-agreement between social partners, which had been argued in an earlier report to Jacques Delors (Holland, 1993), and invited by the Portuguese Presidency of the European Council (Holland, 2000). This paper extends this reasoning and draws upon methodologies which we have independently and jointly developed, including a project for the European Commission to follow through the commitment of the Lisbon Agenda to lifelong learning (Oliveira, 2003).

It does so first by considering contrasts between flexible labour market theory and flexible production theory. Second, it addresses the widespread presumption that the 'flexible production debate' is over, or its claims exaggerated, suggesting inversely that its implications for western economic and management theory and practice have been understated. Third, it addresses the degree to which effective flexible production depends on explicating tacit knowledge, latent abilities and implicit skills within organisations. Fourth it suggests that social dialogue on the basis of principles of feasible mutual advantage for organisations and their employees can operationalise the principles of Lisbon Agenda and enhance both economic and social efficiency, before drawing some

1 This paper followed the FEUC Conference Series *Europe in Question* April-June 2003, sponsored by the Bank of Portugal and opened by the President of the Republic, and was available for the FEUC seminar series *Can Portugal Compete? The Autoeuropa Paradigm*, January-June 2005.
2 In Portugal, both João Proença and Carvalho de Silva, general secretaries of the two leading trades union confederations, endorsed the flexibility-by-consent approach at a conference on *Innovation-by-Agreement* at the Faculty of Economics of the University of Coimbra in 2003.

1. Conflicting Flexibility Paradigms

conclusions concerning the relation of economic and social efficiency in terms of enhancing competitiveness by more flexibly meeting employee needs.

Gosta Esping-Andersen and Marino Regini (2000) have observed that 'worker protection is not just a matter of welfare, but also may be conducive to efficiency'. They admit that hard trade-offs are involved. Yet add that: 'Firms - and entire nations - which choose to compete on quality rather than mere price, need a qualified, dependable and cooperative workforce. Cheap labour cannot guarantee such qualities… As a growing literature attests, markets alone are not very capable of assuring adequate workforce training. Over deregulated markets may engender a low skill equilibrium, the long run effect of which is productivity lag and loss of competitiveness'.

Flexibility-by-Constraint

Since EU enlargement, few firms in the former EU-15 have been impressed by this argument. Notably, since 2004, leading companies have opted for flexible working time by constraint. Siemens led the way by proposing in the spring of 2004 to move 2.000 jobs in two plant, producing cordless and mobile phones, from North Rhine Westphalia to Hungary. In June 2004, the workers at both German plant agreed to work 40 rather than 35 hours a week in return for a commitment not to move the jobs out of the country until 2012, and to do so for no increase in pay. Within a week, Daimler-Chrysler announced that it also wanted to increase working time from 35 to 40 hours for no pay increase. Karstadt-Quelle, a department store and mail order company, announced its intention to do the same, as did Thomas Cook in Germany, and Continental Tyre (Münchau & Atkins, 2004).

This challenge rapidly leapt borders. In France, within days of the Siemens deal, Bosch gained an agreement from a majority of its workers at a components plant near Lyon to do an extra hour a week without extra pay. The sanction was otherwise relocating in the Czech Republic. By December 2005 Bosch also was seeking a 40 hour week for no extra pay. Dozens of other companies followed suit including EADs, the giant high tech engineering and defence group, which is a major shareholder in Airbus. Hewlett Packard was offering to reduce job cuts in France by a quarter in return for longer hours, but while still planning to move most abroad (Hollinger, 2005). This was despite landmark legislation in France only a few years earlier for a 35 hour week. By the end of 2005, according to official figures, French workers on average already were working 39 hours a week (Hollinger, ibid).

Suzanne Berger (2006) recently has argued that there are two strategic choices for enterprise faced with the option of gaining access to lower cost labour: reorganise or relocate. The German and French firms which just have lowered unit labour costs by gaining longer hours for the same pay are playing a variant on this: cooperate or we relocate. And their strategy is consistent with the insider-outsider model of Assar Lindbeck and Dennis Snower (1988) that their competitiveness is in question because insiders within strongly unionised companies defend high wages and benefits against outsiders who would be prepared to work longer for less on both accounts. The sanction of relocating to where labour costs and benefits are lower is a variant on this theme, which itself has wide support in German management thinking. Hans Werner Sinn, head of the Ifo institute in Berlin, claimed that a 42 hour working week - a net average increase of seven hours - should be the German industry norm (Sinn, 2003). Klaus Zimmermann, head of the less conservative DIW institute in Berlin called for more than double this increase to a standard 50 hour week (Münchau & Atkins, 2004).

Such claims can be challenged on macroeconomic grounds. For instance, in contrast with the claim of allegedly inefficient European labour with more productive US labour, productivity per hour worked is higher in France than in the US. Nor are longer hours in themselves either a necessary or sufficient condition for international competitiveness. Germany in 2004 overtook the US as the leading export economy in the world. Since in

population terms it has less than a third of the population of the United States, this indicates that Germany as a whole is more than three times as competitive as the United States. Besides, where Germany domestic productivity may be low, this is much related to low growth in its domestic market, attributable less to the flexibility or otherwise of its labour markets than to constraints from the EU's stability pact (Rühmann, 2004; Soukiazis & Castro, 2005).

Flexibility-by-Consent

Also, behind the different views of the flexibility debate, there is a paradox. It is not flexible labour markets which give leading Japanese firms such as Toyota a competitive advantage over their global competitors but flexible production, product innovation and continuous improvements in methods of work organisation (Colenso, 2000; Womack & Jones, 2005). Japanese firms emulating the Toyota production system have achieved this because they guarantee their core employees lifetime employment and profit sharing. It is precisely because they are 'insiders', with both job security and a share in the success of the firm, that they are so willing to propose innovative methods of work operation. (Womack, *et al.,* 1990; Womack & Jones, 2005). And flexible production is a global winner. In 1946 Toyota was producing only as many vehicles in a year as General Motors was producing in a day. By the early 1980's its output already was half that of GM, and now it is set to overtake GM to become the world's no 1. automobile producer (The Economist, 2004b, 2005).

The Japanese flexible or 'lean' production paradigm reverses the Lindbeck-Snower (1988) 'insider-outsider' model and also the western flexible labour market model. Western firms, as in a standard Cobb-Douglas production function, have tended to treat capital as a fixed cost and labour as a variable cost. But because of their commitment to lifetime employment, the companies leading Japanese firms have to treat labour as a fixed cost. It is this that drives them to improve and diversify their investment by long-term process and product innovation to ensure efficiency and competitiveness. Nor have Lindbeck and Snower (1988) tried to reconcile the Japanese combination of lifetime employment and flexible production with their 'insider-outsider' model. Snower has admitted that they have not even looked at it[3]. Paul Samelson (2004), and Gomory and Baumol (2004) have explained much of what is happening in terms of downwards wage pressure with globalisation in terms of factor price equalisation. But, again, as with the Lindbeck-Snower (1988) model this stays within a standard Cobb Douglas production function in which innovation, or technical progress, or labour skills, or operational culture are residuals, if they feature at all.

By contrast, the Japanese have come closest to Schumpeter's (1949) claim that innovation merits being seen as itself a value-creating factor of production. Innovation as a strategy has been typical of most leading Japanese firms since the 1973 oil shock. While western companies then cut costs by reducing labour, or as now by downsizing or demanding longer hours, the Japanese leaders, encouraged by the Ministry of International Trade and Industry (Okimoto, 1989) innovated their way out of global recession from the 70's by bringing forward R&D and accelerating introduction of the range of products in which they now dominate world markets. We later suggest that these central differences in production and labour relations paradigms have been missed by those critics of Japanese flexible production who see it only as a more sophisticated form of Fordism, or cost cutting, because it also is mass production. We also submit that many commentators who have seen the later trend to 'in house' company unions in Japan, have missed key role played by trades unions in the origin of the Toyota production system and the social partnership central to it.

Kenichi Toyoda, whose family name means rich rice field, had been producing staff cars or the Japanese military during WW2 and with a depressed civilian market, in 1946, was only

3 When one of us put this point at the launch of their joint book by Dennis Snower in London in 1988, he replied: 'I don't know about Japan. It may be different'.

producing a few thousand vehicles a year. He had visited Ford's River Rouge plant in the States and realised that he could not possibly achieve high volume Fordist economies of scale. Instead, in 1950, he opted for cuts in labour costs and benefits, as European producers now are. But, under the US occupation, Japanese trades unions enjoyed rights drafted by American New Dealers who had failed to get them accepted in the States in the thirties, including the right to occupy a plant if not consulted on redundancies. They did so, brought Toyoda to his knees, and thereby opened the dialogue which resulted in an end to job demarcation, the introduction of multi-tasking and multi-skilling, and economies of scope. Most centrally they gained the right to profit sharing and lifetime employment which assured the crucial condition for continuous improvement that workers could see that innovations in terms of work operation were to the mutual advantage of themselves as well as the management. Sensitive to the fact that he needed a better brand name than 'rich rice field' Kenichi Toyoda had gained advice that changing the 'd' to a 't' in the family name would suffice since Toyota, in Japanese, meant nothing. Now it means near everything in terms of a post Fordist production paradigm (Womack, *et al*., 1990 and direct enquiry).

One of the key advances in economies of scope, or gaining more from the same capital equipment, was reducing die changes on giant cold steel presses for body parts from three weeks to a few minutes. The US auto majors could afford to take three weeks, since this suited their by then well established 'planned obsolescence' strategy of introducing new models annually in the autumn. Workers during the summer holiday break would fit, test and then fix the new dyes for pressing new body parts for each new model on its dedicated assembly line. It was by positioning the dyes horizontally, rolling them into place and fitting them with clips, that Toyota's engineers and workers managed to reduce changing them from three weeks to three minutes. Combined with other advances such as just-in-time delivery of parts to the point of assembly, or *kanban*, this meant that Toyota could produce more than one vehicle on one assembly line. Just-in-time parts delivery rather than Henry Ford's just-in-case stocking of parts reduced costs by a tenth or more (Womack *et al*., 1990). Also, unlike earlier practice by the US auto majors, and following Toyota's example, Japanese workers can stop the production line if a fault is going through which, essentially, is how they have achieved fault-free production.

Big Leaps – Small Steps

Kaizen or 'continuous improvement' is more important in terms of understanding the efficiency gains of leading Japanese firms than just-in-time delivery or kanban, most of which the US and European auto majors have replicated. *Kanban* has been crucial in reducing or eliminating stocks, and also has been improved over time. *Kanban* in Japan was improved after its introduction by enabling the components for an individual product, such as a car, to be customized to the specifications of individual consumers who then were delivered 'their car' within days of ordering it, Some US and European producers have achieved a high degree of product customization, notably Dell in computers, which is a key feature of its success. Volkswagen's Autoeuropa plant in Portugal has brought this to a fine art, and can make multiple variants of the same model on the same assembly line (FEUC Autoeuropa, 2004). Inversely some auto producers such as DaimlerChrysler are concerned that relocating entire plant will seriously disrupt the *kanban* system, which works best when the component suppliers either are local or not distant, and already have been successful on the basis of both iterative trial and error, and mutual trust. This in turn echoes a wider point made by Berger (2006) in that a unit cost gain in terms of wages and benefits from relocation may be nullified by a loss in the efficiency derived from both current skills and previous experience.

In terms of learning from or at work, Toyota gives the equivalent of seven years retraining either formally, or informally on-the-job. Koike and Inoki (1990) evidence what they with reason call 'a phenomenal growth of up-grading training' in leading Japanese firms

across sectors following the impact of the first OPEC oil price increases in September 1973. At the time, in reaction to falling rates of growth of global demand, western firms were laying off workers and dispersing their skills. In the Japanese case they were continually up-grading them. On job rotation and variation, workers in leading Japanese companies can spend some years in production, some in marketing, some in cost control and accounts, some in relations with supplier companies. Spending time with suppliers facilitates 'voice' rather than 'exit' (Hirschman, 1970). Not understanding how a supplier could assure both quality and a low price for a component, Toyota, again, invited itself to visit it, and came to realise that it was spending too little on R&D. It agreed to increase the price paid for the component on condition that the company developed its R&D division and developed its own innovation trajectory (direct enquiry). Job rotation also facilitates understanding of both the scope and constraints facing other parts of an organisation or a production plant. On these principles, the middle managers in Volkswagen's Autoeuropa plant in Portugal have initiated an 'in my shoes' policy by which they spend the equivalent of several weeks a year working alongside other managers, such as the manager for cost control with a production manager, in a manner in which the implicit conflict of their demands can be better understood and reconciled (FEUC Autoeuropa, 2004).

2. Flexible Production in Context

Some commentators have suggested that both Toyota and the auto industry are special cases and that other sectors of the Japanese economy are more typical of inflexible Fordist mass production. Wood (1989, p. 33) has argued of flexible production that 'nothing in these innovations implies an end to mass production'. Berggren (1989, p. 172) has claimed that the Japanese are 'the modern masters' of standardisation and Taylorist task segmentation. But we submit that this is misconceived. Of course, Toyota is into mass production, otherwise it would not be about to overtake General Motors as the world's no. 1 auto producer. But its paradigm is not inflexible mass production of standardised products but flexible, customised volume production. It is flexible production as a flexible response to individualised demand that enables Japanese consumers to identify eighty or more specifications that they want in or on 'their' vehicle and have it delivered to and for them within days (direct enquiry).

Otherwise, Japanese flexible production is not Berggren's (1989) 'modern mastery of Taylorism' but its inverse. In Taylor's (1911) operational logic, what was to be done was according to his 'scientific management', and decided top-down. The instruction needed to do a job was minimal because the task was so, with Taylor notoriously claiming that if you gave him a man for minutes he would train him for life. Taylor did not want craftsmen who were multi-skilled and multi-tasked because his design was to reduce labour to its least possible task, and de-skilling rather than re-skilling (Lacey, 1987). It was because his shop floor experience showed him that workers skilled in multiple tasks could slow down the pace of work that he had designed a de-skilled production system (Monin & Monin, 2003). Taylorism is the inverse of the Toyota production system in which the main aim is to achieve multi-tasking through multi-skilling, and continuous improvement in methods of work operation suggested by employees rather than designed top-down in a Taylorist manner (Womack *et al,* 1990; Womack & and Jones, 2005). Taylorism also is by definition inflexible. His presumption that there was 'one best way' meant that it could not be changed once achieved unless top-down by a new 'scientific' operational design. Such a Taylorist operational logic excludes organisational learning. Toyota's is based on it.

The further claim that Toyota and the auto industry are special cases is correct but in degree rather than in kind. Continuous improvement for years has been integral to all Japanese management thinking in bigger business (Nonaka, 1994, 1998; Colenso, 2000). And, even within the Japanese auto industry, Toyota has been exceptional rather than typical. It has been up to five times more productive per employee than other vehicle producers such as Mazda; Mitsubishi has run into difficulties; Nissan's own problems prompted its joint venture with Renault. But Carlos Ghosn of Renault in reverse learned

from the operational practice of kaizen style continuous improvement in Japan. And Toyota still is the global production pacemaker in terms of both process and product innovation. Its hybrid Prius is gaining global volume at 200.000 vehicles a year at a time when US companies are calling for federal subsidies even to develop hybrid technology. To claim that the Toyota production system does not represent a paradigm for other industry is as useful as to claim that Fordism as a production paradigm is meaningless because it also originated in the auto industry.

None of which implies that Toyota gets everything right all the time. With other Japanese auto producers it can make big mistakes, as it did in with its first European FDI foray at Burnaston in Derbyshire in 1992, finding that European consumers did not want 'bland boxes', even if they were fault free. As Thierry Dombreval, head of sales for Toyota recently put it: 'We didn't have a product that really appealed to the European customer in terms of exterior or interior design, powertrain or driving dynamics', and the break even point of 200,000 vehicles a year at Burnaston, only after entirely new models, took another five years (Mackintosh, 2006a). But the difference between a culture of commitment to continuous improvement meant that Toyota learned and reacted, within half a decade, whereas the US auto majors have failed to do so for decades, still producing models that, other than 4x4 pick-ups, US consumers did not want, not least because they were unreliable (Mackintosh, 2006b).

Also, if approaching a Weberian ideal type in production efficiency (Weber, 1947), the Japanese flexible production model should not be idealised. In Japan it involves varying degrees of implicit constraint. Non performance or non compliance can result in loss of promotion which, in a system where pay in the main has been through seniority, can mean both loss of income and loss of face. Where Japanese firms have transplanted flexible production to other countries without guaranteeing lifetime employment, or offering profit sharing, case studies have found it to be as much 'mean' as 'lean'. Tacit resistance and high labour turnover are common in several Japanese transplants, just as they were under Fordist mass production (Parker and Slaughter, 1988; Garrahan and Stewart, 1992; Wilkinson *et al.*2001).

Nor is it feasible in most cases to replicate Japanese lifetime employment in Europe for those companies exposed to globalisation, even if they could well be advised to offer no involuntary redundancy agreements for the lifetime of a product or product range, which could have a similar effect in terms of increasing willingness to suggest methods of work operation and continuous improvement. Many European companies have managed the 'big leap' from Fordist standardised mass production and inflexible economies of scale to post Fordist flexible economies of scope, and especially the auto majors. But it is evident that those that now are opting for longer working hours rather than continuous improvement are failing to maximise the 'small steps' of kaizen or 'continuous improvement' which has given leading Japanese firms their competitive advantage in global markets (Colenso, 2000) despite having some of the highest real wages and social benefits in the world.

Meanwhile, as Toyota is set to become no. 1 in the world auto league, General Motors, Ford and Daimler-Chrysler are finding themselves either with the wrong vehicles (GM) or increased faults and loss of quality with expanded production (Daimler-Chrysler's Mercedes division) and, with Ford, committed to tens of thousands of redundancies in both Europe and the US (Milne, 2005; Milne & Mackintosh 2006). The fact that the big three in the US, despite some renegotiation, are faced also with private health and pensions for former employees equivalent to adding $1.500 or more to the cost of a vehicle is giving rise to claims that they may need to file for chapter 11 bankruptcy proceedings unless they are bailed out by the federal government. GM has used this prospect to gain wage cuts and reduce pension rights from the UAW (Simon & Mackintosh, 2006). But this is a defensive tactic, not a long-term strategy. And it is in particular their failure to achieve continuous improvement that underlies the long run competitive failure of the US auto majors (The Economist, 2004a, 2005).

For instance, GM should know everything there is to know about flexible production and post Fordism since it entered a joint venture in 1986 with Toyota in the NUMMI production facility with Toyota in California (Womack *at al.,*1990). But while it learned the operational logic of production flexibility and just-in-time components delivery, GM focussed on flexible production as a technique rather than on continuous improvement as an organisational paradigm. It prioritised cost rather than innovation, and thereafter took organizational decisions that were the inverse of the Toyota hand-in-hand relations with suppliers and concern to develop joint innovation trajectories. It hived off its internal components division to an independent company, Delphi Automotive Parts which, in 2005 filed for bankruptcy (The Economist, 2005). Yet it is this failure to grasp that flexible production as a paradigm is both about reducing costs and continuous process innovation and quality control that underlies the long term competitive failure of the US majors. For, even with lower productivity levels in the States than in Japan, the Japanese transplants in the US can produce and sell a fault free vehicle for $1.500 less than the big three which, with higher health and pension charges, gives an average vehicle differential of $3.000 (The Economist, 2004a).

– Local and Global Context

Lifetime employment never included more than a seventh of the total Japanese labour force. Much of the rest of the Japanese economy has been less than efficient to hyper-inefficient in terms of employment levels, as in its high cost agriculture, and highly staffed services, including banks. But this has been an implicit societal choice, to ensure high employment levels and social cohesion, supported by transfer of the efficiency gains from its world leading companies to the rest of the economy through taxation.

Therefore in services, and not least banking the Japanese economy is not flexible, waste cutting or 'lean' (Womack *at al.,* 1990; Womack & Jones, 2005). Japan's recession in the 1990's was due to over inflation of property values, loans made on this basis, and defaults and contraction in a major banking crisis when the bubble burst. Yet the long recession in Japan in the 1990's also was not due to a loss of efficiency in its leading firms but in key part to their successful export from the 1980's of its high efficiency, flexible production model through direct investment to the United States and Europe. Up to a third of their global production now is abroad (The Economist, 2005). Japanese production in these major markets substituted for a large share of Japanese exports to them, and thus slowed Japan's economic growth. This effect was noted by Bertil Ohlin in the book for which he gained the Nobel Prize (Ohlin, 1933) but has been neglected by economists ever since.

Ohlin's parallel argument that countries will tend to specialize trade in the factor in which they have a comparative abundance, i.e. capital rich countries in capital goods and poorer countries in labour intensive goods gained prominence in the form of the Hecksher-Ohlin theory, but has been superceded since multinational companies now can combine low cost labour in emerging economies with intensive use of capital and technology. Yet it was not access to lower cost labour that attracted Japanese firms to the US and Europe, but fear of protection, especially from the US, if their greater competitiveness were to decimate the domestic market dominance of US companies, a fear well illustrated by George W. Bush trying to resort to protection for steel, and pressures against liberalisation by US farmers and textile producers. Again, such a tariff effect in promoting FDI had been identified by identified by Ohlin (1933).

During Japan's 1990's recession, and not least following the financial crisis of over exposure of its banks, there were intermittent reports that lifetime employment in Japan was finished. And its context has been changing. Some companies in Japan have been out sourcing more employment. And there has been an increase in part time employment, not least with increased feminisation of the labour force. During the recession, most leading firms introduced a combination of hiring freezes and early retirement to reduce labour costs. The close links of leading

companies to *keiretsu* banks in several cases have been loosened, as the banks addressed their own problems, and restructured. But pronouncements of death of the lifetime employment paradigm are premature. It remains central to the international competitive advantage of its leading Japanese firms. As Pilling has put it, Japanese companies 'have managed to reinvent themselves without aping the Anglo-Saxon model' (Pilling, 2006). Canon, which flirted with shorter term contracts, has reconfirmed the principle of employment from graduation to retirement for the central reasons of building cumulative skill trajectories, and keeping workers' knowledge, skills and experience 'in house'. As Fujio Mitarai, President of Canon, has stressed, the company thereby gets a workforce which is constantly relearning while Canon also keeps its process innovations secrets inside the company (Pilling, 2004).

3. Tacit Knowledge, Latent Abilities and Implicit Skills

Consistent with Fujio Mitarai's claims, it now is widely recognised in management theory and organisational psychology that one of the main competitive advantages of firms is the tacit knowledge that their employees have accumulated from non-formal learning at work. This interest builds on the work of Michael Polanyi (1958, 1962), for whom tacit knowledge is procedural 'know how' rather than semantic 'know that'. Reber (1976, 1989) pioneered the concept of 'implicit learning' in the context of tacit knowledge. Nonaka (1994) claims that organisational knowledge has four dimensions: tacit and individual; tacit and collective; explicit and individual, and explicit and collective, and has drawn on Japanese evidence to illustrate this. As he also puts it, giving examples from NEC, Sharp, Canon, Matsushita, Honda and other companies, when tacit and explicit knowledge interact:

> 'Something powerful happens. It is precisely this exchange *between* tacit and explicit knowledge that Japanese companies are good at developing… What's more, as new explicit knowledge is shared throughout an organization, other employees begin to internalize it – that is, they use it to broaden, extend and reframe their own tacit knowledge' (Nonaka, 1998, pp 29, 31).

In analysing corporate performance in international case studies, Baumard (1999) has stylised 'individual and collective' knowledge modes which are either explicit or tacit. For Ambrosini and Bowman 2001) tacit knowledge is 'deeply engrained' in people or organisations, while abilities or skills may be unrecognised simply because "people never thought of what they were doing, they never asked themselves what they were doing, and nobody else ever asked it either" (ibid, p. 816). Innovation-by-agreement is designed precisely to remedy this by identifying tacit knowledge, latent abilities and implicit skills through social dialogue, and projecting them in new joint 'innovation trajectories' of mutual advantage to both local plant management and other employees.

Recognition of the efficiency derived from tacit knowledge, and mobilising latent abilities and implicit skills through social dialogue contrasts markedly with recent fashions for classifying employees' knowledge as Human Capital (Becker, 1964) or Intellectual Capital (Edvinsson, 1997, 2000). This not only begs the question who 'owns' the stock or flow of such imputed capital and in whose interest it is deployed. Both Human Capital and Intellectual Capital theory stress formal qualifications and inputs because they can be measured, when the knowledge of those who best know what could be improved is mainly tacit, and how it has been learned implicit (Reber,1976, 1989). One of the most commonly cited arguments in the context of globalisation - Porter's 'competitive advantage' - is widely recognised to depend on tacit knowledge despite the fact that Porter himself makes no reference to it, attributing continuous improvement to technology rather than the labour process, and claiming that it has diminishing returns (Porter, 1998).

– Transplanting Gains

Where the Japanese flexible production and kaizen style continuous improvement model have been translated with success, this in some cases has been because it fits with pre-existing work attitudes and values. Consistent

with Riesman's (1954) distinction of 'other directed' and 'self directed' work, Swedish workers have found that kaizen is a set of practices and ideas, or 'technologies of the self', that enable them to 'take care of operations' (Styhre, 2001). But they have done so in large part because this was the farming tradition which shaped attitudes to work in the transition of Sweden from an agricultural to industrial society, and in particular the 'fix it' rather than 'send for help' culture typical of isolated farms (Styhre, op. cit).

In China, innovation in new methods of work organization varies between companies and sectors, as does quality. According to Hal Sirkin of the Boston Consulting Group, some big car makers initially reconfigured their capital-labour ratios in China to use more labour in their Chinese plant (The Economist, 2004). A major recent World Bank sponsored study into the vehicles sector found that in key components Chinese firms have moved to high levels of capital intensity, using robot welding, even if as yet using a higher level of manning on robots than is customary in high wage countries. As the report says: 'By so doing, they can achieve major cost savings by attaining levels of scrap losses that are extremely low relative to international best practice'.(Sutton, 2004). So, certainly, some companies in China are learning flexible or 'lean production'.

However, it should not be assumed that major relocations because of lower labour costs necessarily can match the efficiency gains feasible from continuous improvement in developed industrial countries. Neither Volkswagen nor Siemens have made a success of their low cost labour operations in China. Early into China, by 2004 VW saw its market share fall from nearly half of the FDI auto market in China to single figures. Siemens has failed both in Europe and in China with cordless and mobile telephones and within a year of gaining longer hours for the same pay in its plant in its German plant sold both of them and its China operations to a Taiwanese company (Wassener & Hille, 2005).

Some of the reasons, and the formidable operational gains that can be made in high wage countries from drawing on workers' tacit knowledge and implicit skills are apparent from an analysis of Japanese-Thai and Japanese-Malay joint ventures in different sectors, in which a University of Tokyo study found that even where the Thai or Malay ventures were using newer plant and technology, their efficiency ranged from only one fourth to one third that of the Japanese partner companies' production in Japan (Koike and Inoki, 1990). Holding capital and labour constant, they attribute productivity differences to the differences in skills and experience of the respective labour forces. They stress that such skills for the most part are derived from informal work experience and innovative work practices and noted a phenomenal growth of 'up grading training' in Japan from the time of the impact of the first oil crisis in 1973. This is customised to what workers already have learned in on-the-job training and is an extension and formalisation of informal skills (Koike and Inoke, ibid. pp 237-238). They also note that efficiency is greatly improved when production workers are able to point out 'some part of the process that should be modified according to their own experience' and add that for this 'such workers must know both the structure of the machines and the logic of the production process' (Koike and Inoke, ibid. p.9).

It therefore is by drawing on implicit skills and with commitment of both management and labour to continuous improvement, that high wage cost Japan for decades has been able to keep ahead of low cost Asia even when the Asian firms concerned are using the same or more modern technology, and the same or similar methods of work organisation. This is why Toyota, with high labour costs and with a strong yen, continue to be more competitive from Japan than any other world auto producer. It also implies that European firms still located in the EU-15 can in principle achieve major efficiency gains if they and their employees can mutually commit to continuous improvement.

By contrast, lengthening working time for the same pay without continuous improvement already can be one foot in the grave for the plant concerned, its workers *and* its local management, as already has been the case in Germany. When most companies were national, their operating management tended to side with the interests of owners and

shareholders rather than employees. However, the classic oppositional tactics of national management and national unions now are being transformed by the need for plant management and unions to cooperate in achieving efficiency gains precisely under the threat that, unless they achieve them, the company for which they both work will relocate. For, if production is relocated either elsewhere in Europe, or outside Europe, the jobs of local management also are in question. Even if some of them are offered postings elsewhere, few of them will be willing to take them if this means leaving or relocating their partners or families. Both employees and managers at plant level therefore have formidable incentives to achieve efficiency gains through social dialogue.

This is evident from a case study of Autoeuropa in Portugal, where management and employees were able to pull it to near top in Volkswagen's European efficiency league table. Autoeuropa made the 'big leap' to post Fordist methods of flexible work operation but also did so in terms that have 'internalised' the operational psychology of continuous improvement in precisely Nonaka's (1994, 1998) and Baumard's (1999) sense. With each new model, unlike Taylor's (1911) 'one best way', there is a learning curve because continuing improvement is possible. Autoeuropa still is only on the mid slopes of this with its current model. It also is constrained because it is a one-car plant, where the model is chosen for it rather than by it. Which vehicle it can produce, on what design, and with which components, is decided entirely by head office management. If market demand for the model is not strong, this feeds back into strains on the principle that employees in times of slack demand, should be redeployed or offered leave rather than made redundant. Nonetheless, the discretion of local managers and employees in seeking new methods of work operation through continuous improvement has been total, and Autoeuropa have made the most of it through mutual voice and dialogue within individual work groups, and between different groups and managers. Within wider global constraints, it has shown that in terms of operational efficiency 'Portugal Can Compete', and do so well (FEUC, 2005).

4. Recovering the Social Agenda

Such involvement of employees in change, and enabling them to give 'internal voice' at all levels is vital for operational learning and innovation, whether the context is radical, such as transition from inflexible Fordist to flexible post Fordist production, or evolutionary in the sense of successive small steps achieving continuous improvement (Oliveira & Holland, 1998; Colenso, 2000). And such voice is vital if flexible production and continuous improvement is to be gained on the basis of consent.

What emerges from international evidence on worker participation (Heller, op cit.) is that the essence of a learning organisation is not only a style of leadership which encourages and recognises such learning, but proactive participation in proposals for either organisational or operational change. To be effective these should be 'middle-up' (middle management to plant level or plant management to organisation level) and 'base-up' (any employee or group of employees) rather than only 'top-down'. The organisation therefore becomes more self-directed (Riesman, 1954) in its learning from the tacit knowledge, latent abilities and implicit skills of its workforce than 'other-directed' by only top-down design for change.

This does not mean that there should not be an initial conception or design for operational or organisational change. Someone has to start the process, whether senior corporate management, or plant management, or employees, through a trades union. Yet Argyris and Schön (1974, 1996.) have found from widespread international case studies that the failure to achieve deep 'double loop' learning of the kind implied by a paradigm shift is mainly by top and middle management. Resistance to paradigmatic change also can confront the tacit norms and implicit rules of what other employees think is to be, or ought to be done, or not done (Oliveira, 2002). Proposals for change in operational logic also are unlikely to succeed unless they make allowance for what Pascale (1990) calls 'creative dissent'. Feedback by middle management on an initial proposal for a change in operational or organisational

logic from top management may be common. Asking employees themselves what they could do with their skills and experience is less so. Asking them also to propose rather than react to changes in methods of work operation is uncommon. Yet proposals of the kind vital for continuous improvement are more likely to succeed if they can be made by employees at all levels and given voice through dialogue of the kind which can achieve both operational and thereby organisational learning and improvement. And this is central to the case for innovation-by-agreement.

– Mutual Advantage

Innovation-by-agreement therefore offers dialogue on organisational learning and innovation not only in terms of employees responding to change decided already by management, but how they and middle management can contribute to it in a manner which is of mutual advantage to themselves and the organisation.

On the other hand, as already stressed, European companies faced with global competition and increased market insecurity, may be able to offer employees profit sharing within various bonus schemes, but cannot readily assure them lifetime employment. It was for this reason that the background paper recommending innovation-by-agreement to the Portuguese Presidency of the European Council (Holland, 2000) proposed:

1. The right to negotiate the incidence of work time and personal or life time.

2. The right to formal skills extension in the context of skills path planning and 'customised' training extending the informal skills of groups of workers.

3. Recognition of implicit skills and experience and explicit skills extension in the form of job redesign and re-designation.

4. The right to propose new methods of work operation.

Innovation-by-agreement is a process. The commitment in Japan to lifetime employment and profit sharing is not explicit in terms of an employment contract but closer to what Guest (2003, 2004) and others have called a 'psychological contract'. This works in Japan because it has been embodied in both custom and practice for decades. In Europe, not least in view of the seismic shifts since 2004, mutual advantage is more likely to be achieved if the organisation can gain consent to flexible production and continuous improvement, while employees have the right to enhance personal fulfilment at work and to negotiate a more flexible balance between their work life and family or social life. Further, such a mutual advantage paradigm has the potential to combine what Japanese models of continuous improvement have not: both economic efficiency for the enterprise and social efficiency in the sense of more effectively meeting the personal needs of employees.

Innovation-by-agreement does not exclude parallel or integrated bargaining over pay and working conditions. It is not a substitute for increased pay justified by efficiency increases or increased sales. Nor is it a substitute for promotion. But part of its force is precisely that the process should extend collective bargaining beyond pay and working conditions to enhance the economic and social efficiency of enterprise, and facilitate continuous improvement in learning organisations. The challenge of individualising rights and life time needs within a collective bargaining framework is demanding. But the principle of innovation-by-agreement can be included in a collective bargaining agreement, with the practice being an ongoing process of social dialogue at plant level and the rights of individual workers or groups of workers to negotiate the incidence of working time. The process can:

- include both managers and workers, rather than just managers or just workers;
- enable individual proposals for new methods of work or task operation to be individually recognised and credited;
- allow non-formal learning-from-work to be recognised and credited in terms of job redesign or re-designation;
- combine flexible methods of work organisation with job variation and job rotation to offset alienation from doing one job and one job only;

- facilitate customised training and 'enhanced competence profiling' to extend and diversify the application of skills;
- enable skills path planning for both managers and workers rather than only career planning for upper levels of management;
- enhance the relation of non-work life to life at work by allowing negotiation of the incidence of individual or group working time to non-work time to suit family or other personal needs;
- recognise overtime working as 'time credits' which workers or managers later can draw on as 'undertime' when they may, on an agreed basis, take time off for recreation, further education or training, or for enhanced family time.

Time credits negotiated within the context of an innovation-by-agreement framework therefore would allow for overtime by a significant share of the workforce when market conditions demanded it, but allow workers the right to offset this by being able to customise the incidence of their working time. In this context trades unions might choose to negotiate individual work and life time agreements within three broad categories: (a) younger employees who have, or as yet have, no children; (b) employees choosing to extend maternity and paternity leave to care for children, and (c) older employees with no direct family responsibilities. Being able to draw on overtime credits therefore could be customised to individual needs and significantly enhance quality of life, while allowing management greater flexibility in terms of working time, within a negotiated framework.

Again, it is consistent with the principle of innovation-by-agreement that new methods of work operation should fully involve those at the most relevant level in the organisation in their design, and that the *aim* of the redesign should be mutual advantage. It is on such a basis, building on and extending the Toyota production paradigm that one can gain both economic flexibility-by-consent and social efficiency-by-consent in the sense of enabling employees to reconcile personal needs with work needs.

Conclusion: Re-Launching the Lisbon Agenda

Trades unions have to act at a national and international level. They must do so on a delegate basis. But plant level bargaining through a process such as innovation-by-agreement is well suited to more direct democracy. It also can work in general public administration and services rather than only in footloose manufacturing. Continuous improvement negotiated through innovation-by-agreement therefore need not be limited to the production sphere or private services. It can include:

1. the right of workers and managers in both the private and public sectors to expect negotiation to range beyond wages and working conditions and to include the relation between their work and non-work lives as well as retraining, job redesign, skills path planning and career planning.
2. the degree to which personalisation of service and 'continuous improvement' in education, health, public administration and other public services can directly benefit the public, enhance social efficiency and improve the quality of life.

This is a broad agenda, but one that offers a paradigmatic alternative to the presumption of most governments that the only was to increase efficiency in the social sphere or public administration is to cut costs by cutting employment and extending working hours, either within a week, or year, or within a working lifetime, as now being proposed in Portugal by the government for hospital administration. Alternative paradigms for such organisation, modelled on post Fordist and post Taylorist principles (Oliveira & Holland, 2006) indicate that units costs can be reduced and the quality of patient service improved by redeploying the tacit knowledge and implicit skills of health workers, with job enhancement through re-design, rather than postponing retirement, or reducing employment.

We therefore suggest that innovation-by-agreement, as intended by the Lisbon Agenda, can offer new efficiency paradigms both for both an economy and for society. It can achieve positive sum internal economies

in terms of new methods of work operation based on consent because the process reinforces individual rights. But it also offers positive externalities for society as a whole. This obtains for health, but also for education. This in the main, especially at secondary and tertiary levels, still is Fordist mass production of learning. It now is less 'educare' of the kind which Rousseau advocated in Émile (Rousseau, 1960), in the sense of the leading out of a self-directed individual into society with widened experience and understanding, than 'inducare' or induction into narrower areas of Taylorist specialisation (Oliveira & Holland, 1998; Atkinson and Claxton, 2000; Mintzberg, 2004).

Such a contrast between 'education' and 'induction' also is a central issue for the lifelong learning of the Lisbon Agenda inasmuch as many of the skills which people need to extend by customised training are implicit in their learning-from-work or learning-from-life, rather than formally or professionally acquired. As confirmed in our four country case study for the European Commission (Oliveira, 2003), lifelong learning (or LLL), needs to distinguish and integrate non-formal learning-from-work (LfW), and informal learning-from-life (LfL). Especially, skills profiling as the basis for skill path planning can and should personalise or customise retraining for individual workers or groups of workers with already given skills. This can enhance and extend what they already can do well at work and in life, rather than being formally trained to do things they have never done, nor are sure they can do well. This methodology, based on recognising tacit knowledge, latent abilities and implicit skills directly informed the Lisbon Agenda case that the Commission and member states should 'encourage agreements between the social partners on innovation and lifelong learning by exploiting the complementarity between lifelong learning and adaptability through flexible management of working time and job rotation' (European Council, 2000).

Therefore the Lisbon Agenda indeed was ambitious, but in under-recognised and still feasible ways. Its case for 'agreements between the social partners on innovation' were designed to enhance not only competitiveness but also service to the public, whether in health, education, public administration or local services. In Weber's (1947) sense of articulated hierarchy and division of labour, many public sector services have become bureaucratic not because they have no profit motive, but because employees who best know how they could be remedied or made more responsive to the public have no voice through social dialogue to propose innovation in methods of work operation on the basis of mutual advantage. In these regards, innovation-by-agreement arguably represents both a project for economic efficiency in the competitive sphere, and a wider project for society itself. It is precisely in such regards that the ambition of the Lisbon Agenda to re-launch the European Social Agenda both makes sense, and could be activated.

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