Evaluating the effect of organizational architecture in developing science and technology parks under differing innovation environments.

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Abstract:

Science and Technology Parks (STPs) are often used as tools to foster regional development. They seek innovations, innovators and encourage innovation amongst the constituent firms, including by networking and knowledge spill over between the inhabitants, Universities and sources of capital. The low success rate of STPs led us to investigate how STP architecture can best cope with a changing and challenging innovation environment, through start-up to early maturity and full maturity, in a preliminary effort to arrive at an evidence-based scheme to help avoid failure.

Three different types of architecture were investigated: open (market), star (hierarchy), and closed strong (adhocracy, ambidextrous). Open (market) architecture suffered both from high transaction costs while not protecting against poor decision-making. Results show that it is very beneficial to have a central Cluster Initiative (CI) controlling the decision-making process (star, hierarchy) in the early stages of STP development, where potential gains and losses are relatively modest. However in the early maturity stage with commitment to a high-growth trajectory, a high quality of decision–making is required amongst managers and decisions are best taken by the CI with the input of optimally two individual on-cluster firms. The situation where CI is supported by good-quality decisions from on-cluster firms – an *ad hoc*, ambidextrous situation – is superior when good innovations abound and the STP has acquired some maturity. However, in environments with a surfeit of poor-fit innovations, this becomes a high-risk strategy with high potential losses and indeed in this situation, retaining a hierarchical (CI only) decision process is most helpful, even when the quality of decision–making amongst CI managers is poor. Results indicate that success involves attracting enough small innovative firms which - in turn - attract larger firms, whose detailed sector-relevant insight improves CI decision-making.

Keywords. Innovation; organizational architecture; Monte Carlo; Science and Technology Park; Structural Equation Modelling (SEM)

1. Introduction

One way in which governments and local authorities seek to enhance regional development is through support for business clusters, a high-tech form of which is the Science and Technology Park (STP). Although there is no general agreement on the definition of business clusters (Zhao et al., 2009) the International Association of Science Parks and Areas of Innovation (IASP) define STPs as "… *an*

organisation managed by specialised professionals, whose main aim is to increase the wealth of its community by promoting the culture of innovation and the competitiveness of its associated businesses and knowledge-based institutions" and that *"The expressions "technology park", "technopole", "research park" and "science park" encompass a broad concept and are interchangeable within this definition"* (IASP, 2016). A broader definition is by Porter who regards them as a set of interconnected firms working in close proximity and related industries that are connected to a reputable Higher Education Institute (HEI) and Venture Capital (VC) and sometimes supported by local authorities (Porter, 1998; Porter, 2000).

The STP is a popular tool, indeed IASP reports that they have more than 344 members in 77 countries (IASP, 2016), while in Europe alone there are more than 365 STPs with more than 750,000 employees (Rowe, 2014). Expenditure can be considerable e.g. Wallsten (2004a) and Wallsten (2004b) reported that in 1999 Hong Kong invested 2 billion US dollars in building an STP.

Unfortunately, there is a high failure rate for STPs (Wadhwa, 2013). The World Bank, report success rates of around 20% and a rate of abject failure of around 20%, both figures globally (Kelly and Firestone, 2016), while in Wales 60% failed recently (Pugh et al., 2018). Ernst and Young (2017, p19) states that for the £2.2bn UK Catapult programme, "…*it is unlikely that the impact of the network overall has been significant …*", however these authors do also point towards the importance of high-quality of decision-making in an environment containing many risky innovations *"Catapults that had a chairperson with relevant business and industry experience ... performed relatively more strongly ..."* Ernst and Young (2017, p17)

The research presented here investigates why many expensive failures occur while some STPs grow and succeed. Recent reviews recount the factors which have been considered as success factors for STPs, see e.g. Cojocaru and Ionescu (2016) as well as Diez-Vial and Fernández-Olmos (2017) and results from panel data studies showing that in a successful mature STP, the corporate performance of on-cluster firms (here referred to as "F") is highly and positively correlated to total social expenditure i.e. investing in social networking (Al-Kfairy et al., 2017; Al-Kfairy et al., 2018), a finding that supports earlier work indicating that tacit innovation strongly affects product and development innovation (Casanueva et al., 2013), and problem solving (Mellor, 2003; Mellor, 2011). Clearly, state actors may establish large parks (a "top-down" approach) where the role of the CI is largely the collection of rent from tenants, but here we are concerned with small start-up STPs developing around a science theme ("bottom-up").

To change perspective from the point of view of the inhabitants, to the view of the STP itself, it is clear that the STP is created and then develops over time. Within any given period, some inhabitants will leave and, within the parameters that STP has (for example, the amount of space available), new inhabitants will be selected. Indeed, in order to avoid technology "lock-in", STPs must have a continual influx of new innovations (i.e. innovative firms), which it turns demands that new inhabitants are chosen that are in harmony with, and can enhance, the direction of the whole STP (Al-kfairy et al 2019a). For STPs to be successful, it has been argued that they must attract and select the most suitable and innovative firms to reside on the park. Indeed, Chen et al. (2006) concluded that selecting suitable tenants to inhabit the Park is crucial to create a successful STP. Furthermore, because the central Cluster Initiative (CI) performs the selection, makes all decisions and implements them, the quality of CI management team is positively related to STP performance (Albahari, 2015; Albahari et al. 2016).

Researchers including Will et al. (2019) emphasise that innovations are not all positive and that especially in environments seeking innovations, that costly negative "bad" innovations abound (Mellor, 2019). At its most simple, then where the benefit of a "good" innovation is *I* and the costs to achieve it are *C*, then the net gain is *I-C*. Where an innovation is unsuitable for whatever reason, then the net loss is larger, namely; *−(I+C)* (Mellor, 2019) implying that STPs need a constant positive-sum

game just to survive. How this is achieved is a research gap (see e.g. Lönnqvist and Laihonen, 2017). Because most studies on STPs evaluate them using financial or quantities indicators (Klofsten et al., 2015) with very little attention being paid about how STPs are organised and operate. Nonetheless, it is important to analyse which organizational architectures may be superior regarding selecting good projects (as addressed in the literature on the ambidextrous organization (Benner and Tushman, 2003; Benner and Tushman, 2015; and O'Reilly III and Tushman, 2013), because it is the organizational architecture of the corporation that defines how risky decisions are made and implemented (Sah and Stiglitz, 1985; as well as Sah and Stiglitz, 1986), thus it is the organizational architecture that determines outcomes for organizational performance.

Organizational architectures are conduits for networks; in STPs participation in networking activities has been shown to promote knowledge sharing among inhabitants (Koçak and Can, 2014) and indeed Al-kfairy et al. (2019b) found that networking (measured as social expenditure) was highly correlated with good performance in a mature STP. Models provided by Al-kfairy et al. (2019a) showed that in the initial stages of a nascent STP, the "star" architecture is most efficient, where all firms inhabiting the STP have one connection to the CI and no other connections, because this architecture is very economical on transaction costs. Later in STP development a "strongly connected model" may develop where some firms may liaise intensively together and with the CI (Al-kfairy et al., 2019a). Structural equation modelling (SEM) analysis showed that the potential rewards from this model can be very large, concomitantly however the risks of significant losses are also extremely high (Al-kfairy et al., 2019a).

The importance of a central CI in STPs is widely acknowledged; this is the executive instance of the organisation that manages the STP helping on-cluster firms to grow (e.g. Díez-Vial and Montoro-Sánchez, 2016) via e.g. providing a set of activities, support policies and selecting new inhabitants. In environments where positive innovations abound the decision-making capacity of the CI and the organizational architectures assume low importance. Conversely, STPs may be erected in geographical localities that have too few positive potential inhabitants to sustain it, and thus have to accept inhabitants that are poor fits[1] for the STP which in turn leads to the rapid failure of the whole venture. In intermediate situations the ability of the CI, the decision-making process and the STP organizational architecture will in the long run determine success or failure.

STP communication and transaction costs were categorized by Iammarino and McCann (2006) into informal channels (e.g. social networking) where transaction costs are minimized by "trust" between organizations, which in turn, requires complementarities leading to long-term relationships. It is tempting to speculate that failure to correctly manage this tipping-point transition could also contribute to success or failure of the STP. The new Innovation Based View (Mellor, 2015) finally allows SEM analyses to be made at various stages of STP development and therefore differing organizational architectures have been investigated (Markusen, 1996; Cowan et al., 2007) and Monte Carlo methods (Davis et al., 2007; Chib and Greenberg, 1996; Robinson, 2014) used to investigate potential gains for an STP under (a) differing conditions of quality of managerial decision-making and (b) in environments containing different proportions of beneficial innovations.

2. Methodology

Monte-Carlo simulations (Chib and Greenberg, 1996) were performed in Matlab 2018R. Throughout it is assumed that managers choose innovations blindly from an initial portfolio of innovations containing projects with "negative" as well as "positive" consequences for organizational

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[1] From the Innovation Based View (see Mellor, 2015) inhabitants, potential or on-cluster, can be referred to as "innovations" because this view regards the innovative new firm as a mere vehicle for an innovation.

performance, because they always *a priori* assume that their innovation will have positive consequences for corporate performance independently of whether this *ex post* is true or not, or otherwise, that they can distinguish the quality of the innovation and make a "correct" decision. Further assumptions are that "incoming innovation" is encapsulated in a business vehicle i.e. the manager either adds, or not, a new innovative firm (F) to the on-cluster group of firm, and that (in the case of closed network) only two F firms assist the CI in decision making, because although many F firms are available, including more will always over-proportionally increase the transaction costs.

Different decision-making methods were simulated based on the organizational architectures using a Cellular Automata approach (Davis et al., 2007), similar to studies published previously (Al-kfairy et al., 2019a; Will et al., 2019; Mellor, 2014a). Simulations were performed when organisational architecture is based on one of the following:

Table 1: Overview of the architectures *investigated.*

Number	The architecture tested
1	Open network ("market structure") where firms are loosely connected to each other and each firm can invite other firms into the cluster based on their own judgment. This represents a control case to compare with other STP cases, because it violates the most accepted definitions of STPs, but it can form a useful baseline, as shown in Section 2.1, (equations 1 - 3, figures 4 – 5).
2	Start-up structure ("star architecture") where all firms are connected to one CI and decisions are made unilaterally by the CI. This situation also represents a baseline control and is shortly illustrated in section 2.2, (equations 4 and 6, figure 6).
3	Start-up structure ("star architecture") where all firms are connected to one CI and decisions are made by the firms and the CI collaboratively (CI and Firms, section 2.2, equations 4 – 7, figures 7 and 8).
4	Closed network (adhocracy, a strongly-connected model, section 2.3), this is represented by any two firms jointly making a decision without involving the CI (equations 8 – 10, figures 11 and 12).
5	The ambidextrous organisation, operating within a strongly-connected model, where a joint decision is made by any two firms and then the CI (equations 9 and 11, figures 9 and 10) in section 2.3.

For each of the above, the quality of the decision-making at managerial level was varied between:

a. Managers make decisions randomly i.e. 50:50, as in flipping a coin.
b. Managers always make the right decision.
c. Managers can make decisions with a random degree of accuracy between 50% and 100%. (The case of managers making decisions with between 0% and 50% accuracy was omitted from this work because this could be a situation for e.g. state institutions, but not for STPs).

Throughout the simulation, the following vectors were randomly generated:

a. The number of firms in a cluster was randomly generated from uniform distribution between 6 and 500, and stored in the variable (n), which helps to control for cluster size effects.
b. A vector of innovation MU outcome (I-C) was generated from a uniform distribution with a net innovation value of between -1000 and 1000 MU for each firm (f) and stored in the

vector *Innov$_i$*, where (*i*) represents the firm index between 1 and (*n*), and (*n*) changes for each simulation run.

c. Then, we generate a single CI quality value from a uniform distribution, where the CI quality values changes only for each simulation run. The value was selected to be between 0 and 1 and stored in (q_c).

d. After that we generated a number of vectors from a uniform distribution representing the quality of firms managers ($q_{f,i}$), random decisions of firms (d_i), and random decision of CI as (CI_i), where (*i*) is from 1 to (*n*), and each value is between 0 and 1. The same vectors were used foreach of the different simulated architectures to ensure the consistency of the simulation results.

e. The cost of innovation was generated between 0 and 100 from a uniform distribution and was stored in the vector (*TC$_i$*), where (*i*) is from 1 to (*n*).

The simulation was run 5000 times to ensure the production of robust results.

The different situations were used at aggregate level, which reflects the overall innovation at cluster level because of the assumption that cluster innovation is the total of the innovation of the firms inhabiting the STP. Thus, STP success is the total net benefit gained by all actors. The different types of innovations were evaluated using equations (1 - 11) in sections 2.1 – 2.3.

2.1 Open Network Business Cluster Structure (market architecture)

In this case (table 1, number 1), the STP includes a number of firms, which are not connected to each other, and each firm implements its innovation independently of CI or other firms. Then, the quality of management decisions is simulated with the parameter ($q_{m,i}$), where for F managers it is between (0.5 and 1.0) and randomly generated from uniform distribution, so that if ($q_{m,i} < 0.75$) indicates that a manager with a medium quality of decision, who most likely makes 50:50 random decisions (as in flipping a coin). Otherwise, they are of a very high quality and will make the right decision (i.e. accepting good innovations and rejecting bad innovations). A vector of (*n*) element was then generated representing all managers in on-cluster firm level (F1, F2, etc), where each manager is different from any other in both decision-making capabilities, and the cash value of innovations generated. Random decisions are simulated with the value (d_i) which is between (0 - 1) generated from uniform distribution and indicates that if ($d_i > 0.5$) meaning a positive decision and accepting the innovation regardless of the actual outcome (positive or negative). For each run, a new number of firms (*n*) is generated, which enables us to control for the role of cluster size.

Using open network architecture, the following cases were simulated:

i. On-cluster firms implement an innovation independently of CI and of any managers, so any incoming project can be implemented. This case is implemented as a control experiments for comparison purposes with other cases. So, no quality checks are done in this case, and no control for random decisions. In this case, the net innovation cash flow for all firms (*b*) is calculated using equation 1, where $Innov_i = I_i - C_i$ and *I$_i$* is the innovation outcome cash value, and *C$_i$* is the cost of implementing that innovation:

$$b = \sum_{i=1}^{n} Innov_i \,,$$

b is the net total innovation, Innov$_i$ is the incoming innovation project value for firm (i)

(1)

ii. The managers of on-cluster firms decide. If they have good decision-making skills ($q_{f,i} > 0.75$)- where $q_{f,i}$ is the quality of the decision making for firm at index (*i*) - then they only

implement good innovations $((Innov_i - TC_i) > 0)$, TC_i is the decision making cost (transaction cost), otherwise the innovation is rejected (see equation 2):

$$b = \begin{cases} \sum_{i=1}^{n} Innov_i - TC_i, if\ (\ q_{f,i} > 0.75)\ and\ (Innov_i - TC_i) > 0)\ or\ (d_i > 0.5) \\ b - TC_i, if\ (q_{f,i} > 0.75)\ and\ (innov_i - TC_i) < 0) or\ (d_i) \end{cases} \quad (2)$$

iii. Then, the quality of decisions made is not checked, meaning that F managers will only approve if $(d_i > 0.5)$ regardless of the value of the innovation (random decisions). This is summarised in the equation 3:

$$b = \begin{cases} \sum_{i=1}^{n} Innov_i - TC_i, if\ (d_i > 0.5) \\ b - TC_i, if\ (d_i < 0.5) \end{cases} \quad (3)$$

2.2 Start-up Structure (star architecture)

In this case, STP firms are connected to the central organisation called Cluster Initiative (CI), which act as control agency helping firms connecting with VCs and build internal relationships as well as coordinating activities and innovations. The baseline control (table 1, number 2) assumes a stable functioning steady-state STP scouting for innovations examines 100 innovations each worth 100 Monetary Units (MU) and in this case the costs for implementing a decision are fixed for the purposes of illustration to 20 MU and the decision-making costs to 2 MU. Table 2 is a simple illustration and briefly shows that even with 100% dependable decision-making by CI managers, the returns are dependent on the quality of the innovations presented to that STP.

Table 2: Returns from 100 innovations each worth 100 MU where the innovations are of varying quality and presented to a CI management with 100% correct decision-making ability.

Percent of "good" innovations	Return (MU)
100	7800
50	3800
0	-200

Moving to the case of table 1, number 3, the mean (average) quality of the F decision-makers checking the innovation must be greater than the cut-off point (0.75) $(\mu(q_{m,i}, q_{f,i}, \dots) > 0.75)$ and this figure is reached because at this point two good quality F managers can overcome the poor decision of a third F one. However, this cannot happen without cost (e.g. discussion times), which is in this simulation is obtained randomly for each firm (from a uniform distribution) with a value of $(0 \leq TC_i \leq 100)$, and the value of a beneficial innovation value is simulated with $(-1000 \leq Innov_i \leq 1000)$ MU, meaning that an innovation with the value $(Innov_i \leq 0)$ is a poor innovation.

In contrast, the decision-making quality at CI level was given a random constant quality because, as shown in figure 1, the quality of CI decisions applies to all other on-cluster firms indiscriminately (i.e. it does not change according to the number of firms in the STP) with the value $(0.5 \leq q_c \leq 1)$, and (q_c) is the quality of the CI managerial decision making, so each time an innovation has to be

considered this can change between $(0 \leq CI_i \leq 1)$ where $(CI_i < 0.5)$ indicates a probable rejection (regardless of whether the outcome would have been positive or negative). Figure 1 shows the science park organisation, where each firm is connected to the central organisation CI, in a star architecture reflecting the state-centred cluster organisation.
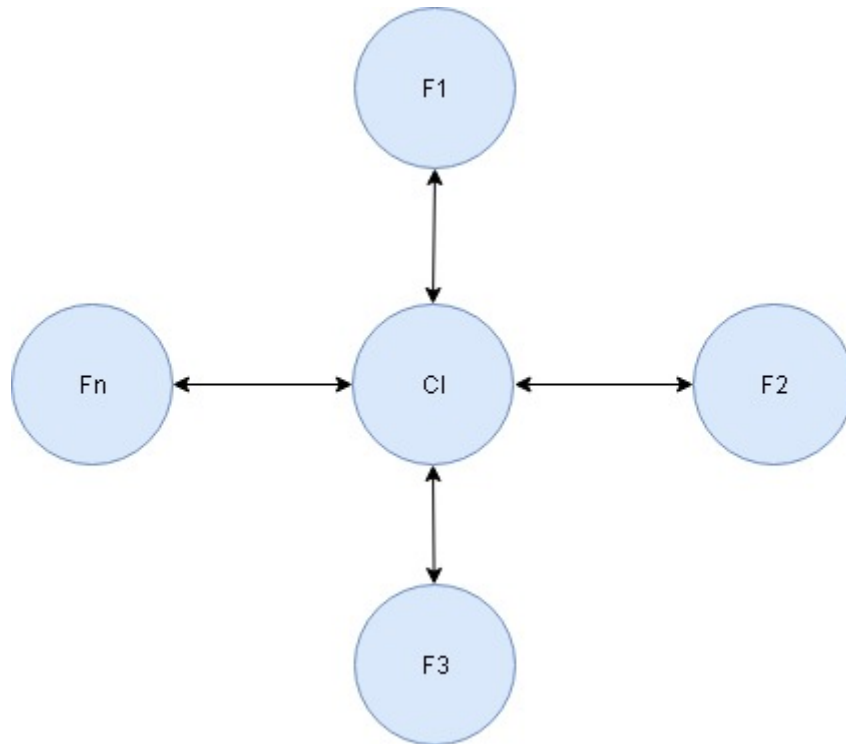

Figure 1 Science Park Organisation (star architecture)

Using organizational architecture as in figure 1, there are four different situations for types of decision-making:

i.   Similar to table 1, number2, incoming innovations are evaluated by CI, and a decision depends on the decision-making quality within the CI, so if quality high $(q_c > 0.75)$ the innovation will be implemented if $((Innov_i - TC_i) > 0)$ resulting in a positive cash flow, otherwise, the innovation is not approved. On the other hand, if CI managers are of average quality, then the innovation will be if $(CI_i > 0.5)$, where *CI_i* represents a random decision made by CI management. See equation 4:

$$b = \begin{cases} \sum_{i=1}^{n} Innov_i - TC_i, \text{if}(q_c > 0.75) \text{ and } (Innov_i - TC_i) > 0) \text{ or } (CI_i > 0.5) \\ b - TC_i, \text{if } (q_c > 0.75 \text{ and } (innov_i - TC_i) < 0) \text{or } (CI_i \leq 0.5) \end{cases} \tag{4}$$

ii.   Incoming innovations are evaluated by both the F manager of the on-cluster firm responsible as well as the CI. In the first case star architecture structure is taken, and the quality of the decision is calculated as the mean of both managers quality, meaning firstly that if the mean quality is below the cut-off point, then an approval of both managers must be obtained, which in turn involves doubling the transaction costs, as given in the following equation 5:

$$b = \begin{cases} \sum_{i=1}^{n} Innov_i - 2 \times TC_i, if \left(\mu(q_c, q_{f \cdot i}) > 0.75 \text{ and } (Innov_i - 2 \times TC_i) > 0) \text{ or } ((d_i > 0.5) \text{and } (CI_i > 0.5)) \right) \\ b - 2 \times TC_i, if \left(\mu(q_c, q_{f \cdot i}) > 0.75 \text{ and } (innov_i - 2 \times TC_i) < 0) \text{or } ((d_i < 0.5) \text{ or } (CI_i < 0.5)) \right) \end{cases} \tag{5}$$

iii.　In the third case, there will be no quality checks. Consequently, implementing any innovation projects approval is done by the CI, and depends on the approval value of the CI, if $(CI_i > 0.5)$, then the innovation will be implemented. Otherwise, it will be rejected. It is assumed that the decision will change between different firms over time. This is summarised in the following equation 6:

$$b = \begin{cases} \sum_{i=1}^{n} Innov_i - TC_i, & if\,(CI_i > 0.5\,) \\ b - TC_i, if\ (CI_i < 0.5) \end{cases} \tag{6}$$

iv.　In the last case, the check is done by both the F managers and CI managers. However, the approval of both managers must be obtained. On the other hand, the transaction cost will be doubled as it needs checking from two managers, and even if the second check would take less time, but two managers will still be involved. This is simulated using the following equation 7:

$$b = \begin{cases} \sum_{i=1}^{n} Innov_i - 2 \times TC_i, if\ ((d_i > 0.5)\,and\,(CI_i > 0.5)) \\ b - 2 \times TC_i, if\ ((d_i < 0.5)\ or\ (CI_i < 0.5)) \end{cases} \tag{7}$$

Next, the different decision-making process situations applied when having a strongly connected STP architecture are discussed

2.3 Closed Network (Strongly connected: Adhocracy and Ambidextrous)

In the third case, the cluster organizational architecture modelled consisted of a closed network (strongly-connected model) organisation where the decision will be discussed between two on-cluster firms making decisions (table 1, number 4) or two on-cluster firms with the CI (table 1, number 5), illustrated in figure 2. The simulations involved:
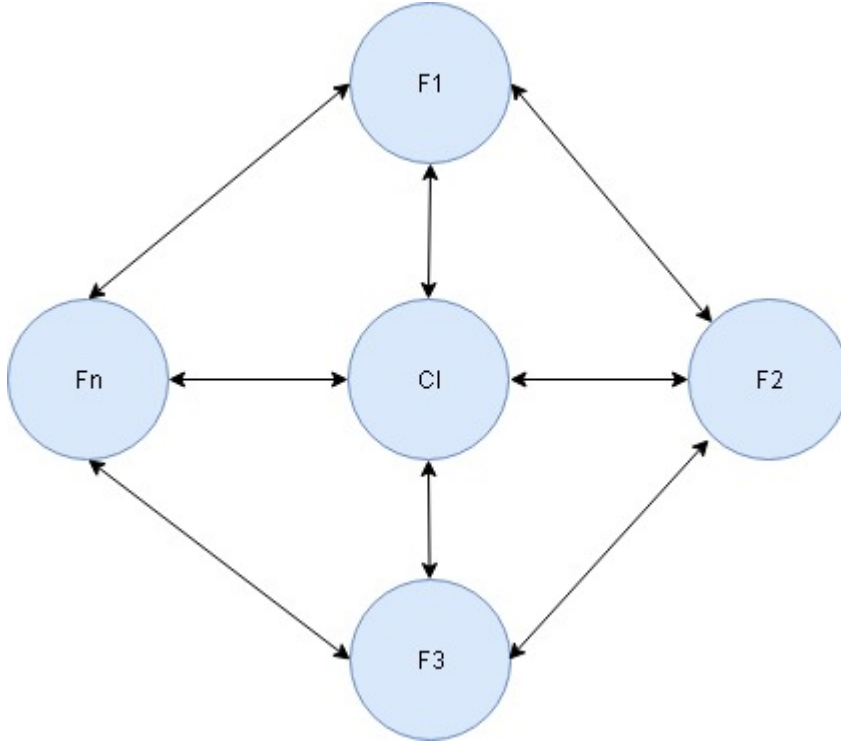
Figure 2 Strongly-connected with CI

i. In the first case, the decision is discussed between the two F managers at F1, and F2 collaboratively (Figure 2). Similar to previous cases, the quality of both F managers is the mean quality of both F managers, and if that exceeds the cut-off point, then they will make the right decision. Otherwise, introducing the innovation will need both managers approval. This is simulated using the following equation 8:

$$b = \begin{cases} \sum_{i=1}^{n} Innov_i - 2 \times TC_i, if\left(\mu(q_{f,i}, q_{f,i})\right) > 0.75 \; and \; (Innov_i - 2 \times TC_i) > 0) \; or \; ((d_i > 0.5) and \; (d_j > 0.5)) \\ b - 2 \times TC_i, if \left(\mu(q_{f,i}, q_{f,i})\right) > 0.75 \; and \; (innov_{ci} - 2 \times TC_i) < 0) or \; ((d_i < 0.5) \; or \; (d_j > 0.5)) \end{cases} \quad (8)$$

ii. The second case controls if the CI is involved in the decision-making process. In that case the quality of the decision will be the mean of the three decision-makers. We chose the mean of the three managers quality in order to obtain comparable results and thus be consistent throughout the simulation. Otherwise, the decision is approved if it gets approved by the three managers. Of course, the check cost (transaction cost) will be different from other cases, however, the assumption is that it will be triple the actual check cost. This is more of a tree hierarchal structure. This case was modelled using the following equation 9:

$$b = \begin{cases} \sum_{i=1}^{n} Innov_i - 3 \times TC_i, if\left(\mu(q_c, q_{f,i}, q_{f,i})\right) > 0.75 \; and \; (Innov_i - 3 \times TC_i) > 0) \; or \; \left((d_i > 0.5) and \; (d_j > 0.5) \; and \; (CI_i > 0.5)\right) \\ b - 3 \times TC_i, if \left(\mu(q_c, q_{f,i}, q_{f,i})\right) > 0.75 \; and \; (innov_i - 3 \times TC_i) < 0) or \; \left((d_i < 0.5) \; or \; (d_j > 0.5)\right) or \; (CI_i < 0.5)) \end{cases} \quad (9)$$

iii. The same cases were then simulated, but without looking into the quality of the decision makers, assuming that decisions are made randomly, which enables us to distinguish between having high quality decision makers and

coin-flipper decision makers in a hierarchal cluster model. Thus, when the decision is discussed between the two F managers at F1, and F2 (Figure 2). Similar to previous cases, to introduce in innovation will need both managers approval. This is simulated using the following equation 10:

$$b = \begin{cases} \sum_{i=1}^{n} Innov_i - 2 \times TC_i, if \ ((d_i > 0.5) and \ (d_j > 0.5)) \\ b - 2 \times TC_i, if \ ((d_i < 0.5) \ or \ (d_j > 0.5)) \end{cases}$$

(10)

iv. Then, it controls if the CI is involved in the decision-making process. In that case the decision is approved if it is accepted by the three managers. Then, the check cost will be triple the actual check cost. This case is modelled using equation 11.

$$b = \begin{cases} \sum_{i=1}^{n} Innov_i - 3 \times TC_i, if \ \left((d_i > 0.5) and \ (d_j > 0.5)\right) and \ (CI_i > 0.5)) \\ b - 3 \times TC_i, if \ \left((d_i < 0.5) \ or \ (d_j < 0.5)\right) or \ (CI_i < 0.5)) \end{cases}$$

(11)

3. Results

3.1 Open Network "Market" architecture

The results presented in Table 3, number 1, illustrate perhaps unsurprisingly that in this case, the best outcomes occur when high-quality decisions are made by firm (F) managers, while random decisions give rise to outcomes that are not as favourable, although the best-case situations do not show significant differences between firms with high-quality F managers and firms which implement any upcoming innovation. Correlation analysis on the quality of decisions showed a moderate correlation of around *0.110 and p-value of less than 0.001*. Thus, the size (number of firms) and the average innovation income from project initiatives (table 3) were compared and found that the size of the cluster does not have any correlation when there is no control at all, not even random 50%. However, it does positively impact overall levels of innovation when F managers exhibit high decision-making quality and is negative when F managers are coin flippers (50:50 outcomes). Table 3 shows the number of simulation iterations (N) and indicates that in the extreme worst case (min values), random decisions are almost as bad as implementing any incoming innovation in the open market situation. However, in best case situation (no check) is almost double that of the random decision case, confirming that random decision-making is good when incoming innovations are poor, but random reduces the total final innovation outcome when innovations are beneficial.

Figures 3, 4 and 5 show the relationship between the number of firms in a cluster and the net innovation income, showing the random relationship between cluster size and net innovation in the absence of quality control (figure 3), while it is negative when decisions are random (figure 5), and positive when quality checks are available (figure 4). Furthermore, table 4 illustrates that average innovation income is the main determinant when there is no quality check, while both the number of firms, as well as the quality of managers, are both positively correlated with the net innovation income when innovations are checked at firm level. On the other hand, the number of firms negatively impact the net innovation income when decisions are made randomly, which in turn has a negative effect on cluster scalability. These results highlight that if an STP accepts any incoming innovation, then the main determinant is the average innovation cash value. But because it is not possible to have good innovations all the time, the implication is that this this unstructured "market" architecture should be avoided.

Table 3 Descriptive Statistics of Different Decision-Making Configuration

Decision making procedure	N	Min	Max	Mean	STD
No Check	5,000.00	-40,798.00	40,180.00	47.42	9,251.95
Check by Firm(with quality control)	5,000.00	-13,014.00	53,329.00	9,608.89	9,455.28
Random Decision by Firm	5,000.00	-46,945.00	23,537.00	-6,268.25	8,536.72

N is number of simulation iteration, Min is the minimum net innovation measured as MU, Max is the maximum net innovation measured as MU, and mean is the mean net innovation measured as MU

Table 4 Pearson Correlation (Open Network architecture)

	No Check	Check by Firm(with quality control)	Random Decision by Firm
Average Innovation	0.656**	0.322**	0.349**
NOF	0.007	0.579**	-0.408**

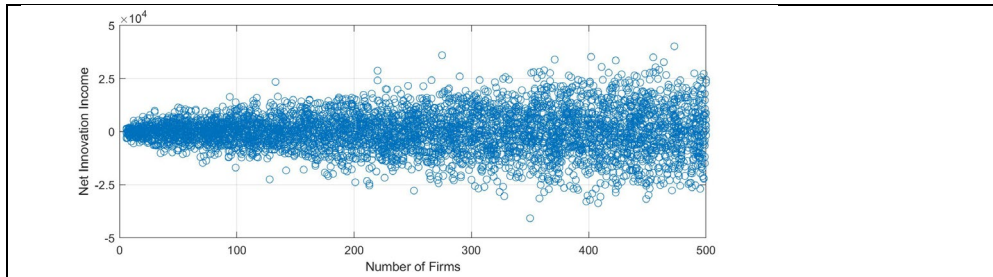** statistically significant at 99% , NOF is Number of Firms

Figure 3: Open Network, firms implementing any incoming innovation VS the number of firms inside the business cluster (equation 1).
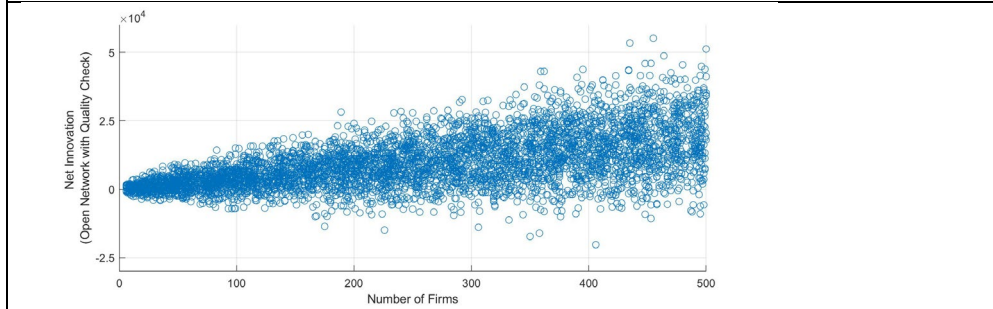

Figure 4: Open Network, Firms implementing incoming innovation based on Firms Managers Quality and Value of the Incoming innovation VS number of firms inside the business cluster (equation 2).
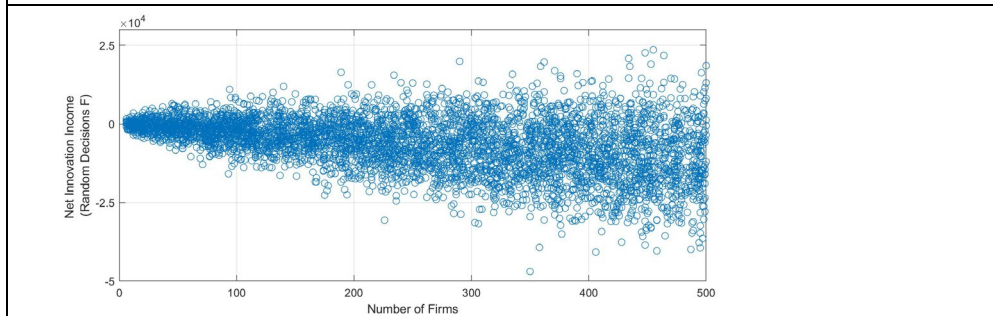

Figure 5: Open Network, Firms implementing incoming innovation based on a random decision made by firms manager VS number of firms inside the business cluster (equation 3).

3.2 Start-up Structure (star architecture)

This section deals with the situations in table 1, numbers 2 and 3, i.e. a "star" start-up structure when a CI is involved. The different cases investigated are:

i.   Decisions are made by CI, and CI quality is checked.
ii.   Random decisions are made by CI management.
iii.   Collaborative decisions are made by CI and F management with quality checks.
iv.   Random collaborative decisions by CI and F management.

Table 5 Descriptive Statistics Star architecture

	N	Min	Max	Mean	STD
Check by CI (with quality control)	5,000.00	-41,352.00	129,583.00	9,839,03	33,080.00

	N	Min	Max	Mean	
Check by CI and Firm (with quality control)	5,000.00	-58,022.00	63,431.00	-4,435.28	15,575.27
Random Decision by CI	5,000.00	-41,352.00	25,242.00	-6,239.06	8,535.59
Random Decision by CI and Firm	5,000.00	-64,590.00	16,571.00	-12,529.71	11,940.63

N is number of simulation iteration, Min is the minimum net innovation measured as MU, Max is the maximum net innovation measured as MU, and mean is the mean net innovation measured as MU

Table 5 presents descriptive statistics of star architecture structure showing that in the worst-case, all decisions making situations are – almost – equivalent. This is because in an environment with many negative innovations even coin-flipping managers avoid expensive mistakes to almost the same extent as discriminating managers do. Best-case occurs when CI managers have a high quality and decide alone, the reason being that collaboration between CI managers and F managers (which is also good) also doubles the transaction costs, thus detracting from the final value.

In order to understand the impact of different factors in each of the decision-making situations, the correlation analysis was controlled between average firms' innovation, average check cost, number of firms and the final net innovation values obtained (table 6).

Table 6 Correlation Analysis Star architecture and Average Innovation,

Check Cost, and Number of Firms

	Average Innovation	Average Check Cost	NOF: Number of Firms
Check by CI (with quality control)	0.075**	-0.130**	0.146**
Check by CI and Firm (with quality control)	0.110**	-0.476**	-0.184**
Random Decision by CI	0.362**	-0.417**	-0.422**
Random Decision by CI and Firm	0.144**	-0.600**	-0.599**

** Statistically significant at 99%

Table 6 shows that in case of random decisions, net innovation is mainly impacted by the number of firms (negatively), average firms' innovation (positive), and check cost (negative). However, in case of decision making with quality check, these factors had mainly moderate to low impact (figures 6-8), and the impact of managerial decision-making on net innovation (in the case of quality check), shows a very strong correlation (the net total innovation 0.744 and the quality of CI managers 0.633), indicating that a major role is played by qualified managers, a finding apparently confirmed when increasing the number of firms (thus also increasing the number of managers). However when

comparing decision-making by the CI only and by the CI and F-managers in the star architecture (where firms communicate over the CI), any positive effect is counteracted by the increased transaction costs; table 6 showing a low negative value. This underlines that in start-up conditions (as well as under conditions of negative innovation environment) the hierarchical star architecture is always most efficient (Al-kfairy et al, 2019a).
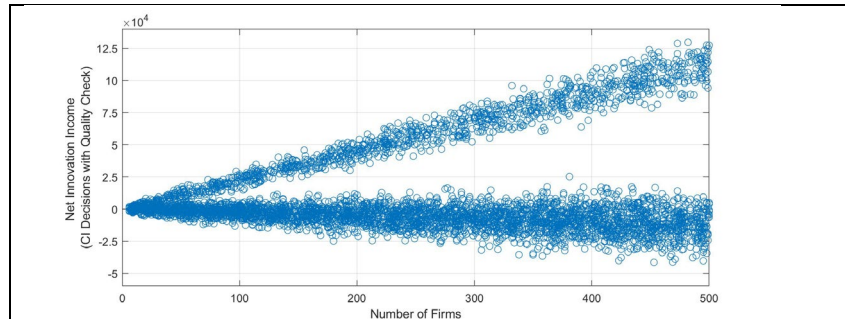

Figure 6: Star architecture, firms implementing incoming innovation based on the CI managers quality of decisions making VS number of firms (equation 4).
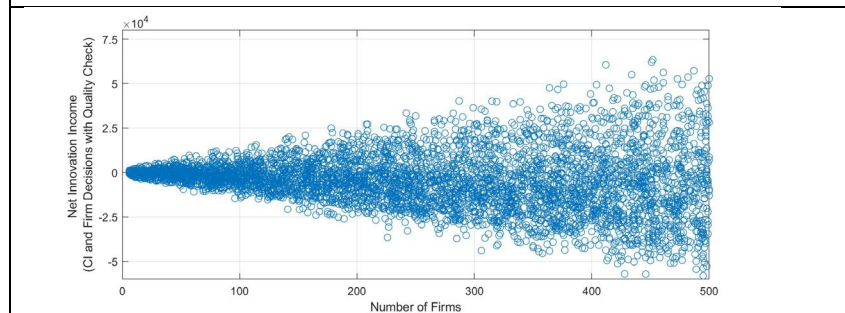

Figure 7: Star architecture, firms implementing innovation based on the quality of its own managers and CI managers VS number of firms (equation 5).
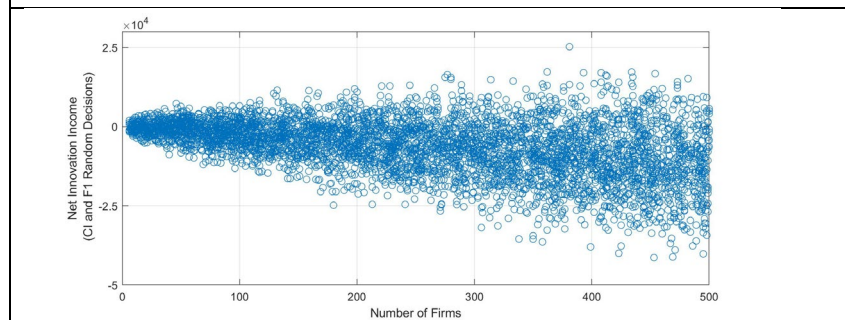

Figure 8: Star architecture, random collaborative decision between CI managers and firms' managers VS number of firms (equation 7).

This indicates, as previously reported (Will et al 2019) that there is little difference between qualified and non-qualified managers in environments with many bad innovations. It also implies there could be scalability issues in the "star" model when expanding the STP, if there is not a concomitant increase in the decision-making quality in the CI.

3.3 Closed Network (Strongly Connected: Adhocracy and Ambidextrous)

In this situation (Table 1, numbers 4 and 5) decision are made by F managers (especially by neighbouring firms in the architecture, representing two networked inhabitants making decisions collaboratively) with and without the CI, and thus the range of alternatives are:

i.   A decision is made jointly between two F managers, where the quality of both F managers is controlled for (table 1, number 1, figure 11).
ii.   A random decision is made by two F managers (table 1, number 1, figure 12).
iii.   A random decision is made by CI managers together with two neighbouring F managers (table 1, number 5, figure 10).
iv.   A decision is made between two firms collaboratively with CI managers with quality checks (table 1, number 5, figure 9).

Results are presented in table 7 which shows that in the worst cases situations, the values for the minimum net innovation values (the column named "min" in table 7) are approximately similar, for example the difference between decisions made by qualified F managers (two firms), and non-qualified F managers (two firms), is not very high, around 10,000. Conversely the difference between ambidextrous organisation with qualified managers and random decision makers is around 5,000, indicating clearly that in the worst-case situation, more hierarchies will reduce the difference between qualified "good" managers and random decision makers.

Moving on from the worst-case situations there is a perhaps unsurprising gain from having qualified F managers and CI managers, even though the transaction costs will be doubled when CI is involved together with F managers (with quality check) nevertheless it is under these conditions that the value gain is highest. This represents the "ambidextrous" situation (table 1, number 5) and would be the preferred situation during times of expansion and scaling up the STP not only because the higher quality of decision-making will better shape the selection and intake of new innovative firms, but also because it would spread the use of resources and help prevent over-straining the CI. In more detail; figures 9-12 show the negative impact of growing the STP (this effect is due to the increasing transaction costs) however this negative tendency diminishes when quality control is added (figures 9 and 11).

Table 7 Descriptive Statistics Strongly-Connected architecture

	N	Min	Max	Mean	STD
Check by Two Firms (with quality control)	5,000.00	-46,757.00	28,682.00	-4,684.05	10,091.34
Check by Two Firms and CI (with quality control)	5,000.00	-80,394.00	54,878.00	-11,835.29	17,305.20
Check by Two Firms (without quality control)	5,000.00	-59,252.00	14,974.00	-12,584.96	11,877.17

Random Decision by Two Firms and CI	5,000.00	-84,959.00	13,495.00	-18,768.45	16,767.01

N is number of simulation iteration, Min is the minimum net innovation measured as MU, Max is the maximum net innovation measured as MU, and mean is the mean net innovation measured as MU

Table 7 leads to our current working hypothesis; that during an initial stage, the CI of start-up STPs must choose very innovative new inhabitants both to build the STP and to replace "churned" inhabitants. Mistakes in this stage incur modest costs. Ideally, this innovative base attracts larger firms and the managers of these larger firms can help the CI to make correct decisions. If the STP cannot attract larger firms with experienced management, then the CI will continue alone but, especially under conditions of growth and expansion, the cost of poor decisions will increase until eventual market failure ensues. Future research could investigate this hypothesis using panel data in STPs a various stages of development.
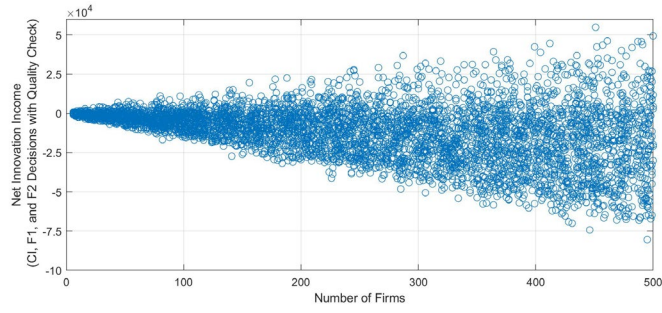
Figure 9: Ambidextrous Organisation, (F1, F2, and CI) collaborative decision making with quality check VS number of firms (equation 9).
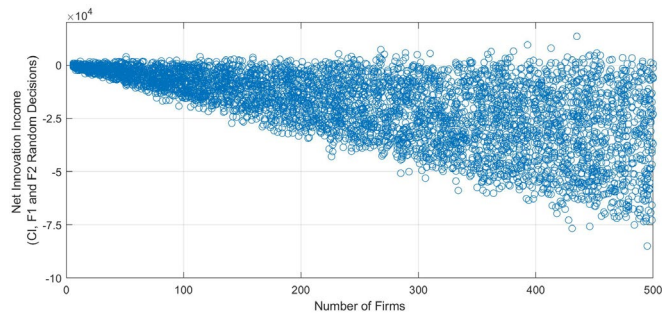

Figure 10: Ambidextrous Organisation, Random collaborative decision by (F1,F2, and CI) VS number of firms (equation 11).
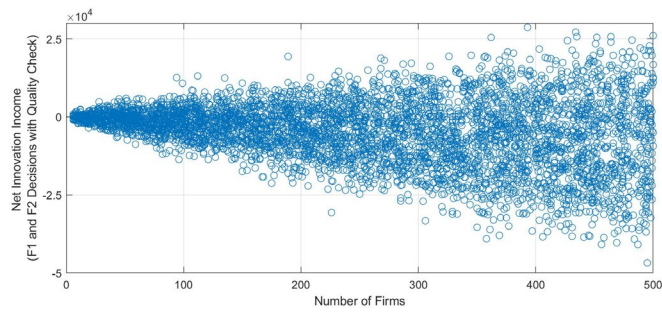

Figure 11: Ambidextrous Organisation, Collaborative decisions of (F1 and F2) with quality check VS number of firms (equation 8).
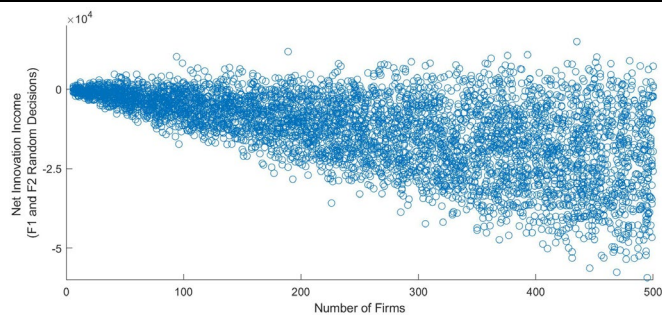

Figure 12: Ambidextrous Organisation, Collaborative random decisions of (F1 and F2) VS number of firms (equation 10).

3.4 Comparing Different Cluster Architectures

Sections 3.1 – 3.3 discussed simulation results obtained by using different STP architectures under different decision-making conditions and best-case results are shown in table 8.

Table 8 Best Cases in all three architectures

Architecture	Best Case	Optimal NOFs	Optimal Check Cost	Optimal Average Innovation Income	Net Innovation
Open Network	Checked by Firm with Quality Control	314.00	5.16	49.12	53,329.00
Star architecture	Check by CI (with quality control)	482.00	1.48	33.41	132,316.00
Strongly Connected architecture	Check by Two Firms and CI (with quality control)	451.00	2.03	36.96	54,878.00

NOF is Number of Firms

Table 8 presents the best cases in all the three different STP structures combined with the optimal number of firms, innovation income and check cost. It shows that the best outcomes occur when there is a quality check at either F or CI level. Table 8 indicates that the star architecture structure is the best for achieving the highest return on incoming innovations, which is because of lower costs, i.e. a lower average innovation can achieve higher returns when decisions are centralized, although this may break down when the STP becomes significantly larger and, in agreement with the results of Al-kfairy et al (2019a) the strongly connected architecture model would be advantageous at this point.

A comparison of different cluster architectures under worst-case conditions is shown in table 9. This confirms that all worst-case situations occur when decisions are randomly made, and average income is quite low. The most damaging situation is encountered when innovations of low average value encounter an open (market) network architecture, which allows harmful innovations to proliferate without any embargo from the CI. Overall in the two other architectures the least-worst case is when innovation approval is happening at F level with qualified F managers and the worst-worst case when random decisions are made at the three levels (two F and CI), which is due to increased decision costs.

Table9: Worst Cases in Three Topologies

Architecture	Worst Case	NOFs	Check Cost	Average Innovation Income	Net Innovation
Open Network	Random Decision by Firm	350.00	35.20	-116.57	-46,945.00
Star architecture	Random Decision by CI and Firm	495.00	49.86	-0.53	-64,590.00
Strongly Connected architecture	Random Decision by Two Firms and CI	495.00	49.86	-0.53	-84,959.00

NOF is Number of Firms

4. Discussion

This study complements previous studies focused on the role of networking in innovation development and knowledge spill-over (Cowan et al., 2007; Bathelt et al., 2004; Bell, 2005; Zhang et al., 2017), and studies on the role of CI management e.g. (Ruiz et al., 2017; Klofsten et al., 2015; Sotarauta, 2010). However, as Nobel laureate Joseph Stiglitz points out, it is organizational architecture via decision-making that determines organizational profitability (e.g. Sah and Stiglitz, 1985). Thus, we go further by adding the dimension of organizational architecture into the debate, as well as exploring the quality of decision-makers at both F and CI levels under regimes that include differing innovation environments.

Three different types of architectures: open (market), star (hierarchy), and closed strong (adhocracy, ambidextrous) architectures (see Cowan et al., 2007) were investigated and the results are broadly in agreement with previous studies. An open (market) model may for example include property-related services like the provision of infrastructure and most commonly utilized services (Salvador, 2011) encompassing conference and meeting rooms, restaurant and cafeteria, as well as more specialised facilities e.g. biowaste incinerator and chemical storage, where appropriate (Rowe, 2014). In this "top-down" structure barriers to entry are low, poor-fit firms can inhabit the STP and "bad" innovations can abound unchecked. Furthermore, the decentralised nature of decision-making in this architecture increases transaction costs. This situation may benefit from establishing a CI with a clear vision for the future direction for the STP.

The star (hierarchy) and closed strong (adhocracy, ambidextrous) models both contain a strong CI: The results presented here underline the crucial role played by the CI in sustaining and developing an STP at the start-up stage and into early maturity. However, where this study differs from others is that the results presented here indicate that achieving a mature successful STP is not by a simple linear progression from earlier forms, rather they are different developmental trajectories that are pre-determined early on by the form of corporate organizational architecture chosen.

Clearly one starting point could be a costly large project, probably state-supported and, especially if large firms can be persuaded to participate, then a closed strong model may predominate and be successful. However, as Ernst and Young (2017) point out, this is a risky strategy because of many unknowns including that the size of the catchment area, in terms of potential inhabitants, is a large research gap, as are other important but unknown factors e.g. what are acceptable churn rates amongst inhabitants?

Another situation is a new small start-up STP containing small and micro-firms, and in this case the star (hierarchy) architecture is most suitable in early stages due to low transaction costs (Al-kfairy 2019a). Under certain circumstances this model can progress to an ambidextrous model, but star hierarchy should be retained in environments where the catchment is modest and high growth cannot be expected (table 7). Although these analyses support the views of (Chen et al., 2006; Albahari, 2015; Albahari et al., 2016) in that the quality of the CI management team can be positively related to STP performance, the results underline that a CI is also of benefit where the quality of CI decision-making is poor and the environment has relatively few suitable innovations or many poor-fit potential inhabitants, indeed table 2 shows a precarious situation where losses can be incurred even in steady-state, so the CI in star hierarchy could be especially important in a situation where the STP is a start-up and the on-cluster firms are also inexperienced start-ups.

In an analysis of a large mature STP, Al-kfairy et al. (2019b) observed that part of the STP demographic consists of micro-firms and many of these leave the STP after 4-5 years, and also a tendency for firms achieving a size of 100-120 employees to leave after 15-17 years, so

STPs do indeed need to continually choose new inhabitants both for corporate performance but also – more importantly – to refresh the innovation base of the whole cluster and avoid "lock in" with old technology. Choosing new innovative inhabitants is inherently risky. The results presented show that concepts of "business ambidexterity" (see Benner and Tushman, 2003; Benner and Tushman, 2015; and O'Reilly III and Tushman, 2013), can be extended to clusters of firms, in this case STPs. However, there are unexpected differences between STPs and single organizations: Will et al. (2019) showed that for spreading innovations inside a single organization, multiple layers of F managers making decisions at close to coin-flipping (50:50) efficiency were still beneficial because at each decision round, moving up the hierarchy, 50% of expensive "bad" innovations were removed. In contrast, in the STP case, increasing the number of hierarchies showed a negative impact even when decision-making was good at both CI and F levels, and this is due to increased transaction costs negating the advantage gained. Put simply, a firm co-locating to an STP entails a larger slice of costs than departmental decisions inside a firm. Ambidexterity, however, still has a place as the STP develops and strong inter-firm connections are formed, whereupon ambidextrous decision-making can be shared between the CI and others, and this has a knock-on effect that the CI can remain compact and cost-competitive as the STP reaches full maturity. To reach this outcome the CI can include those managers at F level who are experienced and skilful decision-makers and this, in turn, underlines the importance of STPs of attracting large firms. Start-up STPs are ideally filled with innovative small firms and this situation (at an appropriate stage) can attract larger firms that do not want to miss out on these new innovations (perhaps by acquiring the aforesaid small innovative firms) and future research can investigate this using e.g. panel data from STPs in these early stages. Managers in the CI have their routine tasks to do and may well not be aware of latest technologies and specialised market trends. Larger firms can contribute experienced F managers (presumably technically qualified and forward-thinking) who can co-operate with the CI in making decisions. The tipping point is where the benefits from improved decision-making intersect with or exceed the increased transaction costs and consequently at this stage the structure of the STP moves to a growth-oriented form; a strong ambidextrous architecture with a CI at the centre encouraging valuable networking (Mellor, 2014b). The results presented here indicate however that the most valuable ratio includes the CI and only any two of the larger firms; including more will drive the transaction costs up exponentially.

In conclusion, the timing of the transition from the star architecture to ambidextrous will be fraught, and from the overview presented in the introduction to this paper, only one in five STPs will achieve this situation. Those not able to do so can survive longest with a strong CI star hierarchy, because this should enable them to avoid 50% of harmful innovations.

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