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Smart Specialization Strategy and Directed Technological Change

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Abstract

The smart specialization strategy (S3) is a key driver in the EU policy. We formalize the smart specialization policy and the entrepreneurial discovery process in order to generalize and implement the concept of S3. We find that the smartest specialization strategy increases the productivity of the largest input in the region. Finally, we describe the proprieties required for an efficient smart specialization process using the directed technological change approach.

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1. Introduction

The smart specialization strategy (S3) is revolutionizing the EU policy (Foray and van Ark, 2008, Foray *et al.*, 2009, and Dhéret *et al.*, 2014). Indeed, S3 is a cornerstone of the integrated economic policy aimed at supporting convergent growth so that the EU can compete with the other world economies (McCann and Ortega-Argilés, 2014, 2015). The key message of the S3 is that the innovation process must be differentiated at regional level because it must be closed to the regional endowment of inputs (Montresor and Quatraro, 2015, and Foray, 2015).

At the best of our knowledge, only two papers try to describe the process of S3 with a formal model. The theoretical framework proposed by Martinez and Palazuelos-Martinez (2014) is focused on the entrepreneurial discovery process. They proposed an analytical method for selecting the entrepreneurs who are able to use regional inputs in a more efficient way under uncertainty. The political implication is to select the entrepreneurs that have expectations and forecasts closest to the observed values. Furthermore, Boschma and Gianelle's (2014) paper formalizes both the regional policy of S3 and the entrepreneurial discovery process with a network analysis at firm/industrial level. They conclude that the policy is smart if it supports new activities that can draw on regional inputs rather than just mimics an efficient policy from elsewhere. Finally, they observe that the regional technological relatedness and the regional diversification are the main drivers of the efficient process of S3 (Balland *et al.*, 2018).

Our paper tries to complement the previous approaches formalizing the policy of S3 and the entrepreneurial discovery process with a macro analysis at regional level. The standard notion of technological change proposed by Solow (1957) is not able to capture the policy of S3 because it is neutral at the regional endowment (Antonelli and Quatraro, 2010, and Feder, 2018a). For this purpose, we then use the directed technological change approach to formalize the concept of S3. The technological change is directed when it has a differentiated impact on the productivity of the inputs and then the cost of regional input markets becomes the key variable (Acemoglu, 1998). The directed technological change is formally represented as a change of output elasticity of inputs (Acemoglu, 2015). As suggested by Aghion *et al.* (2011), the directed technological change approach is useful for the EU policy as (i) it induces structural changes in the economy, i.e. it describes an innovation process, and (ii) it selects specific policies for regional heterogeneity of endowment, i.e. the policies are tailored to the regional endowment of inputs.

The rest of the paper is organized as follows. Section 2 formalizes in a simple way the concept of S3 starting from the notion of directed technological change. Section 3 shows the main results. Section 4 discusses the properties of the model and, finally, Section 5 concludes.

2. Model

Let us assume that in a region there is a policy-maker and an aggregate of firms. In the first step, the policy-maker selects the policy of S3, P. In the second step, each firm chooses the entrepreneurial discovery strategy, D. In the last step, the firms produce goods and services, Q, using N inputs, I_n where $n = 1, ..., N$. Let us assume that the production function is a Cobb-Douglas:[1]

$$Q = \prod_{n=1}^{N} I_n^{\alpha_n}, \tag{1}$$

where α_n is the output elasticity of input n, I_n, and measures its productivity. Indeed, when the exponent of an input increases and all other things held constant, production function increases, i.e. the input becomes more productive. From constant returns to scale $\sum_{n=1}^{N} \alpha_n = 1$, and then without loss of generality the output elasticity of I_N is $\alpha_N = 1 - \sum_{n=1}^{N-1} \alpha_n$ (Arrow, 1994). Then the production function increases with α_n if and only if $I_n > I_N$.

A shock of the output elasticity of inputs affects the GDP, Q, and the impact strongly depends on the regional inputs. Moreover, the shock of α changes the structure of the production function. As the S3 is both a differentiated regional strategy and an innovation strategy, it affects the output elasticity of inputs, i.e. the direction of the technological change. By combining Antonelli (2012) and Foray (2015), we assume that both the smart policy, P, and the entrepreneurial discovery process, D, affect the output elasticities of inputs. In other words, we assume that for each $n = 1, ..., N$ the output elasticity of inputs is:

$$\alpha_n = \beta_{0,n} + \beta_{1,n} D_n + \beta_{2,n} P_n, \tag{2}$$

where $\beta_{0,n}$ measures the constant component of α_n, e.g. the global forces and the regional social infrastructures (Hall and Jones, 1999), and $\beta_{1,n}$ and $\beta_{2,n}$ measure, respectively, the marginal effect of the entrepreneurial discovery on input n, D_n, and the smart policy on input n, P_n, on the output elasticities of input n, α_n. Therefore, it is implicitly assumed that both the policy pf S3 and the entrepreneurial discovery process could be directed to increase the productivity of a specific input, and then $D = \sum_{n=1}^{N} D_n$ and $P = \sum_{n=1}^{N} P_n$.

When focusing on the effect of directed technological change both the intensity and the bias of technological change are relevant. It is then essential to study for each input n both the strength of the entrepreneurial discovery, D_n, and the policy of S3, P_n, and also whether they affect positively or negatively the overall productivity. In other words, this theoretical framework allows the productivity to be observed in relative terms. When

[1] Adding the (Hicks-)neutral augmentation of the inputs or other production functions, all key results hold (Antonelli and Scellato, 2015, Antonelli, 2016, and Feder, 2018b).

$\beta_{1,n} > (<)0$ the entrepreneurial discovery process increases (decreases) the productivity of input n with respect to input N. Vice versa, when $\beta_{2,n} > (<)0$ the policy of S3 increases (decreases) the productivity of input n with respect to input N.

Let us assume that firms choose the quantity of inputs, in order to maximize their profits, $\Pi = Q - C$, whit the total cost:

$$C = \sum_{n=1}^{N} c_n I_n + T, \tag{3}$$

where T is a lump-sum tax, and c_n is the marginal cost of input n. Therefore, it is assumed that the supply of inputs is flat so that the cost of the inputs is not affected by changes in the demand of inputs.

Assume that, in a previous step, firms choose the entrepreneurial discovery strategy, D, maximizing Π. In order to simplify the analysis without omitting important characteristics of the process, let us assume that there is an exogenous level of potential innovation expenditure (e.g., R&D) that each firm can use to innovate. Let E be the maximal innovation expenditure at the regional level that the entrepreneurs can invest in their discovery strategy, D, thus $D \leq E$. Therefore, the entrepreneurs decide how much to invest in the productivity of each of the N inputs given the maximal innovation expenditure E.

In the first step, the regional policy-maker chooses the policy of S3 that maximizes regional GDP, Q.[2] Let P_n be the public expenditure aimed at boosting the productivity of input n, which is able to modify the output elasticity of input n, i.e. the smart policy, which affects the level of innovation by using the tax, T, paid by firms. Considering the public budget constraint, the public expenditure on the S3 is not larger than its public revenue, $P \leq T$.

3. Results

We solve the model by backward induction. The maximization problem for the regional private sector is $\max_{I_1,\cdots,I_N} \Pi$, such that (1) and (3) hold. By solving, the optimal level of input n is:

$$I_n^* = \frac{\alpha_n (C - T)}{c_n}. \tag{4}$$

Therefore, if the output elasticity of inputs and/or their costs vary among regions, the demand for inputs in each region may then diverge. In particular, if the output elasticity of input n, α_n, increases and/or its cost, c_n, decreases, then the amount of I_n increases.

In the previous step, the private sector chooses the efficient entrepreneurial discovery strategy that maximizes the profit. Therefore, the maximization problem for the private

[2]The process is more complex because the regional policy is not chosen directly by policy-makers, but it is chosen through an informative process where the suggestions of local entrepreneurs emerge. However, even if the theoretical framework should be complicated in this way, as with a bargaining process, all results would hold.

sector in the region is $\max_{D_1,\cdots,D_{N-1}} \Pi$ such that (1), (2), (4) and $D \leq E$ hold. By solving it, the first-order condition required for establishing the efficient level of the entrepreneurial discovery strategy, D_n^*, $\forall n = 1, ..., N-1$:

$$\frac{d\Pi}{dD_n} = Q^* \ln\left(\frac{I_n^*}{I_N^*}\right)\beta_{1,n}. \tag{5}$$

where $Q^* = \prod_n^N {I_n^*}^{\alpha_n}$. Thus, the entrepreneurial discovery strategy affects the profit function in a monotonic way. Let us first assume only two inputs, I_n and I_N, the only relevant first-order condition is now (5). If the most-abundant regional input is I_n, then only the entrepreneurial discovery process aimed at increases α_n is able to increase profit. Vice versa, if the most-abundant regional input is I_N, then only the entrepreneurial discovery process aimed at increase α_N is able to increase profit, i.e. decreases α_n. Finally, if there is not a most abundant regional input, then each possible entrepreneurial discovery process does not affect the profit.

Generalizing to more than two inputs, the comparison is from $N-1$ relations like (5). Therefore, the most efficient entrepreneurial discovery process aims to boost the productivity of the most abundant among $I_1, \cdots, I_{N-1}$. Intuitively, (5) increases in I_n and then, a higher level of I_n increases the profit. When all $N-1$ inputs have a negative effect on $d\Pi/dD$, the most-abundant regional input is I_N, and then only the entrepreneurial discovery process aimed at boosting the productivity of I_N is able to increase profit. The implication of the entrepreneurial discovery strategy is therefore that the efficient entrepreneurial discovery process is aimed at boosting the productivity of the most-abundant regional input. Indeed, when more than one regional input has the same (largest) abundance in the region, each possible discovery process on this subset of inputs is efficient.

Therefore, there are N possible technological trajectories in the region but only one is the efficient and smartest path-dependent technological trajectory, and that it is potentially different in each region. In other words, the entrepreneurial discovery process is linked to the concept of technological congruence, because this process is efficient when those regional innovation strategies are congruent with regional firms and the productive system (Abramovitz, 1986, and Antonelli, 2016).

In the first step, the public sector chooses the efficient policy of S3, P_n^*, that maximizes regional GDP, Q^*, such that (2), (4), (5) and $P \leq T$ hold. By solving:

$$\frac{dQ^*}{dP_n} = Q^* \ln\left(\frac{I_n^*}{I_N^*}\right)\beta_{2,n}. \tag{6}$$

Therefore the policy of S3 affects (6) in a monotonic way, and then all previous comments are easily replicable for the policy-maker strategy. Independently of the regional endowment of inputs, the efficient regional policy of S3 is then aimed at boosting the productivity of the most-abundant regional input. Also in this case, when more than one regional input has the same (largest) abundance in the region, each policy of S3 on this subset of inputs is efficient and smart.

The technological trajectory to increase regional economic growth could diverge in each region, and it is necessary to implement its most efficient path. In particular, the choice of where to direct the innovative efforts depends on the regional endowment and, in particular, on the need to make the most abundant regional input as productive as possible. Although this feature is well known in the literature of S3 (Aghion *et al.*, 2011, Boschma and Gianelle, 2014, and Foray, 2015), this is also reflected in the simple formalization presented.

In the real world, in each period the decision-making process restarts at the first step of the model. The impact of both strategies depends on the intensity of the entrepreneurial discovery (E) and the smart policy (T). Furthermore, the relevance of both strategies depends of the marginal effect of D_n and P_n on the output elasticities of inputs, $\beta_{1,n}$ and $\beta_{2,n}$. Moreover, if the largest input among regions is the same, they consequently follow the same paths of technological change. Vice versa, if the regions have different largest inputs then their paths diverge. The theoretical framework obtained static results, but by repeating the decisions over time in the rare cases where there is not a most-abundant regional input, the conclusion could be different. Indeed, if the regional policy is directed, $P^* \neq 0$, the quantity of regional inputs will change in the following period by (4), thus creating a regional path and a technological trajectory for this region as well. Indeed, a largest input will now exist in the region. Therefore, even small differences at the beginning of the process may lead to great divergences in regional specializations.

4. Proprieties

Using the previous formalization, the smart specialization concept indicates those regional innovation strategies that are congruent with regional firms and the productive system. On examining the literature on the new industrial policy, Foray and Goenaga (2013) explain five additional characteristics of the S3. First, the policy is mid-granular, i.e. the regional policy of S3 must support new activities and not sectors or single firms. Second, the entrepreneurial discovery process is a pivotal step of the overall smart process. Third, the political support of firms is limited over time. In other words, the policy of S3 is progressive and selects new opportunities and options in each period in order to induce structural changes in the economy. Fourth, there is the ease and transparency of the pre- and post-evaluation of the strategies. This is particularly relevant for the experimental nature of both the regional policy and the entrepreneurial discovery process. Fifth, the policy is inclusive, i.e. every sector could present a congruent entrepreneurial discovery strategy. In this section, let us focus on the consistency of the theoretical framework with these suggested proprieties of the S3.

Let us start by analyzing the mid-granularity of the policy. An innovation could be supported by a policy of S3 if it is not specific to particular sectors or firms, but is an inter-sectoral innovation and is useful for a potentially large set of firms. Using a production function at the regional level, the sectoral level of analysis or the firm level is not specifically analyzed. Therefore, the policy that affects the output elasticity of inputs positively affects the subset of firms, with the entrepreneurial discovery process efficiency directed, independently of their specific sectors. In other words, the model describes policies that only affect the firms in an inter-sectoral way. In addition, the model describes an efficient activity to direct the specialization strategy in a smart way, and not a generic characteristic at regional, sectoral or firm level. In conclusion, the level at which priorities are identified has the correct mid-granularity because it is between sectors and micro-activities.

Moreover, the entrepreneurial discovery process of firms is pivotal in the model (Foray *et al.*, 2011, Foray, 2014, and Aranguren *et al.*, 2018). In particular, the proposed theoretical framework incorporates the entrepreneurial discovery concept in a simpler way and approximates the aggregate behavior of firms, but, most importantly, it also shows the key characteristic of the efficient strategy of firms. Indeed, the theoretical framework formalizes the entrepreneurial discovery as a strategy at firm level that is the intermediate step between the policy of S3 and the implementation of the innovation process. Therefore, without the entrepreneurial discovery process neither new products and services could be realized nor smart policy could be implemented. In the model both entrepreneurial discovery and the collective-experimentation processes are integral parts of the policy of S3, because only these two processes could affect the output elasticity of inputs at firm level. Finally, only efficient strategies of the entrepreneurial discovery process are supported by the policy of S3, and all of these strategies have the same characteristics: they are technologically congruent with the regional endowment.

Another important characteristic of smart policy is that all the priorities that emerge at time t have a finite public support period. This idea holds perfectly in the theoretical framework with a dynamic point of view. The priorities that had previously emerged can no longer be supported in the following periods. Indeed, in order to obtain public support, the entrepreneurial discovery strategy must change the structure of the production function, i.e. it must implement a new technology, and after this goal is realized no more public support is given to this activity. In other words, all public priorities which emerged at period t that are lacking novelty at time $t + 1$ are no longer supported by the policy-maker in the next period. Indeed, new entrepreneurial discoveries occur all the time; but, after a while, these discoveries are no longer innovative, i.e. it increases α only one time, and therefore public support will no longer be provided. The continual quest for innovation in any direction involves path-dependence of the specialization process. Indeed, each region has potentially a path-dependent and differentiated regional specialization of products that allow for efficient and congruent regional growth.

In addition, the literature of directed technological change describes a transparent method for pre- and post-evaluating the effect of these innovations on the regional productivity (Antonelli and Quatraro, 2014, and Zuleta, 2012). Previous model suggests differentiating the policy of S3 at the regional level and accepting all entrepreneurial discovery strategies that ex-ante may increase the productivity of the largest input in the region. Moreover, in order to evaluate the ex-post effects of the policy, it is sufficient to measure the variation of the effect of directed technological change on productivity. Indeed, if the effect of directed technological change increases, then the public sector has efficiently selected the priorities; vice versa, if the effect of directed technological change decreases, then the public sector has selected the priorities inefficiently. Fortunately, only a standard database is required to measure the effect of directed technological change on productivity (Feder, 2018a, 2018b). Therefore, even if the nature of all innovation policies is uncertain and experimental, the model described in the previous sub-section is able to catch the effects of S3 in a clear and inexpensive way.

Finally, S3 is an inclusive strategy. Using a macroeconomics analysis at the regional level, both dynamism and productivity at firm level are irrelevant. For this reason, even less dynamic and less productive firms can bring about smart innovation. In particular, the only limitation of entrepreneurial discovery is that it supports a new technology congruent with regional endowment, independently of the characteristics of the firm. On the one hand, the most productive firms possess the most congruent technology with the regional endowment of inputs, so they probably propose an efficient directed entrepreneurial discovery strategy. On the other hand, the less productive firms benefit more from the congruency of the directed technological change with the endowment of inputs, so their entrepreneurial discovery strategy may be efficiently directed. In addition, in the proposed theoretical framework, the public sector supports all congruent entrepreneurial discovery strategies independently of the intensity of positive effects. Indeed, the efficient policy does not support all the good proposals, because they may be not congruent with the regional endowment, but it supports each entrepreneurial discovery process that wants to increase the productivity of inputs, independently of the age, the size, or the productivity of the firm. From the model, also each region could increase its own productivity, independently of its endowment. Therefore, the inclusive property also holds at regional level and then S3 has a positive impact on regional convergence.

5. Conclusions

A specialization strategy is smart if firms innovate considering own regional endowment. The paper proposes the directed technological change approach for generalizing and developing the concept of S3. Indeed, scholars observe that the endowment of the region becomes a key variable of the technological change (Aghion *et al.*, 2011). We then propose a simplified theoretical framework that use a limited set of equations to correctly describe the S3. Indeed, each required characteristic of the regional policy of S3 and of the entrepreneurial discovery process presented in literature holds. The formalization is reduced to its simplest expression in order to underline some stylized facts and to propose a theoretical framework with almost infinite extensions (Feder and Kataishi, 2017).

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