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A PRELIMINARY FRAMEWORK TO OVERCOME THE DICHOTOMY BETWEEN SPECIALIZATION AND DIVERSITY

Abstract

Two distinct approaches have been originated in the literature on industrial structures facing the match between knowledge externalities and economic growth: the former supports industrial specialization and is based on the Marshall-Arrow-Romer (MAR) externalities, while the latter is turned to sustain industrial diversity and refers to the Jacobs externalities. This paper attempts to overcome the existing dichotomy between the two approaches and proposes a preliminary framework, derived from the Lotka-Volterra equations, to investigate the complementary dynamics between specialization and diversity on the long-run.

JEL Classification: O18; R11

Keywords: Industrial Structure, Knowledge Externalities, Economic Growth, Ecological-Economic Model

1. Introduction

Since Marshall (1920) several scholars have been focusing on knowledge externalities as emergent phenomena of agglomeration economies and engine of growth. According to Audretsch and Feldman (1996), who provided a comprehensive literature review, knowledge externalities alimented an extraordinarily high number of studies dating back, at least, to Hoover (1936): inter alia, Romer (1986), Lucas (1988), Grossman and Helpman (1991, 1994), Glaeser et al. (1992).

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In literature there is consensus on the fact that geographic concentration boosts business interactions and the transmission and exchange of knowledge and ideas, skilled workers, products and processes, and so on. However, there is discrepancy on what are the specific patterns of knowledge externalities that bring economic growth. Most scholars investigating the link between knowledge externalities and growth adhere to two well distinct approaches: on one side, there are the specialization-driven models of Marshall (1920), Arrow (1962) and Romer (1986) or MAR externalities and, on the other, the studies on diversity and Jacobs externalities (Jacobs 1969, 1984). If both approaches converge on the role of knowledge as facilitator of innovation, these differ in a couple of key assumptions. In short, Marshall, Arrow and Romer suppose that knowledge externalities are relevant only for firms within the same industry (specialization), while Jacobs assumes that knowledge externalities take place among firms active in diverse and complementary industries (diversity).

Evidence on the impact of industrially specialized versus diverse patterns is mixed (see the overview provided by Beaudry and Schiffauerova 2009). Even though computational as well as methodological issues affect results (see Mameli et al. 2008 for a critical review), as a matter of fact it is not clear whether firms should locate in industrially specialized or rather diversified areas to grow faster.

In this paper we propose a preliminary framework to overcome the existing dichotomy between specialization and diversity and, hence, between MAR and Jacobs externalities. We attempt to deem the two approaches as two faces of the same medal. The paper is structured as follows. In Section 2 we put forward our research question. In Section 3 we present the classical prey-predator model and its logics. In Section 4 we focus on the assumptions and conjectures adopted to build our proposed framework. In Section 5 we conclude.

2. Our research question

Does a framework exist to investigate the interaction between specialization and diversity? To answer this question we move from an ecological approach. Georgescu-Roegen (1971), for example, argued that to analyze the dynamics of complex socio-economic system it might be important to take inspiration from biology. This approach is not new to urban and regional economists (see, among others, Dendrinos and Mullally 1981, 1983, Gambarotto and Maggioni 1998, Nijkamp and Reggiani 1987, 1992, Sonis 1986 and Suarez-Villa 1993). Socio-economic systems, such as natural ones, exhibit the same properties of dissipative structures (Nicolis and Prigogine 1977) and are resilient, in the sense of their capacity to resist to internal and external perturbations (Holling 1973 and Perrings 1994, 1998). Moreover, biological analogies are useful to investigate spatial competition and interaction between several components of socio-economic systems.

At the same time, since the evolution of socio-economic structures is intrinsically complex, it is important to find out consistent pathways of non linear dynamic modelling (see, for example, the discussions in Bertuglia and Vaio 2009 and in Nijkamp and Reggiani 1998).

In our view the Lotka-Volterra prey-predator model provides a good interpretative point of departure to investigate the long-run evolution of socio-economic systems, in terms of interaction between industrial specialization and diversity. In this paper we concentrate on this specific interaction and emphasise the existence of underlying cyclical patterns.

To sum up our proposed framework takes into account a series of relevant elements: a multi-disciplinary focus; an emphasis on interactions, dynamics and nonlinear evolution trajectories; a reference to dissipative structures, multiple equilibria and resilience.

3. The prey-predator model and the logics behind

The prey-predator model shows the dynamic interactions between two species (in our case, the two species are specialization and diversity) by using a two difference equations system. The same equations were proposed by Volterra (1926) in a simple model for the predation of one species by another to explain the oscillatory levels of certain fish catches in the Adriatic sea and Lotka (1925) from a hypothetical chemical reaction which he said could exhibit periodic behaviour in the chemical concentrations.

The system of differential equations at the base of the model (Israel 2009) states three main hypothesis: (i) if the growth rate of one species decreases and the other increases, the species are in a predator–prey situation; (ii) if the growth rate of a species is inhibited by the more efficient one, it is a competitive situation; (iii) if each species grow, then we have a sort of mutualism.

If *N(t)* is the number of preys and *P(t)* is the number of predators at time *t*, the model is:

$$\begin{aligned} \frac{dN}{dt} &= N(a - bP) \\ \frac{dP}{dt} &= P(cN - d) \end{aligned} \qquad (1)$$

where *a, b, c* and *d* are constants. The logics is very simple and its assumption are: (i) the unbounded (in a Malthusian way) growth of prey in absence of any predator this is the *aN* term in (1); (ii) the negative feedback in case of predator presence, that is to reduce the prey's per capita growth rate by a term proportional to the prey and predator populations this is the –*bN P* term; (iii) the predator's death rate results in exponential decay, in diminishing of the prey that is, the –*dP* term in (1).

In a nutshell, the increase in the number of preys increases the growth rate of predators, but the increase in the latter generates a negative effect on the number of preys. In turn, a decrease in the number of preys reduces the number of predators, which in turn increases the number of preys and, hence, allows a new cycle to begin. As Murray (2002: 79) argues *"the NP terms can be thought of as representing the conversion of energy from one source to another: bN P is taken from the prey and cN P accrues to the predators"*.

Starting from very simple mathematical equations it is possible to represent a very complex dynamics.

In urban and regional economics many studies made use of the Lotka-Volterra equations to describe several socio-economic phenomena. Dendrinos and Mullally (1981) focus on the interaction between a population (the predator) and their per-capita income (the prey). Orishimo (1987) presents a model based on a divergent logics: population (N) is the prey and land price (r), used as a proxy for the intensity of land use, is the predator. Also, the Lotka-Volterra equations have been used to explain urban growth through the relative dynamics of profits (the prey) and land rents (the predator) on both a theoretical (Camagni 1992) and empirical level (Capello and Faggian 2002). Camagni (1985) and Sonis (1986) employ the same equations to represent the diffusion of innovations, Fortis and Maggioni (2002) and Bischi and Tramontana (2009) apply the model to describe interactions among industrial clusters.

4. A preliminary framework to overcome dichotomy

Our conjecture is based on the assumption that specialization can be meant as predators, while diversification as preys: each territorial unit in our dataset is classified as preys or predators on the basis of the observed degree of industrial specialization or diversity. More specifically, in our model the number of preys and predators is given by the number of employees in, respectively, diversified and specialised territorial units.

We use data on employment levels in 57 economic sectors in 103 provinces and measure their specialization/diversity over the period 1951-2001 by means of the so-called Shannon's entropy index, which measures industrial diversity against a uniform distribution of employment where the benchmark is an equi-proportional distribution of employees among all industries.

To distinguish specialized and diversified provinces we use the index below:

$$E(j,t)=\sum_{i=1}^{57}\frac{o_{i,j}}{T_j}\log_2\left(\frac{T_j}{o_{i,j}}\right) \tag{2}$$

where j indicates the j-th province, t is the observed time interval, o_{ij} is the number of employees in the i-th sector of the j-th province and T_j is the total number of employees in the j-th province.

If the resulting value in equation (2) is below a certain threshold, it indicates a specialized province. Otherwise, if the value of equation (2) is higher we are in presence of a diversified province. To notice that, at each time interval t, between the two thresholds there is a certain number of provinces which do not classify as preys or predators: these provinces are in transition between the two species.

Following the discretization of *E(j,t)* in 100 points, we define two thresholds and calculate the total number of employees in specialized provinces, *x(t)*, and the total number of employees in diversified provinces, *y(t)*:

$$x(t) = \sum_{j \in P_t} \sum_{i=1}^{57} n_{t,i,j} \tag{3}$$

$$y(t) = \sum_{j \in Q_t} \sum_{i=1}^{57} n_{t,i,j} \tag{4}$$

where $\boldsymbol{P}_t$ indicates the ensemble of specialized provinces at time *t* (predators), $\boldsymbol{Q}_t$ indicates the ensemble of diversified provinces at time *t* (preys), $\boldsymbol{n}_{t,i,j}$ the number of employees at time of the *j*-th province in the *i*-th industry.

We start from the following system of differential equations:

$$\begin{cases} \dfrac{dx}{dt} = (a - by)x \\ \dfrac{dy}{dt} = (cx - d)y \end{cases} \tag{5}$$

where *x* is the total number of preys and *y* the total number of predators. In order to identify the Lotka-Volterra parameters (*a, b, c* and *d*), we transform the system in:

$$\begin{cases} \Delta x_{t,t+1} = (a - by_t)x \\ \Delta y_{t,t+1} = (cx_t - d_t)y_t \end{cases} \tag{6}$$

and define $\Delta x_{t,\, t+1}$ and $\Delta y_{t,\, t+1}$ as the preys' increment and predators' increment over time:

$$\Delta x_{t,t+1} = x_{t+1} - x_t \tag{7}$$

$$\Delta y_{t,t+1} = y_{t+1} - y_t \tag{8}$$

Next, by means of a linear regression, we estimate the optimal parameters (*a*, *b*, *c* and *d*) in the model:

$$\begin{cases} \dfrac{\Delta x_{t,t+1}}{x_t} = a - by_t \\ \dfrac{\Delta y_{t,t+1}}{y_t} = cx_t - d \end{cases} \tag{9}$$

under the assumption that:

$$R^2 = \frac{\sum_i (\bar{y}_i - \bar{y})^2}{\sum_i (y_i - \bar{y})^2} \tag{11}$$

where y_i represents the output of the linear regression and y the mean. For parameters a and b we attain $R^2 = 0.96$, while for parameters c and d $R^2 = 0.78$.

Finally, we choose the couple of regressions that maximises simultaneously the R^2 of preys and predators. Taking into account R_p^2 and R_{pp}^2 as, respectively, the R^2 of preys and predators, we maximize the function below:

$$\max_i \sqrt{\left(R_p^2(i)^2 + R_{pp}^2(i)^2\right)} \tag{12}$$

where *i* indicates the *i*-th couple of regressions.

So maximizing the (12) we obtain the parameters of the regression equations of the (9) as follows:

$a = 2.30$
$b = 3.06 * 10^{-7}$
$c = 9.48 * 10^{-8}$
$d = 0.28$.

The positive value of parameters support the existence of a prey-predator relationship between specialization and diversity. Parameter a shows that the birth rate of diversified provinces is high: that is, externalities *à la* Jacobs would be more incline to growth. Parameter b shows the degree of interaction between the two species and, more specifically, how diversity is preyed by specialization. Parameter c shows the degree of interaction between specialization and diversity, measuring how specialization increases in presence of diversity. To notice that b and c are very low and positive. Parameter d shows that the mortality rate of diversified provinces is low: specialization and MAR externalities would be less incline to decay over time.

We find that both species follow a cumulative pattern of growth, in line with the prey-predator model. In industrially diversified territorial units this pattern is robust to mean that these geographical areas might grow by reason of their degree of diversity. Instead, specialization exerts a relatively minor impact. To sum up, diversity grows up and self-fuels more than specialization. This finding is consistent with the value of parameter c, which is low and smaller than b.

5. Conclusions

In this paper we deem specialization and diversity (and, thus, MAR and Jacobs externalities) as not mutually exclusive. In this paper we propose a preliminary framework to link specialization and diversity. To do this, we moved from an ecological point of view. The paper was structured as follows. In Section 2 we put forward our research question. In Section 3 we presented the classical prey-predator model and its logics. In Section 4 we focused on assumptions and conjectures adopted to build our framework.

We proposed a model of conjoint dynamics. The study of the evolution of local socio-economic systems in terms of interacting specialization and diversity might represent a helpful benchmark. The next step is to offer a more robust empirical analysis to substantiate our proposed framework.

Further steps are towards a deeper investigation of the above mentioned cyclical pattern and oscillations of growth parameters. This can be done under several points of view. For example, it might be interesting to study the cyclical pattern of returns of scale. We might assume that the prey-predator model could be set on to highlight the effect of returns to scale in explaining the evolving trade-off between specialization and diversity. The underlying economic logics is: if returns of scale decrease in a certain market, no more firms enter that sector and opt for another one, thus increasing the level of diversity in a certain geographic area. These new firms grow and, then, start to benefit from increasing returns of scale, which in turn increase the number of specialized activities in that area until returns of scale decrease.

Also, with regards to the self-organizing properties of complex socio-economic systems, the prey-predator model could be used to assess the specialization/diversity feedback mechanisms that ensure resilience. In this case to be prayed is the capacity of the system to adjust to exogenous changes: usually specialization, by means of less resilience, puts economic systems in a (more vulnerable) lock-in situation and, thus, could hinder growth, while diversity should be less likely to induce such a negative effect.

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