

Firm Productivity and Infrastructure Costs in East Africa

Atsushi Iimi

Richard Martin Humphrey

Sevara Melibaeva



WORLD BANK GROUP

Transport and ICT Global Practice Group

June 2015

Abstract

Infrastructure is an important driving force for economic growth. It reduces trade and transaction costs and stimulates the productivity of the economy. Africa has been lagging behind in the global manufacturing market. Among others, infrastructure is an important constraint in many African countries. Using firm-level data for East Africa, the paper reexamines the relationship between firm performance and infrastructure. It is shown that labor costs

are by far the most important to stimulate firm production. Among the infrastructure sectors, electricity costs have the highest output elasticity, followed by transport costs. In addition, the paper shows that the quality of infrastructure is important to increase firm production. In particular, quality transport infrastructure seems to be essential. The paper also finds that agglomeration economies can reduce firm costs. The agglomeration elasticity is estimated at 0.03–0.04.

This paper is a product of the Transport and ICT Global Practice Group. It is part of a larger effort by the World Bank to provide open access to its research and make a contribution to development policy discussions around the world. Policy Research Working Papers are also posted on the Web at <http://econ.worldbank.org>. The authors may be contacted at aiimi@worldbank.org.

The Policy Research Working Paper Series disseminates the findings of work in progress to encourage the exchange of ideas about development issues. An objective of the series is to get the findings out quickly, even if the presentations are less than fully polished. The papers carry the names of the authors and should be cited accordingly. The findings, interpretations, and conclusions expressed in this paper are entirely those of the authors. They do not necessarily represent the views of the International Bank for Reconstruction and Development/World Bank and its affiliated organizations, or those of the Executive Directors of the World Bank or the governments they represent.

FIRM PRODUCTIVITY AND INFRASTRUCTURE COSTS IN EAST AFRICA

Atsushi Iimi,[¶] Richard Martin Humphrey, Sevara Melibaeva

Sustainable Development Department, Africa Region
The World Bank

Key words: Firm productivity, public infrastructure, seemingly unrelated regression, stochastic frontier analysis.

JEL classification: H54; H41; D24; C21.

[¶] Corresponding author.

I. INTRODUCTION

Infrastructure is an important driving force for economic growth. It reduces trade and transaction costs and stimulates productivity of the economy. The existing growth literature is generally supportive of this. Canning and Pedroni (1999) find the positive long-run growth effects of various infrastructure endowments, such as telephone access, electricity generation capacity and paved roads. In rapidly growing economies, such as China, infrastructure is considered to play an important role for growth. Démurger (2001) shows that road density and teledensity are among the key growth determinants in Chinese provinces. According to Calderón and Servén (2004), infrastructure is important, not only in terms of providing access, but the quality of infrastructure is a contributory factor in achieving higher economic growth.

Despite rapid growth in recent years, boosted by high international commodity prices, Africa has been lagging behind in the global manufacturing market. Africa's economy is still dominated by traditional agriculture and mining. While other developing countries, particularly in East Asia and South Asia, have enjoyed steady industrialization, the level of industrialization in Africa is less than half of that in Asia and has not been increased much in the last four decades (Dinh et al. 2012). A recent study indicates that without controls, Africa's manufacturing sector performs significantly worse than firms in other regions. But after controlling for geography and the business environment, Africa performs as well as other similar developing countries (Harrison et al. 2011). A variety of constraints may exist to improve firm productivity in Africa.

According to the literature, good quality transport infrastructure seems to be essential to improve firm productivity. Quality roads reduce trade and transport costs of firms. Thus, firms can minimize their inventory costs. Shirley and Winston (2004) show that firm inventory decreases with highway investment and increases with highway congestion in the United States. Limão and Venables (2001) show that international trade is increased by lowering transport costs, which depend on infrastructure (measured by the road density). Because of these positive effects of transport infrastructure, firms are often concentrated along highways (e.g., Holl, 2004).

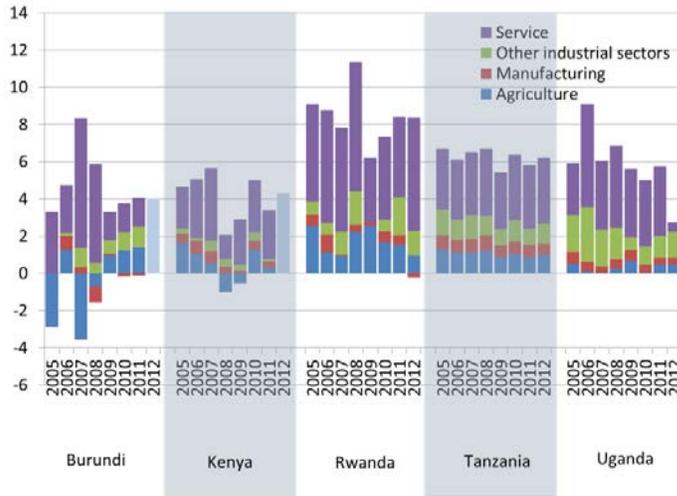
Unreliable electricity supply is also a crucial constraint in Africa. The electrification rate is estimated at 30.5 percent in the region; 580 million of people still live without access to power.¹ Firms may have better access than households. However, the quality of the electricity supply remains poor. Many firms are experiencing frequent power outages, and therefore, firms are highly dependent on own generators, adding to more operating costs. Back-up systems are generally costly. For example, the average cost of a back-up power system is three times higher than the cost of grid electricity in Nigeria (Adenikinju, 2003).

The current paper aims at examining the impacts of improving the quality of public infrastructure services in five East African countries: Burundi, Kenya, Rwanda, Tanzania and Uganda, where the industrial sector, especially manufacturing, has been weak in recent years. While the countries achieved relatively high GDP growth of 5–8 percent, the sectoral contribution of manufacturing was less than 0.5 percent of GDP (Figure 1). Burundi and Rwanda experienced negative growth in the manufacturing sector in recent years. By contrast, the service sector and the construction industry contributed significantly to economic growth in the region.

The paper recasts light on the impacts of the quantity and quality of infrastructure services on firm production. The data come from the 2005 Business Environment and Enterprise Performance Survey (BEEPS), which was conducted by the European Bank for Reconstruction and Development and the World Bank. The remaining sections are organized as follows: Section II provides an overview of infrastructure qualities measured by the BEEPS database. Section III establishes our empirical model and Section IV describes the data. Section V presents our main estimation results and policy implications. Then Section VI concludes.

¹ International Energy Agency World Energy Outlook Electricity Access Database.

Figure 1. Sectoral decomposition of GDP



Source: World Development Indicators.

II. AN OVERVIEW OF INFRASTRUCTURE SECTORS IN EAST AFRICA

Electricity continues to be one of the major development challenges in East Africa. In terms of access to electricity, the proportion of the population with access to electricity is between 9 and 16 percent. The vast majority of people are yet to receive electricity (Table 1), with a significant disparity between urban and rural areas (see Figure 2). For instance, the 2010 DHS data for Rwanda show that about half the population had electricity in urban areas, but the electrification rate in rural areas is only 3.9 percent. Similarly, according to the 2008 DHS data for Kenya, the urban and rural electrification rates were 63 and 7 percent, respectively.

In East Africa, firms are concentrated in major urban areas, in which electricity access is relatively good. About 60 percent of Kenyan firms are located in Nairobi (Figure 3). In Tanzania, the geographic distribution looks less skewed, but the largest firm agglomeration lies in the Dar es Salaam Area, where about 25 percent of all firms are based.² Together with

² The Dar es Salaam Region consists of three districts: Kinondoni, Ilala, and Temeke, where more than 11,000 establishments exist. The total number of registered enterprises is about 45,000 in Tanzania.

major cities, such as Arusha, Mbeya, Mwanza and Tabora, the urban milieu accounts for about 45 percent of total enterprises in Tanzania.

Notably, however, the quality of electricity supply is not necessarily reliable even in urban areas. According to the BEEPS data, electricity was among the most crucial concerns that many firms raised in the region (Figure 4). The main empirical analysis of this paper uses the 2006 BEEPS for Burundi, 2007 for Kenya, 2005 for Rwanda, 2006 for Tanzania, and 2006 for Uganda. Newer data in 2011 were available for Rwanda when this paper was prepared. But the analysis does not use them to maintain consistency across the countries. According to these surveys, in Tanzania and Uganda, electricity was identified as the most crucial business constraint in 2006. In Rwanda, for which more recent data are available, the electricity problem seems to have been partially resolved but remains one of the major constraints. Power outages are a chronic problem in the region. In 2007, Kenya, Tanzania and Burundi experienced outages for 53, 63 and 143 days, respectively (Eberhard et al., 2011).

Transport infrastructure was also identified as a major constraint in the region. It is of particular concern to firms involved in international trade. While about 30 percent of the domestic firms were concerned about transportation, nearly 60 percent of the exporting and importing firms felt constrained by transport (Figure 5).³ Transport infrastructure is clearly a matter of concern for those who are engaged in trade and other international businesses.

Transport infrastructure to access a seaport is particularly crucial to landlocked countries, such as Burundi, Rwanda and Uganda. The nearest major seaport is 1,100 km away from Kampala, Uganda. Kigali and Bujumbura are 1,400 km away from the ports of Mombasa and Dar es Salaam, respectively. Even Nairobi is located 500 km distant from the port of Mombasa (Figure 6). When vehicle operating costs, freight tariffs and waiting time costs at transport nodes, such borders and ports, are taken into account, the transport costs to the port

³ Exporting firms are defined as those who exported at least 10 percent of products to abroad. On the other hand, importing firms are defined as those who responded that they imported any material inputs and/or supplies directly from abroad.

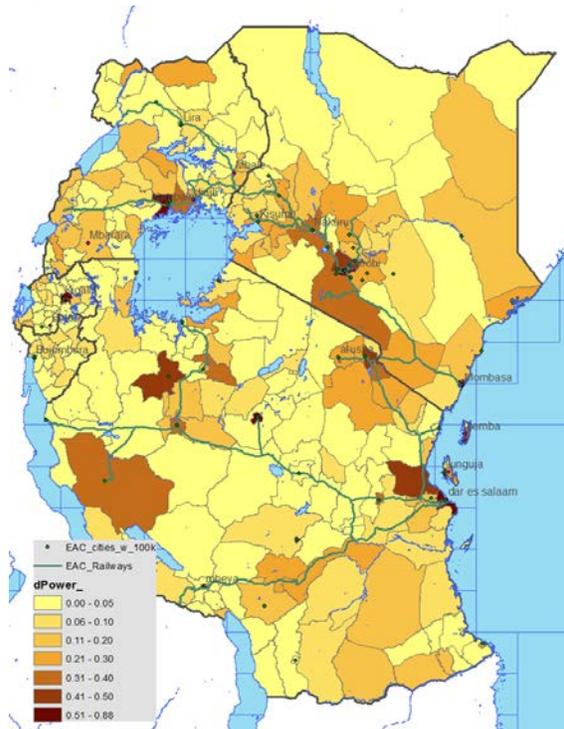
are significant particularly in inland areas (Figure 7). For instance, the transport cost from Nairobi to Mombasa is estimated at about \$120 per ton. The costs from Kampala and Kigali are estimated at \$160 and \$190 per ton, respectively. The cost from Bujumbura to the port of Dar es Salaam is estimated at \$197 per ton.

Table 1. Electrification rates

	Electrification rate (%)	Population without electricity (million)
Burundi	10.8	8.2
Kenya	16.1	33.4
Rwanda	11.0	9.6
Tanzania	13.9	37.7
Uganda	9.0	28.1
Sub-Saharan Africa	30.5	585.2

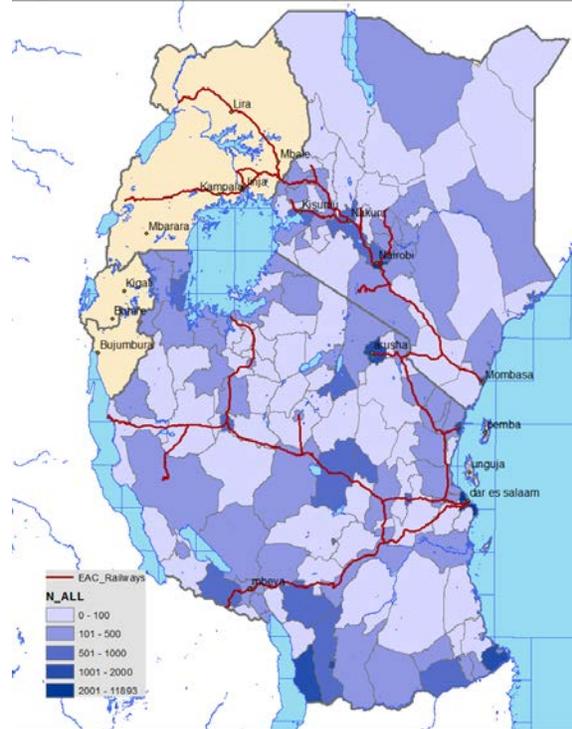
Sources: IEA WEO 2011 for Kenya, Tanzania and Uganda; and estimated based on DHS 2010 for Burundi; and DHS 2010 for Rwanda.

Figure 2. Share of households with electricity



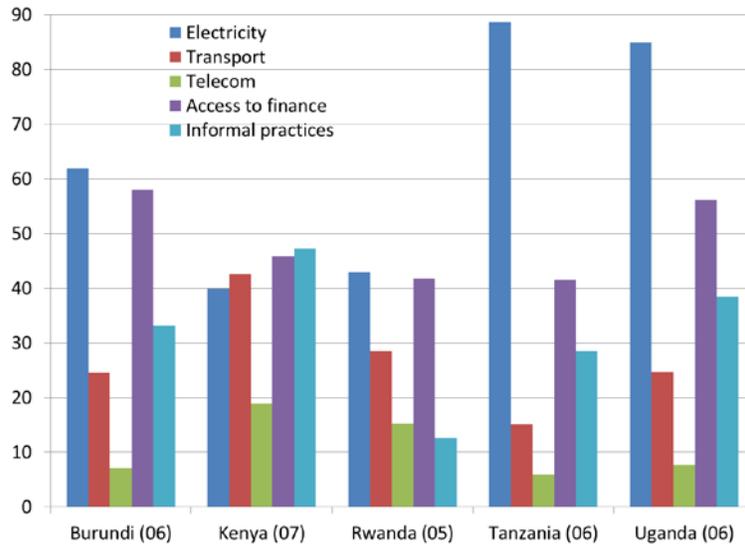
Source: World Bank calculation based on the latest DHSs and LSMSs for 2008-2010.

Figure 3. Number of firms by subnational division



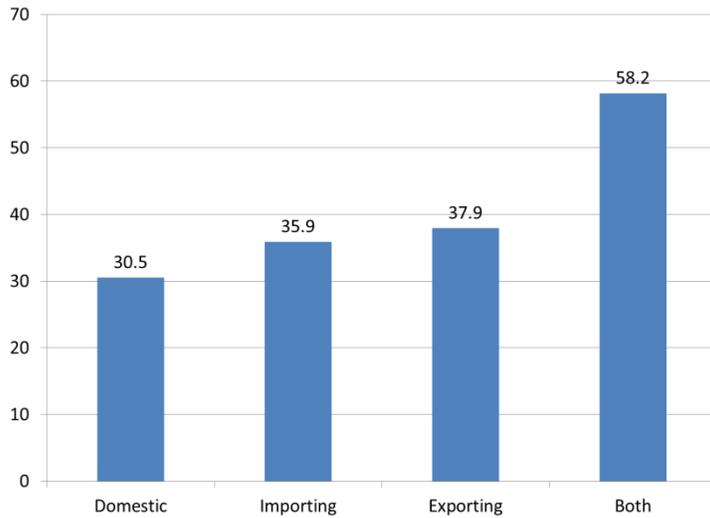
Sources: Kenya National Bureau of Statistics data (2012); Tanzania Central Register of Establishments (CRE) Statistics, 2010

Figure 4. Share of firms that identified each factor as a major constraint (percent)



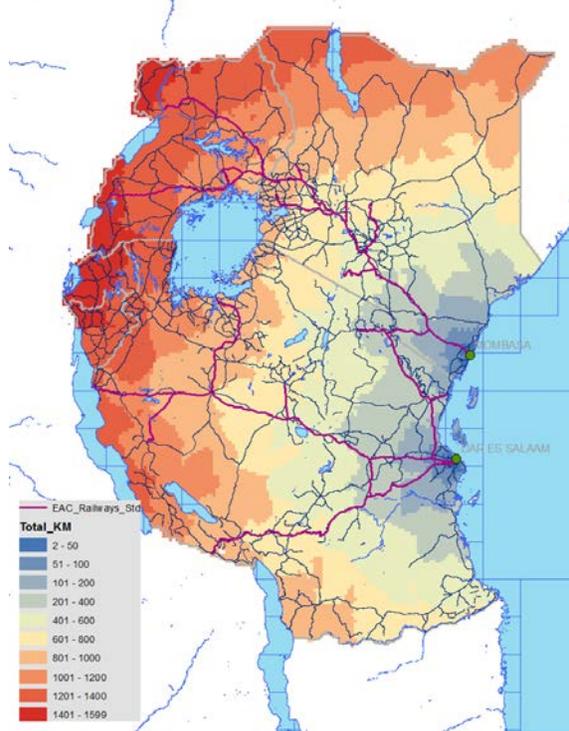
Sources: Authors' calculation based on five BEEPS in the EAC countries.

Figure 5. Share of firms that identified transport as a major constraint (percent)



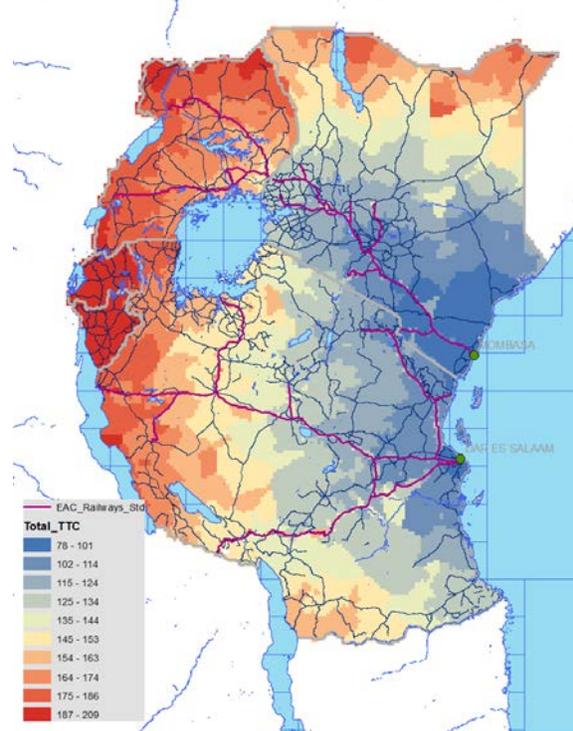
Sources: Authors' calculation based on five BEEPS in the EAC countries.

Figure 6. Distance to the nearest port (km)



Source: World Bank calculation.

Figure 7. Transport costs to the port (US\$ per ton)



Source: World Bank calculation.

III. EMPIRICAL MODEL

To assess the possible impacts of infrastructure investments on firm productivity, the following cost function is considered:

$$C = F(W, Y, Z) \tag{1}$$

where W and Y represent input prices and output, respectively. Each firm is supposed to minimize the operating cost by selecting the levels of various inputs, including infrastructure services, such as electricity and transportation. It is also assumed that firms' productivity (or cost) is dependent on the quality of public infrastructure services, Z . This is probably an exogenous element that is presumably beyond the control of individual firms. Governments or infrastructure operators are responsible for it.

Following the traditional industrial organization literature (e.g., Nerlove, 1963; Christensen and Greene, 1976), the translog cost function is considered:

$$\begin{aligned} \ln C = & \beta_0 + \beta_Y \ln Y + \frac{1}{2} \beta_{YY} \ln Y \ln Y + \sum_i \beta_{W_i} \ln W_i + \frac{1}{2} \sum_i \sum_j \beta_{W_i W_j} \ln W_i \ln W_j \\ & + \sum_i \beta_{Y W_i} \ln Y \ln W_i + \sum_k \beta_{Z_k} \ln Z_k + \frac{1}{2} \sum_k \sum_h \beta_{Z_k Z_h} \ln Z_k \ln Z_h + \sum_k \beta_{Y Z_k} \ln Z_k \ln Y \quad (2) \\ & + \sum_i \sum_k \beta_{W_i Z_k} \ln Z_k \ln W_i + \varepsilon \end{aligned}$$

where C denotes the amount of total operating cost, Y is an output proxy, and W_i is i th input price. Z_k represents the k th measurement of infrastructure quality.

Seven inputs are considered: labor (L), electricity (E), fuel (F), water (W), transport (T), communications (C), and the rest of costs (M). Conceptually, the last can be referred to as capital or equipment. The prices of these production factors are denoted by W_i . For W_L , it is defined by the average wage of each firm. For other factor prices, such as W_E , W_F , W_W , W_T , W_C , they are calculated by the firm's spending on each infrastructure service divided by the replacement cost of the firm's assets (e.g., machinery, buildings, and land). Finally, W_M is defined by the rest of the operating costs (such as annual depreciation and rental fees) divided by the asset replacement cost.

Output is measured by total sales in U.S. dollars. Ideally, this should be measured by some variable in real terms, but this is only the usable common proxy for output in our BEEPS data.⁴ To control for sector heterogeneity, the empirical model incorporates the sector-

⁴ No physical output variable is available in the database, because firms in the sample engage in various businesses.

specific dummy variables. The model is also estimated separately for each sector in order to allow the individual sectors to have different cost structures.⁵

Three infrastructure services are examined: electricity, water supply and transport. For power, the level of service quality is measured by the number of days with power outages per year (Z_E). Similarly, the quality of water services is measured by the number of days without sufficient water (Z_W). The quality of transport infrastructure service is difficult to measure, because it is affected by multiple factors with various transport modes involved. One of the good proxies that are available in the BEEPS data is firm inventory, i.e., the number of days measured by days of production or sales (Z_T). In the conventional economic order quantity model, the optimal firm inventory increases with the cost of purchasing goods, including transport and handling costs. Our paper is supportive of this (see Iimi et al. (2014)).

The cost function is estimated by two estimation techniques: seemingly unrelated regression (SUR) and stochastic-frontier analysis (SFA). To have a well-behaved cost function, the following symmetry and homogeneity restrictions are imposed:

$$\beta_{W_i W_j} = \beta_{W_j W_i}, \beta_{Z_k Z_h} = \beta_{Z_h Z_k}, \sum_i \beta_{W_i} = 1, \sum_i \sum_j \beta_{W_i W_j} = 0, \sum_i \beta_{Y W_i} = 0, \sum_i \beta_{W_i Z_k} = 0 \quad (3)$$

These are primarily theoretical necessities. Particularly, homogeneity of degree one in the factor prices seems essential to avoid unusual estimation results, as discussed in the traditional industrial organization literature (e.g., Greene, 1997).

In addition, by Shephard's lemma, the following factor share equations can be derived from Equation (2):

⁵ In reality, it is reasonable to expect that different industries could be affected by infrastructure in different ways. For instance, one might think that manufacturers would necessitate more stable electricity supply than construction businesses. Quality water supply may be of particular importance for agrobusiness or restaurants.

$$S_i = \frac{\partial \ln C}{\partial \ln W_i} = \beta_{W_i} + \sum_j \beta_{W_i W_j} \ln W_j + \beta_{Y W_i} \ln Y + \sum_k \beta_{W_i Z_k} \ln Z_k \quad (4)$$

where S_i is the cost share of input i .

For the SUR model, the cost parameters are estimated in Equation (2) and six of the factor share equations (4).⁶ An advantage of the SUR is higher efficiency in estimation without wasting the degree of freedom (Christensen and Greene, 1976). A disadvantage may be that a strict cost minimization proposition must be imposed (Kwoka, 2002). By construction, the SUR model assumes allocative and technical efficiencies; any deviation from the frontier is captured by statistical errors. Thus, it cannot control for technical inefficiency in an explicit manner (e.g., Berger and Mester, 1997). This may raise concern in the present context, because many firms in Africa may not strictly follow the cost minimization proposition. Certain hidden inefficiency is likely to be involved.

To incorporate such technical inefficiency, the stochastic-frontier model is also considered. The SFA does not assume allocative and technical efficiency. Firm costs are allowed to deviate from the efficient frontier due to some unknown factors, i.e., X-inefficiency (e.g., Coelli, 1992; Berger and Mester, 1997). In the SFA, the error term is composed of two parts: a non-negative technical inefficiency, u and an idiosyncratic error term, v :

$$\varepsilon = \ln u + \ln v \quad (5)$$

where $\ln u$ is assumed to be independently and identically distributed (i.i.d.) according to a half normal distribution $|N(0, \sigma_u)|$, and $\ln v$ is i.i.d. according to a standard normal distribution $N(0, \sigma_v)$.

⁶ One of the factor equations should be dropped to avoid the singularity problem.

Given the parameters estimated by either SUR or FSA, the price elasticity of factor demand can be calculated using the Allen's partial elasticities of substitution between inputs i and j (e.g., Uzawa, 1962; Berndt and Wood, 1975):

$$\sigma_{ij} = \begin{cases} (\beta_{W_i W_j} + S_i S_j) / S_i S_j & \text{if } i \neq j \\ (\beta_{W_i W_i} + S_i^2 - S_i) / S_i^2 & \text{if } i = j \end{cases} \quad (6)$$

Then, the implied own price elasticity of demand for factor i is written by:

$$\eta_{ii} = (\beta_{W_i W_i} + S_i S_i - S_i) / S_i \quad (7)$$

The possible infrastructure impacts are examined in two ways: First, the output elasticity with respect to factor price i is calculated. This will show how much a firm could save because of infrastructure investments (and therefore, reductions in infrastructure costs):

$$\theta_{iY} = - \frac{\beta_{W_i} + \sum_j \beta_{W_i W_j} \ln W_j + \beta_{Y W_i} \ln Y + \sum_k \beta_{W_i Z_k} \ln Z_k}{\beta_Y + \beta_{YY} \ln Y + \sum_i \beta_{Y W_i} \ln W_i + \sum_k \beta_{Y Z_k} \ln Z_k} \quad (8)$$

Second, the marginal impact (elasticity) of improved infrastructure quality Z_k on firm costs is calculated:

$$\omega_{Z_k Y} = - \frac{\beta_{Z_k} + \sum_h \beta_{Z_k Z_h} \ln Z_h + \beta_{Y Z_k} \ln Y + \sum_i \beta_{W_i Z_k} \ln W_i}{\beta_Y + \beta_{YY} \ln Y + \sum_i \beta_{Y W_i} \ln W_i + \sum_k \beta_{Y Z_k} \ln Z_k} \quad (9)$$

This will indicate what non-cost benefits firms could receive because of infrastructure investments. If the quality of infrastructure service is improved, firms can save various costs.

For instance, unanticipated power outages may damage the quality of products. Firms may have to shoulder an extra cost of inventory if transport infrastructure is unreliable.

IV. DATA

Our data come from five series of the BEEPS in East Africa (i.e., 2006 BEEPS for Burundi, 2007 for Kenya, 2005 for Rwanda, 2006 for Tanzania, and 2006 for Uganda), which originally cover 2,775 firms in 17 cities (Figure 8). The analysis only uses about 2,000 observations, for which all relevant data are available. The distribution of the sample observations is shown in Table 2. The sample includes more than 600 firms in Kenya, followed by Uganda and Tanzania. The service sector has the largest share in total. But a large number of agribusinesses are included in the data for Tanzania and Uganda. In theory, the sample distribution is supposed to reflect the distribution of the entire population in each country.

The summary statistics are shown in Table 3. Firms look different in size as well as factor intensity. The operating cost ranges from US\$100 to US\$300 million with a mean of about US\$1.2 million. The average annual wage is estimated at around US\$2,000. In the sample, the labor cost accounts for 38 percent of total costs on average. The average energy cost share is about 5 percent. The transport cost accounts for 1.4 percent on average.

Regarding infrastructure quality, the number of days without sufficient electricity supply is eight days per year on average, but the service quality seems to vary significantly, depending on location. It ranges from zero to 100 days in the region. Firms do not have sufficient water services about one day a year. Firm inventory also varies significantly. Firms may keep minimum inventory (i.e., zero days) and may keep 730 days of inventory.

Table 2. Number of observations (firms) by sector and country

	Burundi	Kenya	Rwanda	Tanzania	Uganda	Total
Textile and garment	34	117	6	62	17	236
Agro business	43	158	28	133	226	588
Chemical, metal and other energy-intensive industries	19	76	12	47	105	259
Other manufacturing	31	81	13	40	49	214
Service sector (retail, hotel, restaurant, and IT)	174	160	149	78	127	688
Other industries (construction, transport, etc.)	8	21	5	13	16	63
Total	309	613	213	373	540	2,048

Table 3. Summary statistics

Variable	Abb.	Obs.	Mean	Std. Dev.	Min	Max
Total operating cost	C	2048	1,276,698	8,823,662	97	306,000,000
Factor share: Labor	S _L	2048	0.381	0.272	0.002	1.000
Energy	S _E	2048	0.052	0.075	0.000	0.921
Fuel	S _F	2048	0.012	0.031	0.000	0.439
Water	S _W	2048	0.004	0.016	0.000	0.349
Transport	S _T	2048	0.014	0.034	0.000	0.331
Communications	S _C	2048	0.025	0.054	0.000	0.620
Wage (average per full time employee)	W _L	2048	1960	4588	11	150107
Energy cost	W _E	2048	1.573	55.317	0.000	2500.000
Fuel cost	W _F	2048	0.046	1.237	0.000	55.833
Water cost	W _W	2048	0.019	0.558	0.000	25.000
Transport cost	W _T	2048	0.022	0.144	0.000	4.609
Communication cost	W _C	2048	0.194	1.160	0.000	24.000
Other input cost	W _M	2048	4.424	40.210	0.000	1013.889
Output (total sales)	Y	2048	2,747,458	29,800,000	610	1,200,000,000
Number of days without electricity supply per year	Z _E	2048	8.7	7.7	0.0	100.0
Number of days without water supply per year	Z _W	2048	1.3	4.2	0.0	30.0
Number of inventory measured by days of production	Z _T	2048	23.2	38.5	0.0	730.0
Country dummy variable:						
Kenya		2048	0.299	0.458	0	1
Rwanda		2048	0.104	0.305	0	1
Tanzania		2048	0.182	0.386	0	1
Uganda		2048	0.264	0.441	0	1
Sector dummy variable:						
Textile		2048	0.115	0.319	0	1
Agro business (food and wood products)		2048	0.287	0.453	0	1
Chemical and metal		2048	0.126	0.332	0	1
Other manufacturing		2048	0.104	0.306	0	1
Service		2048	0.336	0.472	0	1

The SUR results indicate the importance of labor market issues to increase firm production in the region. To examine how much production would be increased by a small reduction in production factor prices, such as wages, the output elasticities are calculated (Table 5). Labor costs turned out to have the highest output elasticity among other production factors: The elasticity is 0.42–0.63 in absolute terms.

Among infrastructure costs, the output elasticity associated with electricity costs is found to be particularly high at 0.107 in the SUR model. This seems to be consistent with the general perspective of firm managers who identified electricity as one of the most crucial business constraint. However, the SFA results remain inconclusive. The elasticity with respect to transport costs is estimated at about 0.04, which means that a 10 percent reduction in transport costs would increase firm production (or more precisely, firm sales in our case) by 0.4 percent.

Although our infrastructure measurements are not perfect, our results indicate that the quality of infrastructure is important, particularly in the transport sector. The output elasticity with respect to transport infrastructure quality is estimated at 0.06–0.07 in absolute terms, which is statistically significant (Table 6). If transport infrastructure is improved (i.e., firm inventory is reduced) by 10 percent, firm sales would increase 0.6-0.7 percent. In practical terms, this means that an “average” firm could increase its profits by about US\$10,000, holding everything else constant.⁸ In the SFA, the elasticity of water quality is also found significant. If the quality of water supply increases (i.e., the number of days that water supply is suspended declines), the firm output would increase.

Since different industries require different production inputs, the sample firms are divided into five groups: textile, agrobusiness (including food and wood products), energy-intensive manufacturing (such as chemical and metal), other manufacturing, and service, and the SUR and SFA are performed separately. The output elasticities are found to vary across the

⁸ The sample average of sales is US\$2.7 million, while the median is only US\$71,000.

industries (Figure 9). Labor costs are commonly found to be most important regardless of sector. Among other production factors, the results indicate that electricity costs are relatively important in the textile industry. Transport costs are found to be important for agrobusinesses and energy-intensive manufacturers. A few benefits may be expected from cost reductions in water and ICT. While not many firms heavily depend on water infrastructure, it is likely that ICT costs are already very competitive. Therefore, additional benefits are likely to be small.

Table 4. Estimated production factor own price elasticities

	SUR		***	SFA		***
	Elasticity	Std. Err.		Elasticity	Std. Err.	
Labor	-0.684	(0.010)	***	-0.634	(0.038)	***
Electricity	-0.773	(0.006)	***	-1.536	(2.133)	***
Fuel	-0.854	(0.006)	***	-0.847	(0.038)	***
Water	-0.885	(0.014)	***	-1.536	(2.231)	***
Transport	-0.848	(0.007)	***	-0.973	(0.095)	***
ICT	-0.758	(0.036)	***	-0.979	(0.038)	***

Note that the elasticity is evaluated at sample means and calculated based on the estimated cost function. See Equation (7).

Table 5. Estimated output elasticities with respect to factor prices

	SUR		***	SFA		***
	Elasticity	Std. Err.		Elasticity	Std. Err.	
Labor	-0.423	(0.015)	***	-0.628	(0.051)	***
Electricity	-0.107	(0.006)	***	-0.009	(0.032)	***
Fuel	-0.047	(0.003)	***	-0.078	(0.029)	***
Water	-0.023	(0.003)	***	-0.008	(0.027)	***
Transport	-0.039	(0.003)	***	-0.037	(0.023)	*
ICT	-0.026	(0.005)	***	0.107	(0.027)	***

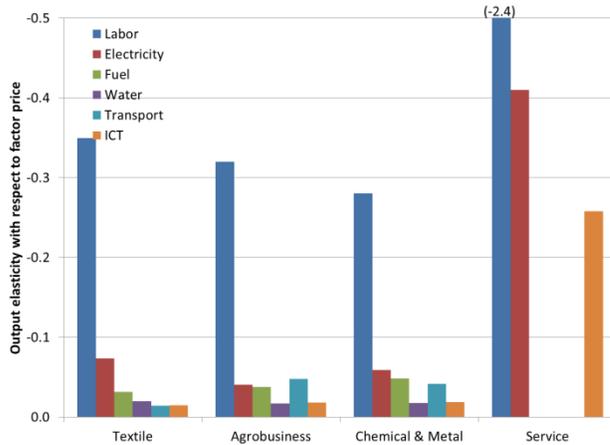
Note that the elasticity is evaluated at sample means and calculated based on the estimated cost function. See Equation (8).

Table 6. Estimated effects of infrastructure quality improvements

	SUR		***	SFA		***
	Elasticity	Std. Err.		Elasticity	Std. Err.	
Electricity	0.015	(0.026)	***	0.015	(0.028)	***
Water	0.040	(0.033)	***	-0.057	(0.034)	*
Transport	-0.072	(0.019)	***	-0.057	(0.020)	***

Note that the elasticity is evaluated at sample means and calculated based on the estimated cost function. See Equation (9).

Figure 9. Estimated output elasticities with respect to factor prices by industry



Note that the elasticity is evaluated at sample means and calculated based on the estimated cost function. See Equation (8).

VI. DISCUSSION

One empirical advantage of using the stochastic frontier estimator is that potential technical (in) efficiency can be estimated: $u = E[\exp(\ln u | \varepsilon)]$. Based on the above pooled model, the average technical inefficiency is estimated at 0.015 percent of total actual costs (Table 7). It may look small, but it is worth recalling that the model assumed a half normal distribution of the technical inefficiency. Thus, the predicted inefficiency is heavily skewed towards zero. By country, firms in Burundi are found to be least efficient, followed by Rwanda. Technical inefficiency also depends on sector. In general the service sector looks less efficient. Textiles, a traditional light manufacturing sector in the region, also has relatively large inefficiency. As expected, energy intensive industry, such as chemical and metal manufacturing, is found much more efficient regardless of country, because this sector is normally capital intensive and much modernized.

Table 7. Estimated technical inefficiency by country

	Pooled model	Industry-specific regression:			
		Textile	Agro-business	Chemical & Metals	Service
All	0.015	0.010	0.005	0.004	0.052
Burundi	0.055	0.026	0.012	0.003	0.132
Kenya	0.008	0.004	0.005	0.004	0.027
Rwanda	0.016	0.010	0.002	0.001	0.033
Tanzania	0.008	0.013	0.004	0.001	0.027
Uganda	0.006	0.006	0.005	0.006	0.013

Another issue of particular interest may be firm agglomeration. Theory suggests that firms prefer to be located close to each other to take advantage of agglomeration economies. The existing evidence is supportive. Procher (2011) finds agglomeration economies for French firms in Europe. Lee et al. (2012) find that there are positive externalities to Korean manufacturers in the United States. Mare and Graham (2013) show that the average agglomeration elasticity in New Zealand is significant and estimated at 0.06.

To examine how economies of agglomeration affect firm costs in East Africa, an additional specification is examined with two types of agglomeration economies considered: localization economies and urbanization economies. While the former is measured by the total number of existing firms in the same industry at the same city (denoted by N_1), the latter is measured by the number of firms in the same city (N_2). The log of N_1 and N_2 and their squared terms are added to Equation (2). To avoid further complication related to endogeneity, the lagged values are used. Recall that our BEEPS data are for 2005 and 2006. Unfortunately, historical business register data are not always available in the sample countries. The relevant data are available only for three cities in Tanzania (Dar es Salaam, Arusha and Mbeya) and Kampala, Uganda.

The results suggest that economies of agglomeration matter to firm production. Especially, economies of localization are statistically significant. The estimated cost elasticity is about -0.03 to -0.04 (Table 8). Thus, if the number of total firms in the same industry at the same locality increases by 10 percent, the firm costs would decline by 0.3–0.4 percent. This can be

considered as strong evidence showing why firms agglomerate in the same place, despite the expected intensification of local competition among themselves. Firms can share the same input market, such as skilled labor, and more business services would likely become available in the agglomerated area. As a result, firm operating costs decline and competitiveness increases.

Table 8. Estimated economies of agglomeration

	SUR		***	SFA		
	Elasticity	Std. Err.		Elasticity	Std. Err.	
Localization economies	-0.043	(0.008)	***	-0.033	(0.008)	***
Urbanization economies	-0.001	(0.081)		0.064	(0.106)	

VII. CONCLUSION

Infrastructure is an important driving force for economic growth. It reduces trade and transaction costs and stimulates the productivity of the economy. Africa has been lagging behind in the global manufacturing market despite its strong growth in recent years, possibly boosted by high international commodity prices. Among others, absence of quality infrastructure is an important constraint in many African countries.

Using firm-level data for East Africa, the paper recast light on the relationship between firm performance and infrastructure. It is shown that labor costs are important to stimulate firm production. Among the infrastructure sectors, electricity costs are found to have the highest elasticity of firm output. Transport costs are also found to be important. In addition, firm production increases with the quality of transport infrastructure measured by firm inventory. All the indications are that the provision of reliable infrastructure services at low costs is essential to improve firm competitiveness and increase firm production.

The paper also found that agglomeration economies are important to increase firm production. Unlike the traditional firm location literature, our evidence is direct to show that

agglomeration can reduce firm production costs. The elasticity is estimated at 0.03–0.04 in absolute terms.

REFERENCES

- Adenikinju, Adeola. 2003. "Electric Infrastructure Failures in Nigeria: A Survey-Based Analysis of the Costs and Adjustment Responses." *Energy Policy* 31, no. 14: 1519-30.
- Berger, Allen, and Loretta Mester. 1997. "Inside the Black Box: What Explains Differences in the Efficiencies of Financial Institutions?" *Journal of Banking and Finance* 21, no. 7: 895-947.
- Berndt, Ernst, and David Wood. 1975. Technology, prices, and the derived demand for energy. *The Review of Economics and Statistics*, Vol. 57, pp. 259-268.
- Calderón, César, and Luis Servén. 2004. "The Effects of Infrastructure Development on Growth and Income Distribution." Policy Research Working Paper No. 3400. Washington DC: The World Bank.
- Canning, David, and Peter Pedroni. 1999. "Infrastructure and Long Run Economic Growth." Center for Analytical Economics Working Paper No. 99-09. Ithaca, NY: Cornell University.
- Christensen, Laurtis, and William Greene. 1976. "Economies of Scale in U.S. Electric Power Generation." *The Journal of Political Economy* 84, no. 4: 655-76.
- Coelli, Tim. 1992. "A Computer Program for Frontier Production Function Estimation: FRONTIER Version 2.0." *Economics Letters* 39, no. 1: 29-32.
- Démurger, Sylvie. 2001. "Infrastructure Development and Economic Growth: An Explanation for Regional Disparities in China?" *Journal of Comparative Economics* 29, no. 1: 95-117.
- Eberhard, Anton, Orvila Rosnes, Maria Shkaratan, and Haakon Vennemo. 2011. *Africa's Power Infrastructure: Investment, Integration, Efficiency*. The World Bank.
- Harrison, Ann, Justin Lin, and Colin Xu. 2013. Explaining Africa's (dis)advantage. NBER Paper No. 18683. National Bureau of Economic Research.

- Holl, Adelheid. 2004. "Manufacturing Location and Impacts of Road Transport Infrastructure: Empirical Evidence from Spain." *Regional Science and Urban Economics* 34, no. 3: 341-63.
- Imi, Atsushi, Richard Martin Humphrey, and Sevara Milibaeva. 2014. Firm inventory behavior in East Africa.
- Kwoka, John. 2002. "Vertical Economies in Electric Power: Evidence on Integration and its Alternatives." *International Journal of Industrial Organization* 20, no. 5: 653-71.
- Lee, Ki-Dong, Seok-Joon Hwang, and Min-hwan Lee. 2012. Agglomeration economies and location choice of Korean manufactures within the United States. *Applied Economics*, Vol. 44, pp. 189-200.
- Limão, Nuno, and Anthony Venables. 2001. "Infrastructure, Geographical Disadvantage, Transport Costs, and Trade." *The World Bank Economic Review* 15, no. 3: 451-79.
- Mare, David, and Daniel Graham. 2013. Agglomeration elasticities and firm heterogeneity. *Journal of Urban Economics*, Vol. 75, pp. 44-56.
- Nerlove, Marc. 1963. "Returns to Scale in Electricity Supply," in *Measurement in Economics: Studies in Mathematical Economics and Econometrics in Memory of Yehuda Grunfeld*, eds. by Carl Christ, Stanford University Press.
- Procher, Vivien. 2011. Agglomeration effects and the location of FDI: Evidence from French first-time movers. *Annals of Regional Science*, Vol. 46, pp. 295-312.
- Shepherd, Ben, and John Wilson. 2006. "Road Infrastructure in Europe and Central Asia: Does Network Quality Affect Trade?" Policy Research Working Paper No. 4104. Washington DC: The World Bank.
- Shirley, Chad, and Clifford Winston. 2004. "Firm Inventory Behavior and the Returns from Highway Infrastructure Investment." *Journal of Urban Economics* 55, no. 2: 398-415.
- Uzawa, Hirofumi. 1962. Production functions with constant elasticities of substitution. *The Review of Economic Studies*, Vol. 29, pp. 291-299.

Table 9. SUR estimation results

	All industries	Textile	Agrobusiness	Chemical & Metal	Other manufacturing	Service
β_Y	0.2539 *** (0.0521)	0.7397 *** (0.1302)	0.4730 *** (0.0703)	0.2576 * (0.1124)	0.4864 *** (0.1442)	-0.1500 (0.2054)
β_{YY}	0.0393 *** (0.0038)	0.0215 * (0.0094)	0.0290 *** (0.0051)	0.0357 *** (0.0079)	0.0168 (0.0094)	0.0230 * (0.0106)
β_{Wl}	0.5653 *** (0.0243)	0.9008 *** (0.0728)	0.7990 *** (0.0517)	0.6565 *** (0.0681)	0.7605 *** (0.1071)	0.5577 *** (0.0516)
β_{We}	0.1111 *** (0.0140)	0.0485 (0.0540)	0.0390 (0.0211)	0.1354 *** (0.0353)	0.0382 (0.0540)	0.1134 *** (0.0334)
β_{Wf}	0.0747 *** (0.0064)	-0.0037 (0.0271)	0.0829 *** (0.0112)	0.1149 *** (0.0201)	0.0917 ** (0.0292)	
β_{Ww}	0.0286 *** (0.0069)	0.0369 (0.0202)	0.0353 ** (0.0122)	0.0430 * (0.0194)	0.0148 (0.0251)	
β_{Wt}	0.0497 *** (0.0064)	0.0373 (0.0229)	0.0384 ** (0.0134)	0.0958 *** (0.0220)	0.0845 ** (0.0275)	
β_{Wc}	0.0634 *** (0.0108)	0.0283 (0.0292)	0.0129 (0.0146)	0.0576 ** (0.0184)	0.0454 (0.0372)	0.0926 *** (0.0254)
β_{WlWl}	-0.0113 *** (0.0016)	-0.0278 *** (0.0056)	-0.0271 *** (0.0037)	-0.0199 *** (0.0045)	-0.0289 *** (0.0060)	-0.0073 ** (0.0024)
β_{WlWe}	0.0110 *** (0.0012)	0.0280 *** (0.0041)	0.0262 *** (0.0023)	0.0272 *** (0.0031)	0.0288 *** (0.0038)	0.0007 (0.0020)
β_{WlWf}	-0.0027 *** (0.0006)	-0.0020 (0.0021)	-0.0005 (0.0012)	0.0013 (0.0017)	0.0011 (0.0023)	
β_{WlWw}	0.0028 *** (0.0008)	0.0006 (0.0019)	0.0031 * (0.0013)	0.0089 *** (0.0018)	0.0082 *** (0.0020)	
β_{WlWt}	-0.0016 * (0.0006)	-0.0027 (0.0021)	0.0015 (0.0013)	-0.0026 (0.0020)	-0.0020 (0.0022)	
β_{WlWc}	0.0074 *** (0.0008)	0.0104 *** (0.0024)	0.0076 *** (0.0014)	0.0036 (0.0019)	0.0089 *** (0.0026)	0.0096 *** (0.0013)
β_{WlWm}	-0.0275 *** (0.0008)	-0.0386 ** (0.0041)	-0.0374 *** (0.0027)	-0.0412 *** (0.0034)	-0.0441 *** (0.0047)	-0.0217 *** (0.0010)
β_{WlWe}	0.0122 *** (0.0006)	0.0237 *** (0.0031)	0.0117 *** (0.0011)	0.0141 *** (0.0020)	0.0126 *** (0.0024)	0.0112 *** (0.0010)
β_{WeWf}	0.0005 * (0.0002)	0.0013 (0.0011)	-0.0004 (0.0004)	0.0005 (0.0008)	-0.0010 (0.0010)	
β_{WeWw}	0.0010 *** (0.0003)	-0.0001 (0.0010)	0.0013 ** (0.0005)	0.0024 ** (0.0008)	0.0000 (0.0009)	
β_{WeWt}	0.0004 (0.0002)	-0.0012 (0.0011)	-0.0003 (0.0005)	0.0015 (0.0008)	0.0016 (0.0010)	
β_{WeWc}	-0.0003 (0.0003)	-0.0001 (0.0012)	0.0002 (0.0005)	0.0003 (0.0008)	0.0006 (0.0012)	-0.0009 (0.0006)
β_{WeWm}	-0.0026 *** (0.0003)	0.0073 ** (0.0023)	0.0023 * (0.0009)	-0.0030 * (0.0014)	0.0032 (0.0020)	-0.0027 *** (0.0005)

β_{WfWf}	0.0042 *** (0.0002)	0.0027 *** (0.0008)	0.0044 *** (0.0003)	0.0053 *** (0.0005)	0.0042 *** (0.0007)	
β_{WfWw}	-0.0001 (0.0001)	0.0002 (0.0004)	-0.0001 (0.0002)	-0.0002 (0.0004)	-0.0002 (0.0005)	
β_{WfWt}	-0.0008 *** (0.0001)	-0.0009 (0.0005)	-0.0004 (0.0002)	0.0001 (0.0004)	0.0002 (0.0005)	
β_{WfWc}	0.0000 (0.0001)	-0.0005 (0.0006)	0.0000 (0.0003)	-0.0002 (0.0004)	0.0000 (0.0006)	
β_{WfWm}	0.0001 (0.0001)	0.0002 (0.0012)	0.0016 ** (0.0005)	0.0002 (0.0008)	0.0003 (0.0011)	
β_{WwWw}	0.0018 *** (0.0002)	0.0025 *** (0.0005)	0.0018 *** (0.0004)	0.0016 ** (0.0006)	0.0011 * (0.0006)	
β_{WwWt}	0.0001 (0.0001)	-0.0001 (0.0004)	0.0002 (0.0002)	0.0002 (0.0004)	0.0002 (0.0005)	
β_{WwWc}	0.0002 (0.0002)	0.0000 (0.0005)	0.0001 (0.0003)	0.0006 (0.0004)	0.0001 (0.0006)	
β_{WwWm}	0.0003 * (0.0001)	0.0009 (0.0009)	0.0032 *** (0.0006)	0.0017 * (0.0008)	0.0025 * (0.0010)	
β_{WtWt}	0.0038 *** (0.0002)	0.0033 *** (0.0007)	0.0045 *** (0.0004)	0.0042 *** (0.0006)	0.0041 *** (0.0007)	
β_{WtWc}	-0.0002 (0.0001)	0.0002 (0.0005)	-0.0005 (0.0003)	-0.0002 (0.0005)	-0.0004 (0.0006)	
β_{WtWm}	0.0001 (0.0001)	-0.0024 * (0.0010)	0.0024 *** (0.0007)	0.0001 (0.0009)	-0.0005 (0.0012)	
β_{WcWc}	0.0048 *** (0.0003)	0.0039 *** (0.0009)	0.0028 *** (0.0004)	0.0030 *** (0.0006)	0.0040 *** (0.0010)	0.0061 *** (0.0005)
β_{WcWm}	-0.0016 *** (0.0002)	0.0003 (0.0013)	0.0026 *** (0.0007)	0.0000 (0.0007)	0.0046 ** (0.0015)	-0.0012 *** (0.0003)
$\beta_{Y_{Wf}}$	-0.0085 *** (0.0013)	-0.0214 *** (0.0046)	-0.0130 *** (0.0031)	-0.0083 * (0.0039)	-0.0091 (0.0057)	-0.0001 (0.0030)
$\beta_{Y_{Wc}}$	-0.0069 *** (0.0009)	-0.0095 ** (0.0033)	-0.0115 *** (0.0014)	-0.0159 *** (0.0023)	-0.0107 *** (0.0029)	-0.0034 (0.0022)
$\beta_{Y_{Wt}}$	-0.0004 (0.0004)	0.0041 * (0.0017)	-0.0025 ** (0.0008)	-0.0048 *** (0.0013)	-0.0040 * (0.0017)	
$\beta_{Y_{Ww}}$	-0.0016 *** (0.0005)	-0.0013 (0.0013)	-0.0024 ** (0.0008)	-0.0056 *** (0.0012)	-0.0042 ** (0.0014)	
$\beta_{Y_{Wm}}$	0.0005 (0.0004)	0.0003 (0.0015)	0.0002 (0.0009)	-0.0016 (0.0014)	-0.0013 (0.0016)	
$\beta_{Y_{Wc}}$	-0.0059 *** (0.0007)	-0.0055 ** (0.0018)	-0.0033 ** (0.0010)	-0.0039 ** (0.0012)	-0.0052 * (0.0020)	-0.0075 *** (0.0016)
β_{Zc}	-0.0252 (0.0207)	-0.1218 * (0.0531)	0.0204 (0.0303)	0.0568 (0.0428)	-0.0426 (0.0813)	-0.0135 (0.0534)
β_{Zw}	-0.0339 (0.0293)	-0.0083 (0.0495)	-0.0774 ** (0.0296)	0.0118 (0.0544)	0.0699 (0.0519)	0.0391 (0.1144)
β_{Zt}	0.0371 (0.0227)	0.1467 (0.0802)	0.0043 (0.0550)	-0.0289 (0.0755)	-0.0154 (0.0930)	0.2883 * (0.1152)

β_{ZeZe}	-0.0002 (0.0022)	0.0044 (0.0042)	0.0023 (0.0030)	0.0019 (0.0039)	0.0047 (0.0037)	-0.0024 (0.0044)
β_{ZeZw}	-0.0008 (0.0005)	-0.0015 (0.0010)	0.0001 (0.0005)	-0.0002 (0.0006)	-0.0034 * (0.0013)	0.0019 (0.0024)
β_{ZeZt}	0.0003 (0.0005)	0.0008 (0.0014)	0.0005 (0.0008)	-0.0014 (0.0011)	0.0045 (0.0086)	-0.0004 (0.0010)
β_{ZwZw}	-0.0055 (0.0037)	0.0022 (0.0060)	-0.0103 ** (0.0038)	-0.0034 (0.0068)	0.0020 (0.0059)	-0.0272 (0.0166)
β_{ZwZt}	0.0006 (0.0008)	0.0064 (0.0034)	-0.0009 (0.0009)	-0.0013 (0.0023)	0.0048 (0.0027)	0.0125 (0.0070)
β_{ZtZt}	0.0045 *** (0.0012)	0.0042 (0.0030)	0.0011 (0.0016)	0.0035 (0.0023)	-0.0024 (0.0029)	0.0044 (0.0023)
β_{YZe}	0.0003 (0.0009)	0.0068 * (0.0028)	0.0005 (0.0013)	-0.0003 (0.0019)	0.0033 (0.0038)	0.0009 (0.0022)
β_{YZw}	0.0005 (0.0008)	0.0008 (0.0018)	0.0010 (0.0008)	-0.0011 (0.0013)	-0.0031 (0.0017)	-0.0234 * (0.0111)
β_{YZt}	0.0009 (0.0014)	-0.0010 (0.0055)	0.0020 (0.0040)	0.0047 (0.0046)	0.0068 (0.0054)	-0.0053 (0.0031)
β_{WlZe}	0.0009 * (0.0004)	0.0029 (0.0020)	-0.0006 (0.0011)	-0.0028 * (0.0011)	-0.0024 (0.0032)	0.0020 ** (0.0007)
β_{WeZe}	-0.0012 *** (0.0003)	-0.0055 *** (0.0012)	0.0003 (0.0004)	0.0003 (0.0006)	0.0009 (0.0014)	-0.0017 *** (0.0005)
β_{WfZe}	0.0002 * (0.0001)	-0.0006 (0.0006)	0.0003 (0.0002)	0.0006 (0.0004)	0.0005 (0.0007)	
β_{WwZe}	-0.0001 (0.0001)	0.0005 (0.0005)	-0.0002 (0.0002)	0.0002 (0.0003)	0.0002 (0.0007)	
β_{WtZe}	0.0001 (0.0001)	-0.0004 (0.0005)	0.0003 (0.0003)	0.0005 (0.0004)	0.0002 (0.0008)	
β_{WcZe}	-0.0008 *** (0.0002)	-0.0033 *** (0.0007)	-0.0004 (0.0003)	0.0003 (0.0003)	-0.0002 (0.0009)	-0.0004 (0.0003)
β_{WlZw}	-0.0015 ** (0.0005)	-0.0012 (0.0010)	-0.0006 (0.0007)	-0.0014 (0.0011)	-0.0023 * (0.0011)	-0.0023 (0.0021)
β_{WeZw}	-0.0001 (0.0003)	0.0003 (0.0009)	0.0000 (0.0003)	0.0002 (0.0005)	0.0012 (0.0007)	0.0001 (0.0014)
β_{WfZw}	-0.0002 (0.0001)	-0.0004 (0.0004)	0.0000 (0.0002)	0.0003 (0.0003)	0.0003 (0.0004)	
β_{WwZw}	-0.0002 (0.0001)	-0.0005 (0.0003)	-0.0001 (0.0002)	0.0002 (0.0003)	0.0003 (0.0003)	
β_{WtZw}	-0.0003 ** (0.0001)	-0.0004 (0.0004)	0.0000 (0.0002)	-0.0001 (0.0003)	-0.0002 (0.0004)	
β_{WcZw}	-0.0002 (0.0002)	0.0000 (0.0005)	0.0001 (0.0002)	-0.0001 (0.0003)	0.0002 (0.0005)	0.0010 (0.0011)
β_{WlZt}	-0.0011 (0.0007)	-0.0013 (0.0039)	-0.0015 (0.0024)	-0.0010 (0.0022)	-0.0006 (0.0039)	-0.0005 (0.0011)
β_{WeZt}	0.0000 (0.0004)	0.0007 (0.0027)	0.0018 (0.0010)	0.0009 (0.0011)	-0.0012 (0.0018)	-0.0003 (0.0007)

$\beta_{w_f z_t}$	0.0000 (0.0002)	0.0000 (0.0013)	0.0000 (0.0005)	0.0006 (0.0006)	-0.0002 (0.0009)	
$\beta_{w_w z_t}$	0.0001 (0.0002)	0.0003 (0.0008)	0.0008 (0.0006)	0.0003 (0.0006)	-0.0005 (0.0009)	
$\beta_{w_t z_t}$	-0.0002 (0.0002)	-0.0008 (0.0010)	-0.0005 (0.0006)	0.0000 (0.0007)	-0.0001 (0.0009)	
$\beta_{w_c z_t}$	0.0000 (0.0003)	-0.0003 (0.0014)	0.0011 (0.0006)	0.0001 (0.0005)	-0.0007 (0.0013)	0.0004 (0.0005)
cons	3.1109 *** (0.4260)	-2.1427 * (0.9547)	1.0956 (0.6146)	3.8378 *** (0.9208)	1.7772 (1.4099)	6.1827 *** (1.7238)
Obs.	2048	236	588	259	214	686
R squared	0.9873	0.9841	0.9804	0.9855	0.9796	0.9922
Chi 2	242461.5	25593.1	45551.5	29662.4	17082.4	122516.6
No. of dummy variables						
Country	4	4	4	4	4	4
Industry	5	0	0	0	0	0

Table 10. SFA estimation results

	All industries	Textile	Agrobusiness	Chemical & Metal	Other manufacturing	Service
β_Y	0.4339 *** (0.1043)	0.7461 *** (0.2254)	0.3929 *** (0.1146)	0.0594 (0.1518)	0.5111 * (0.2195)	0.1424 (0.2861)
β_{YY}	0.0251 ** (0.0079)	0.0074 (0.0186)	0.0196 * (0.0078)	0.0384 *** (0.0102)	0.0236 * (0.0094)	0.0091 (0.0252)
β_{Wl}	1.1144 *** (0.0732)	1.0812 *** (0.1418)	1.0609 *** (0.1212)	0.8980 *** (0.1193)	1.6093 *** (0.2587)	0.5996 ** (0.1944)
β_{We}	-0.0059 (0.0640)	-0.1538 (0.1540)	-0.1742 * (0.0856)	-0.0299 (0.1088)	-1.2645 *** (0.3361)	-0.0750 (0.0977)
β_{Wf}	-0.0481 (0.0412)	-0.2466 * (0.1056)	0.0664 (0.0559)	0.0621 (0.0719)	-0.2424 * (0.1043)	
β_{Ww}	-0.0478 (0.0371)	0.1856 * (0.0750)	-0.0205 (0.0418)	-0.0643 (0.0624)	0.0086 (0.0999)	
β_{Wt}	-0.0806 * (0.0353)	0.1118 (0.1027)	-0.0278 (0.0437)	0.1644 (0.0927)	0.1984 (0.1028)	
β_{Wc}	-0.0338 (0.0398)	-0.2419 * (0.1138)	-0.1402 * (0.0654)	-0.0878 (0.1047)	-0.2536 * (0.1130)	0.3912 * (0.1939)
β_{WlWl}	-0.0655 *** (0.0088)	-0.0847 *** (0.0180)	-0.1034 *** (0.0113)	-0.1069 *** (0.0145)	-0.1663 *** (0.0252)	-0.0472 *** (0.0104)
β_{WlWe}	0.0248 ** (0.0079)	0.0573 ** (0.0196)	0.0629 *** (0.0103)	0.0375 * (0.0154)	0.0657 *** (0.0195)	0.0154 (0.0100)
β_{WlWf}	0.0018 (0.0054)	0.0148 (0.0098)	0.0048 (0.0063)	0.0125 (0.0083)	0.0286 * (0.0140)	
β_{WlWw}	0.0229 *** (0.0049)	-0.0092 (0.0081)	-0.0038 (0.0055)	0.0172 ** (0.0060)	-0.0013 (0.0103)	
β_{WlWt}	-0.0022 (0.0050)	-0.0113 (0.0100)	0.0094 (0.0059)	-0.0044 (0.0124)	-0.0360 ** (0.0122)	
β_{WlWc}	0.0064 (0.0045)	0.0310 ** (0.0112)	0.0082 (0.0063)	-0.0035 (0.0124)	0.0278 (0.0173)	0.0152 * (0.0063)
β_{WlWm}	-0.0205 *** (0.0047)	-0.0568 ** (0.0200)	-0.0352 *** (0.0094)	-0.0090 (0.0138)	-0.0051 (0.0256)	-0.0089 * (0.0045)
β_{WlWe}	-0.0040 (0.0024)	0.0205 (0.0142)	-0.0037 (0.0039)	-0.0140 (0.0083)	-0.0375 (0.0195)	-0.0080 * (0.0035)
β_{WeWf}	-0.0002 (0.0016)	-0.0042 (0.0044)	0.0001 (0.0015)	0.0015 (0.0047)	0.0060 (0.0056)	
β_{WeWw}	0.0038 (0.0024)	-0.0013 (0.0039)	0.0013 (0.0029)	0.0088 (0.0061)	0.0021 (0.0067)	
β_{WeWt}	-0.0016 (0.0023)	-0.0075 (0.0043)	-0.0001 (0.0026)	0.0262 ** (0.0096)	-0.0016 (0.0060)	
β_{WeWc}	0.0029 * (0.0015)	0.0111 * (0.0052)	0.0021 (0.0029)	-0.0242 * (0.0103)	-0.0344 *** (0.0101)	0.0038 (0.0025)
β_{WeWm}	-0.0022 * (0.0011)	0.0150 (0.0089)	0.0071 ** (0.0027)	-0.0023 (0.0055)	0.0343 ** (0.0114)	-0.0012 (0.0012)

β_{WfWf}	0.0056 *	0.0140 *	0.0036	0.0073	-0.0026	
	(0.0028)	(0.0067)	(0.0030)	(0.0045)	(0.0048)	
β_{WfWw}	-0.0005	0.0017	0.0009	-0.0008	-0.0008	
	(0.0007)	(0.0012)	(0.0007)	(0.0014)	(0.0016)	
β_{WfWt}	-0.0016 **	-0.0012	0.0001	-0.0025	0.0041 *	
	(0.0006)	(0.0011)	(0.0006)	(0.0018)	(0.0017)	
β_{WfWc}	0.0008	-0.0042 **	-0.0007	0.0024	-0.0060	
	(0.0008)	(0.0015)	(0.0008)	(0.0015)	(0.0045)	
β_{WfWm}	-0.0073 *	-0.0013	0.0004	-0.0080	-0.0027	
	(0.0029)	(0.0061)	(0.0031)	(0.0067)	(0.0090)	
β_{WwWw}	-0.0034	0.0015	-0.0082 **	-0.0072	-0.0027	
	(0.0027)	(0.0048)	(0.0032)	(0.0051)	(0.0072)	
β_{WwWt}	0.0007	0.0001	0.0003	-0.0004	-0.0014	
	(0.0007)	(0.0009)	(0.0006)	(0.0015)	(0.0020)	
β_{WwWc}	0.0002	-0.0009	-0.0006	0.0002	0.0091	
	(0.0008)	(0.0011)	(0.0007)	(0.0017)	(0.0047)	
β_{WwWm}	0.0094 **	-0.0038	0.0083 *	0.0049	-0.0086	
	(0.0034)	(0.0060)	(0.0038)	(0.0067)	(0.0107)	
β_{WtWt}	-0.0001	0.0035	0.0022	0.0018	0.0015	
	(0.0024)	(0.0050)	(0.0030)	(0.0046)	(0.0031)	
β_{WtWc}	0.0002	0.0001	-0.0005	0.0011	0.0069	
	(0.0006)	(0.0014)	(0.0008)	(0.0015)	(0.0046)	
β_{WtWm}	-0.0035	0.0003	0.0013	-0.0155	-0.0150	
	(0.0030)	(0.0068)	(0.0041)	(0.0103)	(0.0096)	
β_{WcWc}	-0.0090 ***	-0.0092	-0.0079 *	-0.0050	-0.0276 ***	-0.0041
	(0.0024)	(0.0054)	(0.0034)	(0.0064)	(0.0073)	(0.0042)
β_{WcWm}	-0.0035 ***	-0.0032	0.0002	0.0210 *	0.0536 ***	-0.0035 ***
	(0.0006)	(0.0072)	(0.0035)	(0.0101)	(0.0116)	(0.0007)
$\beta_{Y_{Wl}}$	-0.0023	-0.0001	0.0141 *	0.0203 **	0.0134	-0.0015
	(0.0039)	(0.0098)	(0.0061)	(0.0077)	(0.0177)	(0.0074)
$\beta_{Y_{We}}$	-0.0103	-0.0208	-0.0215 ***	-0.0181	0.0354 *	0.0010
	(0.0057)	(0.0110)	(0.0059)	(0.0097)	(0.0150)	(0.0087)
$\beta_{Y_{Wf}}$	0.0068 *	0.0151 **	-0.0036	-0.0059	0.0031	
	(0.0028)	(0.0056)	(0.0031)	(0.0043)	(0.0064)	
$\beta_{Y_{Ww}}$	-0.0090 ***	-0.0052	-0.0028	-0.0086	0.0035	
	(0.0023)	(0.0039)	(0.0027)	(0.0034)	(0.0051)	
$\beta_{Y_{Wt}}$	0.0083 **	0.0009	-0.0008	-0.0011	0.0111	
	(0.0027)	(0.0050)	(0.0032)	(0.0058)	(0.0067)	
$\beta_{Y_{Wc}}$	-0.0074 *	-0.0050	-0.0010	-0.0016	-0.0228 *	-0.0092
	(0.0031)	(0.0084)	(0.0045)	(0.0070)	(0.0098)	(0.0054)
β_{Ze}	-0.0380	-0.1810	0.0346	0.1238	-0.3555	-0.0769
	(0.0359)	(0.1089)	(0.0387)	(0.0660)	(0.2958)	(0.0505)
β_{Zw}	0.0664 *	0.0334	-0.0162	0.1216 *	0.0572	0.5474 *
	(0.0318)	(0.0463)	(0.0360)	(0.0571)	(0.0589)	(0.2552)
β_{Zt}	0.0811 **	0.1814	0.0338	0.1377	0.4297	0.2968 ***
	(0.0275)	(0.1559)	(0.0594)	(0.1203)	(0.3099)	(0.0718)

β_{ZeZe}	0.0014 (0.0023)	0.0070 (0.0051)	0.0015 (0.0029)	-0.0003 (0.0040)	-0.0014 (0.0044)	-0.0028 (0.0048)
β_{ZeZw}	-0.0010 * (0.0004)	-0.0016 (0.0011)	0.0001 (0.0005)	-0.0012 * (0.0005)	-0.0061 * (0.0026)	-0.0008 (0.0016)
β_{ZeZt}	0.0001 (0.0004)	0.0071 (0.0036)	0.0011 (0.0008)	0.0001 (0.0014)	0.0194 (0.0170)	-0.0004 (0.0007)
β_{ZwZw}	0.0047 (0.0035)	-0.0006 (0.0051)	-0.0022 (0.0040)	0.0057 (0.0078)	0.0042 (0.0070)	-0.0252 *** (0.0073)
β_{ZwZt}	-0.0006 (0.0008)	0.0019 (0.0037)	-0.0012 (0.0010)	-0.0034 (0.0027)	0.0069 (0.0036)	0.0107 ** (0.0039)
β_{ZtZt}	0.0049 *** (0.0014)	-0.0040 (0.0043)	0.0012 (0.0013)	0.0053 * (0.0025)	0.0002 (0.0030)	0.0055 * (0.0025)
β_{YZe}	-0.0003 (0.0016)	0.0001 (0.0061)	-0.0014 (0.0018)	-0.0038 (0.0029)	0.0124 (0.0066)	0.0018 (0.0038)
β_{YZw}	0.0001 (0.0010)	-0.0004 (0.0031)	0.0009 (0.0013)	-0.0016 (0.0017)	-0.0048 (0.0026)	-0.0157 * (0.0077)
β_{YZt}	-0.0021 (0.0016)	0.0027 (0.0156)	0.0019 (0.0045)	-0.0080 (0.0074)	-0.0116 (0.0079)	-0.0090 ** (0.0033)
β_{WlZe}	0.0038 *** (0.0011)	0.0195 *** (0.0055)	0.0002 (0.0023)	-0.0067 ** (0.0021)	0.0079 (0.0194)	0.0030 ** (0.0011)
β_{WeZe}	-0.0038 *** (0.0008)	-0.0090 (0.0053)	0.0004 (0.0019)	0.0024 (0.0018)	0.0121 (0.0148)	-0.0034 ** (0.0012)
β_{WfZe}	0.0010 (0.0007)	0.0025 (0.0020)	0.0011 (0.0007)	0.0016 (0.0009)	0.0200 * (0.0094)	
β_{WwZe}	-0.0009 (0.0007)	0.0074 * (0.0035)	-0.0009 (0.0006)	0.0014 (0.0012)	-0.0040 (0.0072)	
β_{WtZe}	0.0002 (0.0006)	-0.0067 * (0.0029)	0.0008 (0.0005)	0.0002 (0.0018)	-0.0192 (0.0110)	
β_{WcZe}	-0.0004 (0.0004)	-0.0088 ** (0.0034)	-0.0008 (0.0005)	0.0004 (0.0020)	-0.0023 (0.0034)	0.0004 (0.0007)
β_{WlZw}	-0.0026 * (0.0011)	-0.0031 (0.0022)	-0.0004 (0.0019)	-0.0052 * (0.0024)	0.0002 (0.0031)	-0.0276 * (0.0108)
β_{WeZw}	0.0020 * (0.0010)	0.0004 (0.0026)	0.0012 (0.0018)	-0.0004 (0.0022)	-0.0013 (0.0024)	0.0020 (0.0016)
β_{WfZw}	-0.0002 (0.0008)	-0.0056 ** (0.0019)	0.0008 (0.0008)	0.0012 (0.0024)	0.0011 (0.0019)	
β_{WwZw}	0.0007 (0.0005)	0.0039 (0.0026)	-0.0006 (0.0004)	0.0004 (0.0009)	0.0032 (0.0027)	
β_{WtZw}	0.0005 (0.0006)	0.0006 (0.0041)	0.0003 (0.0007)	0.0021 (0.0016)	-0.0025 (0.0014)	
β_{WcZw}	-0.0012 (0.0008)	0.0010 (0.0020)	-0.0007 (0.0007)	-0.0024 (0.0024)	-0.0056 (0.0030)	0.0264 * (0.0114)
β_{WlZt}	-0.0019 (0.0013)	-0.0181 (0.0114)	-0.0019 (0.0035)	-0.0024 (0.0057)	-0.0268 (0.0171)	-0.0002 (0.0010)
β_{WeZt}	0.0002 (0.0008)	0.0131 (0.0150)	0.0099 * (0.0044)	-0.0013 (0.0076)	-0.0190 (0.0133)	-0.0015 (0.0010)

β_{wz_t}	0.0013 (0.0009)	0.0031 (0.0049)	-0.0021 (0.0023)	0.0026 (0.0013)	-0.0027 (0.0020)	
β_{wwz_t}	0.0005 (0.0010)	0.0049 * (0.0022)	0.0027 (0.0024)	0.0026 (0.0017)	0.0048 (0.0046)	
β_{wtz_t}	0.0003 (0.0007)	-0.0175 ** (0.0059)	-0.0005 (0.0015)	0.0034 (0.0024)	-0.0028 (0.0049)	
β_{wcz_t}	-0.0004 (0.0006)	0.0057 (0.0068)	0.0015 (0.0018)	-0.0030 (0.0022)	0.0087 (0.0063)	0.0022 * (0.0009)
cons	-2.1740 ** (0.7970)	-3.3265 * (1.3817)	-0.8719 (1.0202)	2.8755 * (1.3459)	-6.1312 * (2.6293)	10.1905 * (4.0758)
Obs.	2048	236	588	259	214	686
Wald stat	249673.5	176089.3	71969.3	163639.6	200556.6	180529.4
No. of dummy variables						
Country	4	4	4	4	4	4
Industry	5	0	0	0	0	0

Table 11. SUR and SFA estimation results with agglomeration economies variables

	SUR			SFA		
β_Y	0.3498	(0.0760)	***	0.4899	(0.1058)	***
β_{YY}	0.0332	(0.0056)	***	0.0103	(0.0073)	
β_{Wl}	0.8230	(0.0430)	***	1.2041	(0.0919)	***
β_{We}	0.0977	(0.0213)	***	0.0487	(0.0782)	
β_{Wf}	0.0607	(0.0107)	***	0.0041	(0.0510)	
β_{Ww}	0.0004	(0.0135)		-0.1176	(0.0482)	**
β_{Wt}	0.0499	(0.0120)	***	-0.0336	(0.0469)	
β_{Wc}	0.0482	(0.0131)	***	0.0274	(0.0445)	
β_{WlWl}	-0.0419	(0.0036)	***	-0.1053	(0.0119)	***
β_{WlWe}	0.0136	(0.0019)	***	0.0383	(0.0100)	***
β_{WlWf}	-0.0011	(0.0011)		0.0052	(0.0069)	
β_{WlWw}	0.0087	(0.0013)	***	0.0140	(0.0066)	**
β_{WlWt}	-0.0016	(0.0011)		0.0008	(0.0072)	
β_{WlWc}	0.0045	(0.0011)	***	0.0050	(0.0054)	
β_{WlWm}	-0.0168	(0.0025)	***	-0.0112	(0.0103)	
β_{WlWe}	0.0134	(0.0009)	***	0.0000	(0.0025)	
β_{WeWf}	0.0001	(0.0004)		0.0011	(0.0016)	
β_{WeWw}	0.0008	(0.0004)	*	0.0008	(0.0022)	
β_{WeWt}	0.0004	(0.0004)		0.0012	(0.0027)	
β_{WeWc}	0.0005	(0.0004)		0.0027	(0.0020)	
β_{WeWm}	-0.0007	(0.0009)		-0.0045	(0.0036)	
β_{WfWf}	0.0037	(0.0003)	***	0.0071	(0.0035)	**
β_{WfWw}	0.0000	(0.0002)		-0.0002	(0.0008)	
β_{WfWt}	-0.0005	(0.0002)	***	-0.0007	(0.0007)	
β_{WfWc}	-0.0001	(0.0002)		-0.0004	(0.0008)	
β_{WfWm}	-0.0003	(0.0005)		-0.0075	(0.0034)	**
β_{WwWw}	0.0016	(0.0004)	***	-0.0094	(0.0032)	***
β_{WwWt}	-0.0003	(0.0002)		-0.0011	(0.0007)	
β_{WwWc}	0.0004	(0.0002)	*	0.0008	(0.0008)	
β_{WwWm}	0.0016	(0.0006)	***	0.0138	(0.0037)	***
β_{WtWt}	0.0041	(0.0003)	***	-0.0021	(0.0032)	
β_{WtWc}	0.0000	(0.0002)		0.0020	(0.0006)	***
β_{WtWm}	-0.0004	(0.0006)		-0.0070	(0.0033)	**
β_{WcWc}	0.0028	(0.0003)	***	-0.0031	(0.0032)	
β_{WcWm}	0.0009	(0.0005)		-0.0001	(0.0015)	
$\beta_{Y_{Wl}}$	-0.0071	(0.0025)	***	0.0147	(0.0054)	***
$\beta_{Y_{We}}$	-0.0063	(0.0015)	***	-0.0167	(0.0052)	***
$\beta_{Y_{Wf}}$	-0.0009	(0.0007)		0.0011	(0.0036)	
$\beta_{Y_{Ww}}$	-0.0031	(0.0009)	***	-0.0052	(0.0032)	*
$\beta_{Y_{Wt}}$	0.0008	(0.0008)		0.0016	(0.0041)	

β_{Yw_c}	-0.0032	(0.0009)	***	-0.0056	(0.0031)	*
β_{Z_e}	-0.0024	(0.0320)		-0.0020	(0.0469)	
β_{Z_w}	-0.1153	(0.0364)	***	-0.0185	(0.0439)	
β_{Z_t}	-0.0523	(0.0425)		-0.0369	(0.0364)	
β_{ZeZe}	-0.0030	(0.0028)		-0.0006	(0.0028)	
β_{ZeZw}	0.0006	(0.0011)		-0.0020	(0.0016)	
β_{ZeZt}	-0.0016	(0.0011)		-0.0018	(0.0011)	*
β_{ZwZw}	-0.0164	(0.0045)	***	-0.0021	(0.0049)	
β_{ZwZt}	0.0019	(0.0010)	*	-0.0002	(0.0010)	
β_{ZtZt}	0.0009	(0.0016)		0.0004	(0.0016)	
β_{YZe}	0.0007	(0.0016)		-0.0010	(0.0025)	
β_{YZw}	-0.0008	(0.0010)		-0.0013	(0.0017)	
β_{YZt}	0.0067	(0.0029)	**	0.0037	(0.0023)	
β_{wYZe}	-0.0004	(0.0010)		-0.0008	(0.0018)	
β_{weZe}	-0.0005	(0.0005)		-0.0021	(0.0012)	*
β_{wfZe}	0.0005	(0.0002)	**	0.0011	(0.0008)	
β_{wwZe}	-0.0002	(0.0003)		0.0007	(0.0007)	
β_{wtZe}	0.0005	(0.0003)	*	-0.0002	(0.0008)	
β_{wcZe}	-0.0003	(0.0003)		-0.0004	(0.0006)	
β_{wIZw}	-0.0001	(0.0010)		0.0050	(0.0020)	**
β_{weZw}	0.0007	(0.0005)		0.0053	(0.0022)	**
β_{wfZw}	-0.0003	(0.0002)		-0.0006	(0.0012)	
β_{wwZw}	-0.0001	(0.0002)		0.0004	(0.0005)	
β_{wtZw}	-0.0001	(0.0002)		0.0005	(0.0009)	
β_{wcZw}	0.0004	(0.0002)		-0.0004	(0.0010)	
β_{wIZt}	0.0023	(0.0013)	*	0.0015	(0.0017)	
β_{weZt}	-0.0008	(0.0006)		-0.0011	(0.0011)	
β_{wfZt}	0.0000	(0.0003)		0.0020	(0.0012)	*
β_{wwZt}	-0.0003	(0.0004)		-0.0006	(0.0010)	
β_{wtZt}	-0.0003	(0.0004)		-0.0006	(0.0009)	
β_{wcZt}	-0.0003	(0.0004)		-0.0007	(0.0007)	
β_{N1}	-0.0212	(0.0040)	***	-0.0167	(0.0042)	***
β_{N1N1}	-0.0024	(0.0005)	***	-0.0018	(0.0005)	***
β_{N2}	-0.1546	(0.1819)		0.0283	(0.2342)	
β_{N2N2}	0.0147	(0.0097)		0.0034	(0.0124)	
cons	2.2875	(1.0021)	**	-2.2624	(1.3381)	*
Obs.	733			733		
Chi2	53416.4					
Wald stat				104838.1		