Understanding the Inputs into Innovation:

Do Cities Substitute for Internal Firm Resources?

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1. Introduction

Innovation does not arise by accident. Firms choose to develop resources and processes to facilitate innovation (e.g., Cohen and Levinthal, 1990; Åstebro, 2002). Geographic location also plays an important role (e.g., Griliches, 1957). Prior work has demonstrated evidence of localization in innovation (Jaffe, Trajtenberg, and Henderson, 1993), suggesting that a propitious location may lower the costs of innovative output (Furman et al., 2005). It is widely assumed that such concerns have motivated firms in information technology (IT) hardware, software, and pharmaceuticals to cluster together (e.g., Saxenian, 1996; Bresnahan and Gambardella, 2004).

There is less understanding of the tradeoff between location and internal resources for investment in process innovation. In particular, there is little empirical evidence on the extent of localization of substitution between internal (firm) resources and purchased external (local) inputs into innovation. This is a surprising gap in understanding. If firms can innovate in their operations by substituting away from internal resources when they locate in areas such as cities, where purchased services are more readily available, then agglomeration will be most important for smaller firms with fewer internal resources. Alternatively, if firms with rich internal resources use them to invest in process innovations, then locating in lower-density areas may have little effect on their ability to innovate.

We examine these trade-offs in a model of process innovation. In this model, establishments face an opportunity cost from redirecting resources to innovation that would otherwise be used for operations. We label these resources "capabilities." Establishments choose what fraction of their existing capabilities to dedicate to a new innovative investment and how many other inputs they should purchase from market suppliers. In this model, location shapes the cost of purchasing services for innovative activity. Firms in good locations can access local markets when they invest in a process innovation, even when they lack internal expertise. Alternatively, if a firm has rich internal expertise, it can innovate without accessing local markets.

We then develop hypotheses derived from this model. We compare these hypotheses with actual investment in an Internet-based process innovation in a large cross-section of U.S. establishments at different locations.

We focus on the largest investors in IT in the United States, a sample that contains considerable heterogeneity in the dimensions of interest. Specifically, we analyze a survey (conducted by Harte Hanks) of use of advanced Internet technologies at 86,879 establishments that had over 100 employees at the end of 2000. This sample consists of established firms rather than start-ups, which allows us to treat establishment location as determined prior to the decision to invest in Internet technologies. Approximately two-thirds of the U.S. workforce is employed in this type of establishment. Most of the organizations in the sample have *some* experience with basic IT technologies, such as personal computers (PCs), but they differ

tremendously in their capacity to manage large IT projects. Only a fraction of these establishments have extensive experience with advanced IT projects. The data contain detailed information about establishment-level IT personnel and infrastructure assets. Because 45,948 establishments come from one of 7,035 multi-establishment organizations, they also vary in their potential to move assets between establishments. Furthermore, establishments come from all over the United States, both major urban areas and isolated rural locations, so they vary in their potential to hire from local labor and service markets.

We show that establishments that are part of firms with greater internal capabilities invest in an Internet-based process innovation more frequently. Furthermore, we provide evidence that establishments in large cities behave as if they draw on local resources to invest in process innovation. Establishments act as if these inputs into innovation are partial substitutes for each other. Establishments also act as if they substitute internal capabilities located at other establishments in the same firm for those available locally. We infer that the marginal contribution of internal resources to innovation is lower in cities than in other areas. We also infer that firms that can draw on rich internal resources can innovate outside of cities. We find no evidence that internal and external resources are complements in process innovation.

Our paper advances the existing literature on the role of capabilities in innovation. First, we provide empirical evidence on the determinants of process innovation related directly to operations. Almost all prior research about the inputs into innovation has employed different measures of innovation inputs or outputs, such as patent citations or patent output (e.g., Singh, 2004). Second, we test our model on a large cross-section of industries and locations. Prior empirical studies of the role of resources in process innovation focus on case studies of a narrower set of industries and locations (e.g., Kelley and Helper, 1999; Henderson, 2003). Third, we develop and test a model of investment in process innovation that rationalizes observed patterns without assuming any unmeasured information spillovers or firm networks. Fourth, our modeling approach links more closely with issues common in estimation of cost functions and production functions rather than the identification of rank, order and stock effects, as is more common in other analyses of new information technology adoption, such as CAD and CAM (e.g., Åstebro, 2002; Karshenas and Stoneman, 1993).

The emphasis in our research and our conclusion contrasts with much of the existing literature on the role of internal expertise in research and development activities (e.g., Arora and Gambardella, 1994; Cassiman and Veugelers, 2006). This literature argues that internal expertise complements the external stock of knowledge. We begin from the opposite premise, that external (local) expertise substitutes for internal expertise during innovative investments, i.e. there is localization of substitution between internal and external inputs into innovation. We find evidence consistent with our premises. In contrast to prior research on localization of innovation (e.g., Porter 1998), we conclude that highly capable firms do not necessarily need to locate in agglomerated areas or clusters to successfully innovate. Capable firms also

may locate in more isolated regions and still, nonetheless, innovate at low cost. Firms without such capabilities, however, will face different concerns when they innovate, and, for purposes of innovating, may benefit from locating near other firms that also innovate.

2. Conceptual Framework and Hypotheses

We consider a simple model of investment in an innovation. The firm has an existing production process it intends to improve with a one-time project. We use this model to develop empirically relevant hypotheses.

We posit a process determining the value of undertaking investment in WEI technologies, where this value is observed by the decision makers in the establishment and not by the researcher. We define

(1) $$Y = \overline{B} - \overline{C}$$

where Y is a latent variable for net benefits, $\overline{B}$ is the gross benefit of undertaking the investment, and $\overline{C}$ is the total cost. We let

$$\overline{B} = B(ec, oc, ps, me, x, t) + u^B$$

$$\overline{C} = C(\frac{ec}{EC}, \frac{oc}{OC}, me, x, t) + ps * c(z) + u^C .$$

Where *B()* is the gross benefit of the investment without the establishment-specific random benefit variable, u^B; *C()* is the total cost of the investment without the establishment-specific random cost variable, u^C; *ec* represents the establishment's internal capabilities invested in the project; *oc* represents the capabilities at *other* establishments within the same firm invested in the project; *ps* represents purchased services from local markets used for the project; *EC* represents the total available establishment capabilities; and *OC* represents the total available capabilities of the organization at other establishments within the same firm We define $u=u^B-u^C$, assume that $u \sim N(0,\sigma^2)$, and rewrite equation (1) as a probit model (David, 1969; Karshenas and Stoneman, 1993):

(2) $$Y(ec, oc, ps, EC, OC, z, me, x, t) = B(ec, oc, ps, me, x, t) - C(\frac{ec}{EC}, \frac{oc}{OC}, me, x, t) - ps * c(z) + u$$

We use this model to derive several hypotheses. Our measure of process innovation is Within Establishment Internet. Our core hypotheses on the substitution between inputs to innovation are:

Hypothesis 3a: The sensitivity of WEI (Internet) investment to increases in location size will be declining as the internal organizational capabilities found in other establishments within the same firm increase.

Hypothesis 3b: The sensitivity of WEI (Internet) investment to increases in location size will be declining as the internal establishment capabilities increase.

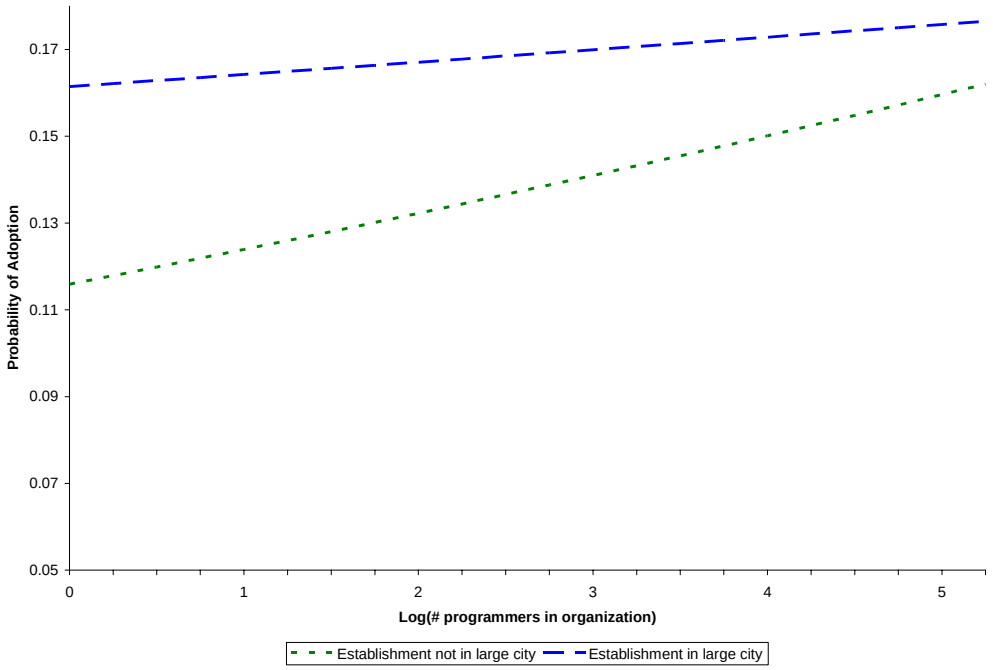
Hypothesis 4: Establishment capability and organizational capability are substitutes.

3. Results

Figure 1 presents a view of the main results. It presents the predicted probabilities of investing in WEI using the results from our baseline regression model under different combinations of location size and internal capabilities. In this figure, we use the log of programmers as our measure of internal capabilities; results using our composite measure of capabilities are qualitatively similar. This figure presents the results for organizational capabilities, the results for establishment capabilities are qualitatively similar. Figure 1 shows that establishments located in sizeable metropolitan statistical areas (MSAs) have a greater likelihood of WEI investment. Moreover, Figure 1 shows that the probability of action increases as organizational capabilities increase, whether or not the establishment is in a sizeable MSA .

Figure 1 also demonstrates how the prediction of Hypothesis 3a shapes behavior: The curve depicting establishments in sizeable MSAs is flatter than that for other establishments. The marginal impact of increasing organizational capabilities is lower for organizations in sizeable MSAs. Changing from low to average capabilities increases the probability of investing in WEI by 1.5 percentage points for establishments in low-density areas, and increases the probability by 0.5 percentage points for establishments in sizeable MSAs. Organizational capabilities, however, are unable to completely substitute for the benefits of an urban location.

Figure 1: Probability of Adoption by Organizational Capabilities



We computed a similar figure for establishment capabilities. Overall, our results for establishment and organizational capabilities suggest that internal capabilities are substitutes for cities when investing in complex technologies. Yet, they also suggest that internal establishment capabilities are more effective at lowering costs than are organizational capabilities.

We also present evidence that establishment and organizational capabilities are substitutes (Hypothesis 4). No matter how we measure capabilities, the interaction between organizational and establishment capabilities is negative and significant at the one-percent level. An increase in the log of organization programmers by one standard deviation will decrease the marginal effect of establishment capabilities by 0.89 percentage points when establishment capabilities are at mean values.

We also run a number of robustness checks. We use instrumental variables to explore our exogeneity assumptions relating to location and capability. We explore different definitions of location size and investment decision. We examine whether our results are driven by industry competition, and examine whether our results apply to both services and manufacturing.

4. Conclusions

In this study, we find extensive statistical evidence of localization of substitution between internal and external inputs into innovation. We show that establishments located in large urban areas innovate as if they face fewer constraints and have lower costs. We also find a symmetric role for internal capabilities: establishments that are in firms with a greater number of IT personnel invested in WEI technology more frequently, as did those with prior experience with related non-Internet applications. Overall, we conclude that the marginal contribution of internal capabilities to investment and co-invention in a process innovation is lower for establishments in cities than for establishments elsewhere.

More generally, we find that establishments engaged in co-inventive activity draw upon a variety of resources: internal establishment capabilities, internal organizational capabilities, and external purchased services. We provide a framework for measuring the contribution of each of these channels to new process innovation. In contrast to prior work, we find that all of these channels are substitutes for one another as inputs into innovative investment.

5. References

All references and a copy of the full paper are available at http://www.andrew.cmu.edu/user/cforman/localizationsubstitution.pdf.