E-Companion to An Internet-Enabled Move to the Market in Logistics

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Appendix A: Transaction Costs in the Context of Logistics Outsourcing

Bounded rationality is the assumption that although decision-makers intend to act rationally, they are constrained by their information processing and communication capability (Williamson 1981). For example, when search costs for information about potential 3PL providers are high, the availability of this information is low and the outsourcers might mistakenly choose a 3PL provider charging high prices while providing low quality services. *Opportunism* is the behavioral assumption that decision makers seek their self-interest given the opportunity. For example, when it is costly for outsourcers to track and trace the shipment status and monitor the on-time delivery performance of carriers, the carriers may take advantage of the information asymmetry, such as disguising delay in delivery, and dishonestly reporting loss and damage. In order to monitor and measure carriers' performance, outsourcers would be subjected to substantial transaction costs.

Asset specificity, uncertainty, and frequency are three dimensions of transactions. *Asset specificity* is the degree to which an asset can be redeployed to alternative uses or users, and it can be measured as the difference in value between first-best and second-best use (McGuigan et al. 2010, Williamson 1989). When asset specificity is high, the continuity of a transaction is important for both sides, resulting in high contractual and organizational safeguarding costs in order to avoid opportunism (Williamson 1985). For example, when a 3PL provider sets up specific facilities and equipment and assign specific employees to work for an outsourcer, the premature termination of the relationship may cause a substantial loss for the provider because specialized assets cannot be redeployed without sacrificing productive value; and thus, the provider may require a long-term contract and the investment of the outsourcer in those transaction-specific assets to lock-in the relationship and reduce risk. *Uncertainty* is the unpredictable changes in circumstances surrounding a transaction. High uncertainty causes adaptation problems when decision-makers are limited by bounded rationality, resulting in costs of communicating new information, renegotiating agreements, and coordination to tackle new situations (Rindfleisch and Heide 1997). For example, at any given time, a manufacturer may have thousands of shipments in-transit, but limited visibility of inventory in-transit causes product availability uncertainty. The manufacturer has to communicate with the carriers to obtain the shipping status, and has to keep safety stock to buffer the impact of late delivery. *Frequency* refers to the occurrence of transactions. A high frequency of transactions gives buyers and sellers an opportunity to transfer tacit knowledge and build reputation and trust, resulting in reductions in transaction costs. For instance, when a firm and a 3PL provider have high transaction volumes that they expect to continue, the 3PL provider can commit to a contract and the firm lowers monitoring and contractual adaptation costs.

Appendix B: The Comparison of Current Study and the Prior

Our estimation model differs from the variants of Cobb-Douglas forms used in prior studies (e.g., Lichtenberg 1995, Brynjolfsson and Hitt 1996, Dewan and Kraemer 2000, Cheng and Nault 2007, 2012, Han et al. 2011), and Table A1 compares our model with those.

Table A1 The Comparison of Current Study and the Prior

Studies	**Level of Analysis**	**Main model**	**Main Contributions**
Lichtenberg (1995)	Firm	$y = \alpha k + \gamma z + \beta_1 l_1 + \beta_0 l_0$	The excess returns to both IS capital and IS labor
Brynjolfsson and Hitt (1996)	Firm	$y = a + \alpha k + \gamma z + \beta_1 l_1 + \beta_2 l_2$	IS spending made significant contribution to output
Dewan and Kraemer (2000)	Country	$q = a + \alpha k + \gamma z + \beta l$	The different structure of returns from capital investment between developed and developing countries
Cheng and Nault (2007)	Industry	$y = a + \alpha k + \gamma z + \beta l + \theta m + \vartheta s$	The effect of supplier-driven IT spillovers on downstream output
Han et al. (2011)	Industry	$y = a + \alpha k + \gamma z + \beta l + \theta_0 m_0 + \theta_1 m_1$	The positive contribution of IT outsourcing to output and labor productivity
Cheng and Nault (2012)	Industry	$y = a + \alpha k + \gamma z + \beta l + \theta m + \varphi c$	The effect of customer-driven IT spillovers on upstream output
Current study	Industry	$y = a + \alpha k + \gamma z + \beta l + \theta x + \delta w + \varphi c$ $\delta(Z, C) = b + \mu Z + vC$	The Internet enables the move to the market form of the provision of goods and services

Notes: The models are log forms of Cobb-Douglas production function extensions. Each lowercase variable represents the log of the corresponding uppercase variable. On the left side of the above models, y is output, and q is annual GDP; On the right side of models, k is non-IT capital stock, z is IT capital stock, l_1 is IT staff labor, and l_0 is other labor, l_2 is other labor and expenses, l is total labor, m is total intermediate inputs, m_1 is IT services intermediate inputs, m_0 is non-IT services intermediate inputs, s is supplier-driven IT spillover index, c is customer-driven IT spillover index, x is non-Logistics intermediate inputs, and w is outsourced logistics. The controls for models are suppressed for brevity.

Appendix C: Data Sources and Construction Procedures

Table A2 Data Sources and Construction Procedure for Dataset I

Variable	Source	Construction Procedure	Deflator
Gross Output (Y)	MFP dataset of the BLS	Gross output by industry converted to 1987 U.S. dollars.	Gross output price deflator
IT Capital (Z)	Requested from the BLS	Productive information capital stock by asset type (Direct aggregate-millions of 1987 dollars).	None
Non-IT Capital (K)	Calculated by using capital stock and information capital stock from the BLS	Productive capital stock of equipment and structure, excluding information capital stock (Direct aggregate-millions of 1987 dollars).	None
Labour (L)	MFP dataset of the BLS	Hours of all persons (in millions).	None
Total Intermediate Inputs (M)	MFP dataset of the BLS	The total intermediate inputs converted to 1987 U.S. dollars.	Intermediate inputs price deflator
Non-Logistics Intermediate Inputs (X)	Calculated by using intermediate inputs and the input-output tables from the BLS	An industry's total intermediate inputs subtract purchased logistics inputs. The input-output tables are in 1987 dollars.	None
Outsourced Logistics (W)	The input-output tables from the BLS	The aggregation of an industry's purchases of the following commodities: SIC40; SIC 421, 423; SIC 422; SIC 44; SIC 45; SIC 46. The input-output tables are in 1987 dollars.	None
Customers' IT Capital (C)	Calculated by using the input-output tables and information capital	$C_i = \sum_{j \neq i} \frac{V_{ij}}{\sum_{j \neq i} V_{ij}} Z_j$, using transactions between industry i and its customers as the weights and the IT capital of each customer as base to get the aggregation of customers' IT capital stock.	None

Table A3 Data Sources and Construction Procedure for Dataset II

Variable	Source	Construction Procedure	Deflator
Gross Output (Y)	BEA Annual Industry Account	Gross output by industry converted to 2005 U.S. dollars.	Chain-type quantity index for output by industry from BEA
IT Capital (Z)	MFP dataset from the BLS	Productive information capital stock by asset type (Direct aggregate-millions of 2005 Dollars).	None
Non-IT Capital (K)	Calculated by using capital stock and information capital stock from the BLS	Productive capital stock of equipment and structure, excluding information capital stock (Direct aggregate-millions of 2005 Dollars).	None
Labour (L)	Requested from the labour productivity and costs section of the BLS	Hours of all persons (in millions)	None
Total Intermediate Inputs (M)	BEA Annual Industry Account	Intermediate inputs by industry converted to 2005 U.S. dollars.	Chain-type quantity indexes for intermediate inputs (IIQI)
Non-Logistics Intermediate Inputs (X)	Calculated by using total intermediate inputs and the input-output tables from the BEA	An industry's total intermediate inputs from the use tables, excluding purchased logistics inputs. Converted to 2005 dollars.	Chain-type quantity indexes for intermediate inputs (IIQI)
Outsourced Logistics (W)	The input-output tables from the BEA	The aggregation of an industry's purchases of the following commodities: NAICS 481, 482, 483, 484, 486, and 493. Converted to 2005 U.S. dollars.	Chain-type quantity indexes for gross output (GOQI) of the sector of warehousing and transportation
Customers' IT Capital (C)	Calculated by using the input-output tables and information capital	$C_i = \sum_{j \neq i} \frac{V_{ij}}{\sum_{j \neq i} V_{ij}} Z_j$, using the transactions between a given industry i and its customers as the weights to get the aggregation of customers' IT capital stock.	None

Table A4 Dataset II (2000-2008): 3-digit NAICS Industry Description

Industry Number	2002 NAICS Industry Code	Industry Title
8	321	Wood products
9	327	Nonmetallic mineral products
10	331	Primary metals
11	332	Fabricated metal products
12	333	Machinery
13	334	Computer and electronic products
14	335	Electrical equipment, appliances, and components
15	336	Transportation equipment
16	337	Furniture and related products
17	339	Miscellaneous manufacturing
18	311, 312 (311FT)	Food and beverage and tobacco products
19	313, 314 (313TT)	Textile mills and textile product mills
20	315, 316 (315AL)	Apparel and leather and allied products
21	322	Paper products
22	323	Printing and related support activities
23	324	Petroleum and coal products
24	325	Chemical products
25	326	Plastics and rubber products

Notes: Industry number is the sequence in which the industries appear in the input-output tables. The codes in parentheses are the ones used in the input-output tables, if different from the NAICS codes.

Appendix D: Robustness Tests and Alternatives

D.1. Estimates with Sector-Fixed Effects

In Datasets I and II, there might be unobserved heterogeneity related to different types of manufacturing such as raw materials and finished goods. To control for this kind of time-invariant industry-specific effect, we may use sector dummies or industry dummies. Estimating the models with industry-fixed effects uses a large degree of freedom because it needs to estimate different intercepts for different industries (Han et al. 2011, Cheng and Nault 2012). Recognizing industries in a sector share relatively similar production processes, we control for sector fixed effects.

Table A5 The Estimation Results for the Pre-Internet Era Based on Dataset I

Variables	The Simple CD	The Extended CD	Full Sample 1987-1999	Main Estimation 1987-1993	Robustness Tests					
					2-digit SIC Dummies	Time Span 1987-1994	Time Span 1987-1995	Redefined IT 1	Redefined IT 2	GMM Estimators
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Non-IT Capital	0.082*** (0.010)	0.037*** (0.010)	0.029*** (0.010)	0.062*** (0.009)	0.055*** (0.013)	0.060*** (0.010)	0.059*** (0.010)	0.016* (0.009)	0.006 (0.008)	0.072** (0.0288)
Labour	0.237*** (0.008)	0.264*** (0.007)	0.272*** (0.007)	0.233*** (0.007)	0.215*** (0.010)	0.242*** (0.009)	0.248*** (0.009)	0.245*** (0.007)	0.225*** (0.006)	0.217*** (0.0268)
IT Capital	0.080*** (0.006)	0.083*** (0.005)	0.073*** (0.005)	0.088*** (0.004)	0.051*** (0.008)	0.099*** (0.004)	0.098*** (0.004)	0.036*** (0.003)	0.048*** (0.004)	0.099*** (0.0136)
Non-Logistics		0.539*** (0.009)	0.546*** (0.009)	0.581*** (0.007)	0.577*** (0.013)	0.553*** (0.007)	0.539*** (0.012)	0.586*** (0.012)	0.614*** (0.007)	0.579*** (0.0319)
Outsourced Logistics		0.104*** (0.006)	0.118*** (0.007)	0.052*** (0.005)	0.105*** (0.010)	0.060*** (0.005)	0.071*** (0.007)	0.138*** (0.009)	0.118*** (0.006)	0.044** (0.0182)
CustomerIT		0.025*** (0.005)	0.034*** (0.005)	0.012*** (0.004)	0.001 (0.007)	0.014*** (0.004)	0.017*** (0.005)	0.027*** (0.005)	0.028*** (0.004)	0.020 (0.0157)
OwnIT * Outsourced_ Logistics			4.24e-06** (1.72e-06)	-8.13e-06*** (1.70e-06)	-6.37e-06*** (1.06E-06)	-9.68e-06*** (1.98e-06)	-1.31e-05*** (2.36e-06)	-1.45e-05 (1.03e-05)	-4.98e-06 (5.41e-06)	-5.44e-06** (2.35e-06)
CUSIT * Outsourced_ Logistics			6.19e-06*** (1.79e-06)	-8.57e-06*** (2.20e-06)	-1.06e-05*** (2.77E-06)	-7.83e-06*** (2.32e-06)	-2.74e-06 (2.28e-06)	9.04e-07 (1.35e-05)	1.44e-06 (5.79e-06)	-1.17e-05 (7.43e-06)
Intermediate Inputs	0.639*** (0.010)									
Constant	1.275*** (0.0518)	1.653*** (0.064)	1.526*** (0.073)	1.597*** (0.063)	1.636*** (0.094)	1.682*** (0.068)	1.710*** (0.076)	1.720*** (0.082)	1.691*** (0.060)	1.491*** (0.215)
Observations	1105	1105	1105	595	595	680	765	560	765	510

Notes: (1) OwnIT and CUSIT are an industry's IT investment and its customers' IT investments, respectively. OwnIT and CUSIT are in levels and other variables are in natural logs. (2) We control for panel-level heteroskedasticity (HE) and panel specific autocorrelation (PSAR1) for Dataset I. Details of the year fixed effects are suppressed. Standard errors are in parentheses following the estimated coefficients. (3) For redefined IT 1, we use communication assets as IT capital (Z). For redefined IT 2, we use the sum of communication and computers as IT capital (Z). *p<0.10, **p<0.05, ***p<0.01.

In Dataset I, we group the industries by 2-digit subheadings resulting in 19 sector dummies. We continue to control for panel-level HE and PSAR1. The estimation results with sector fixed effects for the pre-Internet era are reported in Column 5 of Table A5, and for the post-Internet era are reported in Column 2 of Table A6. These results are similar to those in Columns 4 of Table A5 and Column 1 of Table A6, respectively. In

Table A6 The Estimation Results for the Post-Internet Era based on Dataset I

Variables	Main Estimation 1994-1999 (1)	Robustness Tests: 2-digit SIC Dummies (2)	Time Span 1995-1999 (3)	Tim Span 1996-1999 (4)	Redefined IT 1 (5)	Redefined IT 2 (6)	GMM Estimators (7)
Non-IT Capital	0.058*** (0.009)	0.067*** (0.017)	0.045*** (0.008)	0.063*** (0.009)	0.011 (0.010)	-0.020*** (0.007)	0.068 (0.0602)
Labour	0.264*** (0.009)	0.194*** (0.015)	0.276*** (0.010)	0.265*** (0.009)	0.204*** (0.009)	0.231*** (0.008)	0.289*** (0.0564)
IT Capital	0.085*** (0.006)	0.084*** (0.015)	0.084*** (0.006)	0.090*** (0.005)	0.065*** (0.004)	0.072*** (0.004)	0.112*** (0.0257)
Non-Logistics	0.513*** (0.011)	0.509*** (0.015)	0.537*** (0.011)	0.512*** (0.012)	0.575*** (0.008)	0.582*** (0.009)	0.509*** (0.0703)
Outsourced Logistics	0.116*** (0.008)	0.161*** (0.009)	0.111*** (0.008)	0.120*** (0.007)	0.164*** (0.008)	0.162*** (0.007)	0.085** (0.0365)
CustomerIT	0.053*** (0.006)	0.033*** (0.010)	0.065*** (0.006)	0.077*** (0.005)	0.057*** (0.007)	0.049*** (0.004)	0.070** (0.0357)
OwnIT * Outsourced_ Logistics	5.63e-06*** (1.79e-06)	9.80e-06*** (1.53E-06)	7.63e-06*** (1.88e-06)	9.40e-06*** (1.58e-06)	5.89e-05*** (1.64e-05)	2.71e-05*** (4.34e-06)	6.29e-06 (9.58e-06)
CUSIT * Outsourced_ Logistics	8.67e-06*** (2.10e-06)	4.29e-06** (2.17E-06)	1.18e-05*** (2.16e-06)	1.48e-05*** (2.07e-06)	8.64e-05*** (1.35e-05)	1.24e-05*** (2.98e-06)	1.36e-05 (1.40e-05)
Constant	1.355*** (0.082)	1.508*** (0.093)	1.145*** (0.088)	1.060*** (0.081)	1.603*** (0.010)	1.579*** (0.074)	1.002** (0.434)
Observations	510	510	425	340	480	504	425

Notes: (1) OwnIT and CUSIT are an industry's IT investment and its customers' IT investments, respectively. OwnIT and CUSIT are in levels and other variables are in natural logs. (2) We control for panel-level heteroskedasticity (HE) and panel specific autocorrelation (PSAR1) for Dataset I. Details of the year fixed effects are suppressed. Standard errors are in parentheses following the estimated coefficients. (3) For redefined IT 1, we use communication assets as IT capital (Z). For redefined IT 2, we use the sum of communication and computers as IT capital (Z). *p<0.10, **p<0.05, ***p<0.01.

Dataset II, we classify the industries into a durable goods sector and a nondurable goods sector according to the BEA. The results of our regression with sector-fixed effects and controlling for panel-level HE and AR1 are presented in Column 4 of Table A7, and they are similar to those in Column 3 of Table A7.

D.2. Estimates Using Different Time Spans

We split the sample in Dataset I at 1993/1994 because the commercialization of the Internet started as of 1994. However, the widespread diffusion of the Internet across the economy may have taken time. To address this concern, we also use 1994 and 1995 as cutoff for sample split of Dataset I, and estimated our model controlling for year fixed effects, panel-level HE, and PSAR1. The results for different time splits are reported in Columns 6 & 7 of Table A5 and Columns 3 & 4 of Table A6. The estimation results are consistent with the results based on the previous time split.

For Dataset II, the e-commerce collapse in 2000 might be considered as an outlier, so we dropped year 2000. The estimation results based on the data from 2001 through 2008 are reported in Column 5 of Table A7. The results are similar to those in Column 3 of Table A7.

D.3. Estimation with Redefined IT Capital

IT capital stocks in both Datasets include a variety of IT assets. We use the total of those IT assets as IT capital in our model for the following reasons. First, it is reasonable to use total IT assets as the measure of IT capital because all types of IT assets are involved in external transactions and internal governance. Second, information systems implementations become increasing integrated. The same systems have functions for internal production management and external coordination, so it is hard to determine which IT investment is used for what purpose. For example, enterprise resource planning (ERP) systems evolved from prior MRP (materials requirements planning) I and MRP II implementations, and these systems dealt with material flows, inventory and logistics. In the 1990s ERP systems were organization-wide and integrated functions dealing with internal management—such as the functions of production management, accounting management, and human resource management. Since the early 2000s, ERP systems have also been used for external coordination, such as supply chain management and customer relationship management.[1] Therefore, in integrated information systems implementations it is impossible to identify specific IT investments with individual activities like logistics.

For a robustness check, we provide results using subsets of our measure of IT capital. We separately define IT capital as communication (Redefined IT 1), and as computers and communication (Redefined IT 2) for Dataset I. For Dataset II, we separately define IT capital as communication (Redefined IT 1), and computers, software, and communication (Redefined IT 2). The estimation results with redefined IT capital are shown in Columns 8 and 9 of Table A5, Columns 5 and 6 of Table A6, and Columns 7 and 8 of Table A7. The estimated coefficients of interaction terms are positive and significant during the post-Internet era, which is similar to the main estimation results based on our broader measures of IT capital.

D.4. Estimates with Instrumental Variables

In general, endogeneity can be caused by omitted variables, simultaneity, and measurement errors (Wooldridge 2002). In the context of our study, it is possible that some omitted variables such as other productivity-related organizational initiatives may be correlated with the independent variables in our models, such as IT or outsourced logistics. Moreover, the joint occurrence and consequent complementarity between IT and outsourced logistics could be driven by common underlying factors. There is also potential for measurement errors in the variables due to aggregation because our variables are measured at the industry level. There might also be concerns about endogeneity caused by simultaneity. Simultaneity arises when explanatory variables in our model are determined simultaneously along with the dependent variable output. For example, an increase in IT capital increases output, and meanwhile, shocks in output are likely to trigger temporary adjustments in IT capital.

First, we tested for endogeneity of eight variables: IT capital, non-IT capital, labor, outsourced logistics, non-outsourced logistics, and customers' IT as inputs, as well as two interaction terms. Like previous related studies (e.g., Stiroh 2002, Han et al. 2011, Han and Mithas 2013), we use one-year lags of these variables as instruments, and we checked for the endogeneity of our inputs and interaction terms based on Hansen's J and the C statistic tests for exogeneity (Baum et al. 2003). We run these tests for the all eight variables jointly and for two interaction terms separately. All of the tests suggest that we cannot reject the null hypothesis that our input variables and two interaction variables are exogenous. For example, The Hansen-Sargan C

[1] *We discuss the development of ERPs in our alternative explanations section later.*

Table A7 The Estimation Results for the Post-Internet Era Based on Dataset II

Variables	The Simple CD (1)	The Extended CD (2)	Main Estimation 2000-2008 (3)	Robustness Test: Sector Dummies (4)	Robustness Test: Time Span 2001-2008 (5)	Robustness Test: Redefined IT 1 (6)	Robustness Test: Redefined IT 2 (7)	Robustness Test: GMM Estimators (8)
Non-IT Capital	0.196*** (0.044)	0.202** (0.083)	0.164*** (0.062)	0.187*** (0.062)	0.188** (0.074)	0.275*** (0.050)	0.185*** (0.049)	0.032 (0.0875)
Labour	0.122*** (0.028)	0.209*** (0.041)	0.141*** (0.032)	0.112*** (0.032)	0.146*** (0.036)	0.129*** (0.032)	0.103*** (0.029)	0.034 (0.0238)
IT Capital	0.062** (0.0273)	0.042 (0.046)	0.061* (0.037)	0.047 (0.036)	0.054 (0.043)	-0.021 (0.030)	0.033 (0.027)	0.081 (0.0497)
Non-Logistics		0.521*** (0.026)	0.536*** (0.025)	0.550*** (0.024)	0.526*** (0.026)	0.572*** (0.025)	0.577*** (0.025)	0.748*** (0.0431)
Outsourced Logistics		0.068 (0.051)	0.107*** (0.038)	0.102*** (0.036)	0.104** (0.047)	0.067** (0.033)	0.103*** (0.0330)	0.044* (0.0267)
CustomerIT		0.011 (0.031)	0.082** (0.033)	0.090*** (0.031)	0.076** (0.037)	0.055 (0.035)	0.074*** (0.029)	0.110*** (0.0338)
OwnIT * Outsourced_ Logistics			3.88e-06*** (1.47e-06)	4.48e-06*** (1.40e-06)	3.90e-06** (1.87e-06)	4.55e-05*** (1.70e-05)	5.00e-06*** (1.91e-06)	1.48e-06* (8.87e-07)
CUSIT * Outsourced_ Logistics			2.35e-06** (1.10e-06)	2.38e-06** (1.10e-06)	2.24e-06* (1.20e-06)	9.84e-06 (1.41e-05)	1.38e-06 (1.51e-06)	-1.02e-06 (2.24e-06)
Intermediate Inputs	0.611*** (0.024)							0.597 (0.625)
Constant	1.278*** (0.274)	1.138** (0.531)	0.697 (0.465)	0.538 (0.443)	0.611 (0.534)	0.477 (0.376)	0.668* (0.393)	144
Observations	162	162	162	162	144	162	162	144

Notes: (1) OwnIT and CUSIT are an industry's IT investment and its customers' IT investments, respectively. OwnIT and CUSIT are in levels and other variables are in natural logs. (2) We control for panel-level heteroskedasticity (HE) and first-order autocorrelation (AR1) for Dataset II. Details of the year fixed effects are suppressed. Standard errors are in parentheses following the estimated coefficients. (3) For redefined IT 1, we use communication assets as IT capital (Z). For redefined IT 2, we use the sum of communication, computers, and software as IT capital (Z). *p<0.10, **p<0.05, ***p<0.01.

statistic cannot reject the exogeneity of two interaction terms based on the pre-Internet era from 1987 to 1993 ($\chi^2(2) = 0.633$, $p = 0.729$), the post-Internet era from 1994 to 1999 ($\chi^2(2) = 0.624$, $p = 0.732$), and the time period from 2000 to 2008 ($\chi^2(2) = 1.145$, $p = 0.564$).

Second, we applied the two-step Generalized Method of Moments (GMM) procedure for two Datasets. According to Baum et al. (2003), the standard IV estimator is a special case of GMM, and "the advantages of GMM over IV are clear: if heteroskedasticity is present, the GMM estimator is more efficient than the simple IV estimator, whereas if heteroskedasticity is not present, the GMM estimator is no worse asymptotically than the IV estimator" (p.11). As the presence of heteroskeasticity is suggested by our tests for both datasets and there is panel-specific autocorrelation, we use the two-step efficient GMM in the presence of arbitrary heteroskedasticity and autocorrelation procedure. For the two-step GMM, the assumption that the instruments Z are exogenous can be expressed as $E(Z_i u_i) = 0$, where u_i is the error term. The instruments give us a set of moments, and the exogeneity of the instruments means that there are moment conditions or orthorganlity conditions that satisfy $E(g(\beta)) = E(Z_i u_i) = 0$. Each moment equation corresponds to a sample moment; the intuition behind GMM is to choose an estimator of β that solves a sample moment $E(\bar{g}(\beta)) = 0$

(Baum et al. 2003, p.6). The first step of GMM is to run the suspect endogenous variables on instruments, and form the residuals, which are used to form the optimal weighting matrix. Next, calculate the efficient GMM estimator and its variance-covariance using the optimal weighting matrix.

Although our econometric adjustment with PSAR1, year fixed effects, and time-invariant industry-specific effects already help relieve the endogeneity concerns, we further address such concerns by providing estimations using instrumental variables. The lagged values of independent variables are not always perfect instruments, but they are used often, especially in the absence of alternative instruments (Han and Mithas 2013, Kennedy 2003).

The feasible efficient two-step GMM estimates are consistent with our main results. The estimated coefficients of two interaction terms are negative and significant for the dataset from 1987-1993 (Column 10, Table A5), while the estimates of *OwnIT * OutsourcedLogistics* becomes positive and significant for the dataset from 2000-2008 (Column 8, Table A7), just like our main results. The non-significance of the interaction terms in some cases is likely due to the loss of efficiency. In general, in using the efficient GMM estimation, the cost is loss of efficiency for the sake of consistency (Baum et al. 2003, p19-20), which may cause large asymptotic variance of the GMM estimator. Therefore, it is reasonable that some of the GMM estimators are not significant.

D.5. Alternative Explanations

Although our estimation results using different years (1993, 1994, and 1995) as the cutoff for the pre- and post-Intent eras consistently show that IT and outsourced logistics have become complements after the commercialization of the Internet, there may be concerns about other factors that differ pre- and post-Internet that can influence logistics outsourcing. To address such concerns, we analyze the potential factors that may affect logistics outsourcing pre- and post-Internet and discuss how we can rule them out.

First, a critical IT development that in part coincided with the development of the Internet was ERP systems. According to the documented history of ERP (Wallace and Kremzar 2001, Rashid et al. 2002, Umble et al. 2003, Jacobs and Weston Jr. 2007), ERP was developed based on its predecessor systems, Manufacturing Resources Planning (MRP) and MRP II. MRP was first developed in the late 1960s and was used for scheduling materials for complex manufacturing products. In 1980s, the system evolved to MRP II that incorporated the financial accounting system and the financial management system along with the manufacturing and materials management systems. The term enterprise resource planning (ERP) was coined in the early 1990s when MRPII was expanded to incorporate all resource planning for the entire enterprise. Since the mid-1990s, early ERP systems experienced significant growth driven by the need to streamline internal business process, to integrate disparate systems through an enterprise, to resolve Y2K problems, to solve global issues, and to save costs (Themistocleous et al. 2001, Ehie and Madsen 2005, Nah and Delgado 2006, Jacobs and Weston Jr. 2007, McAfee and Brynjolfsson 2008). Indeed, the hype around Y2K is sometimes considered the first wave of ERP (Møller 2005).

In the 2000s, early ERP evolved to extended ERP, or ERP II as coined by GartnerGroup in 2000 (Møller 2005), where the goal of ERP II was to optimize the inter-enterprise collaborative operational processes (Koh et al. 2008). At this time vendor market became consolidated, more modules and functions were developed as "add-ons" (Jacobs and Weston Jr. 2007), and ERP II stretched across the supply chain to incorporate customer relationship management and supply chain management (Rashid et al. 2002) . Indeed, several case studies of extended ERP (or ERP II) are reported from the 2000s (Ekman et al. 2014).

Although there is an overlap in the start of the commercially-available Internet and the development of enterprise software applications parts of ERPs in the mid-1990s (McAfee and Brynjolfsson 2008), ERP systems of the 1990s focused on internal cross-functional integration rather than integration of logistics across the supply chain. With our main results about the impact of IT on outsourced logistics based on Dataset I, where we define the pre-Internet era from 1987 to the mid-1990s and the post-Internet era from the mid-1990s to 1999, our post-Internet era does not correspond with ERP II. Rather, our Dataset II contains the period in which extended ERP was developed, that is also part of the post-Internet era. Due to the timing of ERP II being a half a decade later than the commercialization of the Internet, ERP II cannot be an alternative explanation for our main results. However, the results from Dataset II that continue to show the complementary relationship between IT and outsourced logistics may contain the influence of IT investments related to ERP II.

Second, the development of logistics outsourcing from the 1970s to the mid-1980s was driven by regulatory, economic, and technological factors. In particular, the deregulation of transportation in the 1970s and early 1980s dramatically influenced the for-hire transportation market in terms of freight rate, service, completion etc. (McGinnis 1990, Sheffi 1990). Also, globalization of business and the concentration on core business increased firms needs for high-level logistics services and reengineering logistics systems (Sheffi 1990, Rao and Young 1994, Razzaque and Sheng 1998). Information technology improved logistics coordination and communication among buyers, sellers, and logistics service providers, reducing coordination costs and facilitating strategic partnerships (Sheffi 1990, Lewis and Talalayevsky 2000, Marasco 2008).

Given the time periods of our datasets, 1987 to 2008, we can rule out the impact of deregulation of transportation industries that happened mostly before the early 1980s. By controlling for year fixed effects and industry fixed effects, we are also able to control for the influence of economy-wide events and trends.

Third, during the time periods covered by our datasets there was an increase in international trade, some of which was overseas sourcing. Our data is based on domestic economic activity from industries in the I-O tables, and consequently there is no direct effect of overseas sourcing on our empirical results. Moreover, analyses of transaction flows between industries in the I-O tables finds there has not been much change in the relative proportions of purchases most industries make from their supplying industries over the time periods we study, which suggests an absence of effects of overseas sourcing on domestic sourcing (Gong et al. 2014). Finally, the production function framework allows us to estimate the relationship between IT and outsourced logistics from a production system perspective, which controls the impact of other production factors on outsourced logistics.

References

Baum, C. F., M. E. Schaffer, S. Stillman. 2003. Instrumental variables and GMM: Estimation and testing. *Stata Journal* **3**(1) 1–31.

Brynjolfsson, E., L. Hitt. 1996. Paradox lost? Firm-level evidence on the returns to information systems spending. *Management Science* **42**(4) 541–558.

Cheng, Z., B. R. Nault. 2007. Industry level supplier-driven IT spillovers. *Management Science* **53**(8) 1199–1216.

Cheng, Z., B. R. Nault. 2012. Relative industry concentration and customer-driven IT spillovers. *Information Systems Research* **23**(2) 340–355.

Dewan, S., K. L. Kraemer. 2000. Information technology and productivity: Evidence from country-level data. *Management Science* **46**(4) 548–562.

Ehie, I. C., M. Madsen. 2005. Identifying critical issues in enterprise resource planning (ERP) implementation. *Computers in industry* **56**(6) 545–557.

Ekman, P., P. Thilenius, T. Windahl. 2014. Extending the ERP system: Considering the business relationship portfolio. *Business Process Management Journal* **20**(3) 480–501.

Gong, F., B. Koh, B. R. Nault. 2014. The impact of IT on the structure of production. Working paper, December.

Han, K., R. J. Kauffman, B. R. Nault. 2011. Returns to information technology outsourcing. *Information Systems Research* **22**(4) 824–840.

Han, K., S. Mithas. 2013. Information technology outsourcing and non-IT operating costs: An empirical investigation. *MIS Quarterly* **37**(1) 315–331.

Jacobs, F. R., F. C. Weston Jr. 2007. Enterprise resource planning (ERP)—a brief history. *Journal of Operations Management* **25**(2) 357–363.

Kennedy, P. 2003. *A guide to econometrics*. MIT press, Cambridge, Massachusetts.

Koh, S. C. L., A. Gunasekaran, D. Rajkumar. 2008. ERP II: The involvement, benefits and impediments of collaborative information sharing. *International Journal of Production Economics* **113**(1) 245–268.

Lewis, I., A. Talalayevsky. 2000. Third-party logistics: Leveraging information technology. *Journal of Business Logistics* **21**(2) 173–185.

Lichtenberg, F.R. 1995. The output contributions of computer equipment and personnel: A firm-level analysis. *Economics of Innovation and New Technology* **3** 201–217.

Marasco, A. 2008. Third-party logistics: A literature review. *International Journal of Production Economics* **113**(1) 127–147.

McAfee, A., E. Brynjolfsson. 2008. Investing in the IT that makes a competitive difference. *Harvard Business Review* **86**(7/8) 98.

McGinnis, M. A. 1990. The relative importance of cost and service in freight transportation choice: before and after deregulation. *Transportation Journal* 12–19.

McGuigan, J. R., R. C. Moyer, F. H. deB Harris. 2010. *Managerial economics: Application, Strategy, and Tactics*. 12th ed. South-Western, Cengage Learning.

Møller, C. 2005. ERP II: A conceptual framework for next-generation enterprise systems? *Journal of Enterprise Information Management* **18**(4) 483–497.

Nah, F. F., S. Delgado. 2006. Critical success factors for enterprise resource planning implementation and upgrade. *Journal of Computer Information Systems* **46**(5) 99.

Rao, K., R. R. Young. 1994. Global supply chains: Factors influencing outsourcing of logistics functions. *International Journal of Physical Distribution & Logistics Management* **24**(6) 11–19.

Rashid, M.A., L. Hossain, J. D. Patrick. 2002. *The evolution of ERP systems: A historical perspective*. Idea Group Publishing, Hershey, Pennsylvania.

Razzaque, M. A., C.C. Sheng. 1998. Outsourcing of logistics functions: A literature survey. *International Journal of Physical Distribution & Logistics Management* **28**(2) 89–107.

Rindfleisch, A., J. B. Heide. 1997. Transaction cost analysis: Past, present, and future applications. *The Journal of Marketing* **61**(4) 30–54.

Sheffi, Y. 1990. Third party logistics–present and future prospects. *Journal of Business Logistics* **11**(2) 27–39.

Stiroh, K. J. 2002. Information technology and the U.S. productivity revival: What do the industry data say? *American Economic Review* **92**(5) 1559–1576.

Themistocleous, M., Z. Irani, R. M. O'Keefe. 2001. ERP and application integration: Exploratory survey. *Business Process Management Journal* **7**(3) 195–204.

Umble, E. J., R. R. Haft, M. M. Umble. 2003. Enterprise resource planning: Implementation procedures and critical success factors. *European journal of operational research* **146**(2) 241–257.

Wallace, T. F., M. H. Kremzar. 2001. *ERP: Making it happen*. John Wiley & Sons, Inc., New York.

Williamson, O. E. 1981. The economics of organization: The transaction cost approach. *American Journal of Sociology* **87**(3) 548–577.

Williamson, O. E. 1985. *The Economic Institutions of Capitalism*. Free press, New York.

Williamson, O. E. 1989. Transaction cost economics. *Handbook of industrial organization* **1** 135–182.

Wooldridge, J. M. 2002. *Econometric Analysis of Cross Section and Panel Data*. MIT Press, Cambridge, MA.