REGIONAL ECONOMIC CONTEXT & THE VALUE OF FIRM-LEVEL IT INVESTMENTS

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1. Introduction

To understand whether regional economic and technological environments impact the value of firms' IT investments, we examine a unique panel of IT implementations and firm productivity and performance in a sample of 211 Italian firms over 17 years. By studying the Italian context, which exhibits substantial regional heterogeneity in economic development, the quality of human resources and the strength of IT infrastructures, we are able to estimate the degree to which local economic and technological resources are complements or substitutes for firms' internal IT investments. We examine two competing hypotheses concerning the impact of regional economic context on the value of firm level IT investments. On one hand, strong local human resources and IT infrastructures may complement firms' internal IT investments by providing access to high quality labor or improving the speed and reliability with which internally organized data is shared with suppliers, partners and customers. On the other hand, IT investments made in regions with weak human resource pools and poor technological infrastructure could compensate for firms' lack of access to high quality human, economic and technological capital in the local environment. Our results demonstrate that the marginal contribution of new IT implementations to productivity is lower for firms located in regions with strong human capital and technological infrastructures. These results suggest that firms compensate for a lack of local resources with internal IT investments and that local resources and internal IT investments are partial substitutes. They also replicate estimates of the returns to enterprise systems, which have to date been derived primarily from samples of US firms, in an international context.

2. Theory

2.1. IT & Productivity

Since the early 1990's, firm-level evidence has demonstrated productivity and performance premiums for IT-intensive firms (Brynjolfsson & Hitt 1996), and substantial variation in the returns to IT across firms with the same level of IT investment (Hitt & Brynjolfsson 1995). These results have inspired a stream of research testing alternative explanations for variation in the returns to IT spending including firm heterogeneity (Hitt & Brynjolfsson 1995), investments in intangible assets (Brynjolfsson & Yang 1997) and organizational capital (Aral & Weill 2007). We extend this inquiry to include a new explanation for variance in returns to IT investment: heterogeneity in the regional economic and technical environments in which firms operate. We ask: Does a firm's local context impact the value of their IT investments? Is regional economic and technical development a compliment or a substitute for firms' internal IT resources?

2.2. Regional Economic Context

A number of empirical studies have demonstrated a positive relationship between local economic conditions (e.g. public capital accumulation, investments in technology infrastructures, human resource pools) and total factor productivity (e.g. Aschauer 1989). However, while prior estimates demonstrate differences in marginal factor productivity and positive output elasticities for investments in public capital across countries (Munnell 1990), estimates across regions within countries typically show no marginal effects due to a lack of regional heterogeneity (Evans & Karras 1994, Holtz-Eakin 1994). Italy, on the other hand, is characterized by substantial regional heterogeneity in total factor productivity,[1] public capital accumulation, technical infrastructures and the supply of quality human capital (Putnam 1993, Destefanis & Sena 2005). Recent literature addresses how these local economic and technical conditions can affect firms' internal IT investment choices (Forman et. al. 2006), innovation costs (Furman et. al. 2005), and performance outcomes (Jaffe et. al. 1993). Two competing hypotheses exist. On one hand, internal and external resources may be complements (Arora & Gambardella 1994), particularly in

[1] The gap in Total Factor Productivity between the Mezzogiorno and the rest of Italy has averaged 23% since 1970.

technology clusters (Saxenian 1996). On the other hand, firms may substitute internal IT investments for local resources (Forman et. al. 2006). We examine these competing hypotheses directly by analyzing a national context with substantial regional heterogeneity. Rather than estimating adoption decisions, we analyze whether internal IT investments and local resources are complements or substitutes by examining the impact of their co-presence on firm productivity and performance.

2.3. The Value of Enterprise Systems

Our research also contributes directly to a growing literature on the returns to enterprise systems investments (e.g. Hitt et. al. 2002, McAfee 2002, Aral et. al. 2006). While evidence on the returns to ERP is currently U.S.-centric, there is evidence that differences in managerial practices and organizational characteristics make returns to IT investments in the U.S. unique (Bloom et. al. 2007). We therefore replicate current enterprise systems analyses in Italian firms to see if the returns are comparable to those observed in the U.S.

3. Empirical Methods

3.1. Data

We collected data on the Enterprise Resource Planning (ERP) installation and go-live decisions of 904 Italian firms from 1989 to 2005 from the sales database of a large ERP vendor. Through case studies and interviews, we grouped modules that represent ERP and used factor analysis to verify our grouping. We then matched ERP adoption to a comprehensive financial database containing performance data for all publicly traded Italian firms. As many Italian firms are not publicly traded, 211 of our 904 firms were matched, creating a panel of 211 firms over 17 years.

We collected data on 26 regional characteristics for all 20 Italian regions from 1989 to 2005, including GNP, assessments of human resources such as the number of technology graduates and the number of R&D personnel, and IT infrastructure data such as PC penetration, firm-level Internet penetration, and broadband penetration.

Table 1: Descriptive Statistics					
Variable	Obs.	Mean	Std. Dev	Min	Max
Firm Characteristics					
Revenues (MM$)	2175	1138.258	3695.252	0	4.75E+04
Employee (M)	2129	3954.519	14932.71	0	183488
Fixed Asset (PPE) (MM$)	2175	2154.680	3.72E+04	0	1.23E+06
Total Asset (MM$)	2175	3366.402	5.22E+04	1.699	1.73E+06
Total Debt (MM$)	2175	1483.121	1.73E+04	0	5.80E+06
Cogs (MM$)	2175	712.9008	3078.603	-4626.432	4.15E+04
Book Value (MM$)	2175	1544.551	3.21E+04	-146.092	1.07E+06
Pretax Income (M$)	2175	42928.61	382156.7	-6094949	4247393
Region Characteristics					
Tech graduates	3408	36.03941	7.816024	4.161248	71.777
R&D personnel	3424	3.256631	1.205333	0	6.3789
Public R&D	3424	0.4720886	0.349639	0	1.53394
Private R&D	3424	0.6953072	0.350898	0	1.45536
Patent	3410	87.41558	49.17401	0.608287	191.2891
Internet Penetration	2140	14.56674	13.18044	0.221919	37.73586
PC Penetration	3424	80.94173	11.42919	56.74383	99.62972
Firm Internet Penetration	2140	11.33762	9.876104	0.131559	34.16034
Broadband Penetration	1712	17.89894	18.10903	0.647812	64.44025
GNP	3424	126159.2	74652.42	1781.363	263218.2
MM = Millions, MM$ = Millions of Dollars, M = Thousands, M$ = Thousands of Dollar					

3.2. Statistical Specifications

Following Hitt et al. (2002) (HWZ) and Aral et al. (2006) (ABW), we tested the relationship between enterprise systems adoption and various measures of financial performance using the following general estimating equation:

$$\log(\text{Performance Numerator}) = \alpha + \beta_1 \log(\text{Performance Denominator}) + \beta_2 \text{ Adoption} + \sum \text{Region} + \sum \text{Year} + \sum \text{Industry} + \varepsilon \quad [1]$$

The performance estimation uses ratios that measure labor productivity and intermediate operational measures such as inventory turnover and asset utilization.[2] We controlled for transitory shocks by including a dummy variable for each year and industry controls for 15 industry groupings. We then tested the productivity effects of ERP adoption using a traditional Cobb-Douglas specification, as in equation 2:

$$\log(VA) = \alpha + \beta_1 \log K + \beta_2 \log L + \beta_3 \text{ Adoption} + \sum \text{Region} \sum \text{Year} + \sum \text{Industry} + \varepsilon \quad [2]$$

We then add variables measuring specific regional characteristics and their interactions with ERP adoption:

[2] We estimate the numerator of the performance ratio as the dependent variable and the denominator as a control variable on the right hand side: $\log(A) = \alpha + \beta_1 \log(B) + \text{controls}$. This specification is based on the property that $\log(A/B) = \log(A) - \log(B)$. Putting the denominator on the right hand side allows us to estimate coefficients that may differ from unity.

$$\log(\text{Performance Numerator}) = \alpha + \beta_1 \log(\text{Performance Denominator}) + \beta_2 \text{ Adoption} + \beta_3 \text{ Region Char.} + \beta_4 \text{ RegionCharXERP} + \sum\text{Region} + \sum \text{Year} + \sum \text{Industry} + \varepsilon \quad [3]$$

$$\log(VA) = \alpha + \beta_1 \log K + \beta_2 \log L + \beta_3 \text{ Adoption} + \beta_4 \text{ Region Char.} + \beta_5 \text{ RegionCharXERP} + \sum \text{Region} + \sum \text{Year} + \sum \text{Industry} + \varepsilon \quad [4]$$

3.3. Identification

Several possible sources of endogeneity may exist in this context. First, ERP adoption may be endogenous. Exogenous shocks to productivity or output could inspire ERP adoption, and unobserved heterogeneity could simultaneously drive both ERP adoption and productivity. To address this, we follow Aral et. al. (2006) and separately estimate ERP installation and ERP go-live events. If firm performance is correlated with ERP use, but uncorrelated with installation, then we can reasonably assume that the relationship with performance is not being driven (at least primarily) by the simultaneous determination of adoption and performance. Second, there may be two possible sources of endogeneity in regional characteristics and the relationship between regional characteristics and IT adoption. There may be time-invariant characteristics of regions which we do not observe but which could simultaneously drive productivity and public capital accumulation in technological infrastructures or human resources, such as the general quality of political institutions or politicians. Exogenous shocks to productivity in a region could also inspire increases in public expenditure on infrastructure, technical education or R&D institutions. To address the first issue, we include regional fixed effects, which have been shown to be more effective than instrumental variables in addressing this type of endogeneity (Hausman & Taylor 1981). We also estimate a 2SLS specification using the aggregate regional characteristics of firms in the same industry but in different regions as instruments (akin to Forman et. al. 2006). Firms in the same industry may have similar local environmental needs and thus locate in regions with similar regional characteristics on average. However, the regional characteristics of one regional should have a negligible

direct effect on the output elasticity of public capital accumulation in other regions.[3] We control for time varying exogenous shocks by including dummy variables for each year in our panel.[4] We conduct specification tests to determine the extent to which these sources of endogeneity could bias our results. As our specification tests indicate and as previous work has shown in the Italian case (e.g. Bonaglia 2000), the endogeneity of regional characteristics is not a significant problem and OLS with regional fixed effects and other specifications that control for specific regional characteristics are preferred to our instrumental variables approaches.

4. Results

We first replicated estimates of returns to ERP in the Italian context and compared them to the established results from U.S. data. The results for labor productivity are comparable, with ERP use associated with a 10% increase in labor productivity on average, compared with a 17% percent average increase in the U.S. between 1986 and 1998, and a 7% average increase in the U.S. between 1998 and 2005. These results reflect the relative timing of ERP adoption in Italy and may be due in part to changes in ERP systems over time. 65% of the firms in the Italian sample adopt ERP after 1998, and the parameter estimate of ERP Go-live is small and insignificant prior to 1998 (β = -.0069 SE = 0.082) and larger and significant after 1998 (β = .136** SE = 0.062). Interestingly, for Italian firms, ERP is associated on average with a 10% increase in value added in traditional Cobb-Douglas specifications. These results seem to suggest that the primary productivity enhancement provided by ERP use in Italy is through its effects on labor productivity. Surprisingly, ERP use does not correlate with improvements in inventory turnover in the Italian context, while U.S. firms experience significant inventory efficiencies. Italian firms on average experience a 9% increase in asset utilization associated with ERP use. These results also replicate evidence of a causal relationship between ERP investments and productivity. While ERP go-live

3 While this instrument follows a similar logic to the one used by Forman et. al. (2006), we note the possibility that it is not strictly exogenous as there may be macro economic shocks or regional spillovers that create cross-region correlations between infrastructure, public capital and output.

4 Although we have attempted several solutions for simultaneity bias, they are preliminary identification strategies and we are working to improve our estimates and to find better instruments. We cannot claim that we have provided a definitive solution to all sources of endogeneity, especially exogenous shocks to regional characteristics that drive investments in public capital and the relationship between regional characteristics and ERP adoption. We hope to get valuable feedback from WISE participants.

events are associated with improvements in productivity and operational performance, installation events are not, mirroring results from U.S. data (Aral et. al. 2006).

Table 2. Returns to ERP – US vs. Italy

Test	(1)	(2)	(3)	(4)
	Labor Prod.	Value Added	Inventory Turnover	Asset Utilization
ERP 86-98 (U.S.)	.163***	-.017	.126***	-.016
(Hitt et. al 2002)	(.048)	(.017)	(.061)	(.033)
ERP 98-05 (U.S.)	.069**	-.002	.143***	.155***
(Aral et. al. 2006)	(.028)	(.018)	(.035)	(.024)
ERP 89-05 (Italy) (Current Paper):				
ERP: Install	.071	.079	.06	.024
	(.076)	(.048)	(.087)	(.067)
ERP: Go-Live	.105**	.104***	.091	.092**
	(.051)	(.030)	(.070)	(.046)
Ln(Capital)		.371***		
		(.034)		
Ln(Labor)	.681***	.488***		
	(.025)	(.044)		
Ln(Inventory)			.756***	
			(.036)	
Ln(Assets)				.782***
				(.022)
Control Variables	Industry Year Region	Industry Year Region	Industry Year Region	Industry Year Region
R2	.54	.79	.61	.70

Notes: *** p<.001; ** p<.05; * p<.10

We then tested the effects of regional IT infrastructures on productivity and the effects of ERP on productivity in regions with strong (or weak) IT infrastructures.[5] If regional IT infrastructures complement firms' internal IT investments we would expect to see greater returns to ERP in regions with strong IT infrastructure. If, on the other hand, internal IT investments serve as a substitute for external IT resources and infrastructures, we should see greater returns to ERP use in regions with weak IT infrastructure. We find that regions with strong IT infrastructures experience greater labor productivity (β = .295***), total factor productivity (β = .174***), and asset utilization (β = .206**), suggesting that the output elasticity of public capital accumulation in technology infrastructure is positive, mirroring more general evidence of the positive output elasticity of public capital in Italy (Picci 1999). Returns to ERP

[5] As a few Italian regions have significantly stronger IT infrastructures, with lower levels of variation across the other regions, we identified the top three regions and created a dummy variable that selects them in each year, and did the same for R&D labor.

use are again positive and significant, but on average 10 to 15 percent higher when controlling for the positive performance effect of firms' regional IT infrastructure resources. Excluding the IT infrastructure variable downward biases the coefficient on ERP use, providing some evidence of substitution between internal ERP adoption and external IT infrastructure. At the same time, the interaction term shows that the marginal impact of ERP use on labor productivity, total factor productivity and asset utilization is lower for firms in regions with strong IT infrastructures. Firms in regions without broadband access, less firm Internet use and lower PC penetration experience greater marginal benefits to ERP adoption.

Table 3. Regional IT Infrastructure, ERP Adoption and Firm Performance

Column	(1)	(2)	(3)	(4)
	Labor Prod.	Value Added	Inventory Turnover	Asset Utilization
ERP: Go-live	.271**	.228**	.016	.236**
	(.099)	(.063)	(.115)	(.094)
IT Infrast.	.295***	.174***	.084	.206**
	(.077)	(.045)	(.083)	(.081)
IT Infrast.	-.195*	-.168**	.072	-.185*
*ERP: Go-Live	(.109)	(.071)	(.124)	(.105)
Ln(Capital)		.370***		
		(.034)		
Ln(Labor)	.694***	.497***		
	(.025)	(.042)		
Ln(Inventory)			.752***	
			(.036)	
Ln(Assets)				.777***
				(.022)
Control Variables	Industry Year	Industry Year	Industry Year	Industry Year
Hausman Specification Test Results (OLS & IV)				
Chi	0.18	1.42	0.45	3.85
Prob>chi2 =	1.0000	1.0000	1.0000	1.0000

Notes: *** p<.001; ** p<.05; * p<.10

We find similar results when analyzing the effect of regional R&D personnel on the marginal benefit of ERP adoption. Firms in regions with richer pools of R&D personnel have access to more highly trained, innovative labor and experience stronger labor productivity (β = .257***), total factor productivity (β = .157***), inventory efficiencies (β = .135***) and asset utilization (β = .210***). At the same time, firms in regions with strong pools of R&D personnel experience lower marginal benefits to ERP adoption, suggesting that ERP systems and R&D personnel are partial substitutes.

Table 4. Regional Human Resources, ERP Adoption and Firm Performance				
Column	(1)	(3)	(6)	(9)
Interpretation	Labor Prod.	Output (Prod.)	Inventory Turnover	Asset Utilization
ERP: Go-live	.242**	.168**	.130	.232***
	(.079)	(.051)	(.091)	(.069)
R&D Personnel	.257***	.157***	.135**	.210***
	(.061)	(.039)	(.063)	(.069)
R&D Personnel	-.173*	-.104*	-.078	-.200**
*ERP: Go-Live	(.091)	(.060)	(.103)	(.080)
Ln(Capital)		352***		
		(.037)		
Ln(Labor)	.618***	.463***		
	(.061)	(.063)		
Ln(Inventory)			.744***	
			(.049)	
Ln(Assets)				.773***
				(.040)
Control Variables	Industry Year	Industry Year	Industry Year	Industry Year
Hausman Specification Test Results (OLS & IV)				
Chi2	0.08	0.01	0.06	12.95
Prob>chi2 =	0.9468	1.0000	1.0000	1.0000
Notes: *** p<.001; ** p<.05; * p<.10				

5. Limitations & Future Work

We have assembled a data set that enables us to answer questions that are not easily answered using data from the U.S. context. By examining returns to ERP in a context with substantial regional heterogeneity, we may be able to understand how local economic and technological environments impact the value of firm-level IT investments. However, our results are preliminary and we plan significant improvements to the current work in the near future. First, we plan to fine tune our specifications and make better use of the rich regional data by moving towards estimates of the marginal impact of regional characteristics rather than on the marginal impact of being in strong or weak regions. Second, although we discuss possible endogeneity and present several potential strategies, we have not fully identified our estimates. We are planning to search for better instrumental variables by researching regional policy changes over the last 17 years to identify exogenous changes in local contexts that vary by region. Third, we are limited in our ability to conduct more traditional tests of the elasticity of substitution because our IT variables measure binary adoption events rather than continuous levels of investment or use. We are therefore searching for alternative specifications that may allow us to measure the elasticity of

substitution more precisely. Finally, our use of regional fixed effects specifications are limited by a lack of variation in regional characteristics over time in our current formulations. We are therefore working to improve our measures to take more advantage of the richness of the regional data. We hope discussions at WISE will enable us to improve on these interesting preliminary results.

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