Inf Technol Manag (2011) 12:409–429
DOI 10.1007/s10799-010-0078-x

# Internet-based selling technology and e-commerce growth: a hybrid growth theory approach with cross-model inference

**Shu-Chun Ho · Robert J. Kauffman · Ting-Peng Liang**

Published online: 8 December 2010


**Abstract** Innovations associated with information and communication technology (ICT) have opened up new opportunities for the global economy and ushered in the age of e-commerce. Our objective in this research is to explore the role of Internet-based selling technology, which acts as technology infrastructure for B2C e-commerce growth at the country level. This study proposes the use of a new hybrid growth theory approach as the theoretical basis for examining exogenous and endogenous factors that influence e-commerce growth over time. We estimate three different models to evaluate their explanatory capabilities. We investigate a panel-corrected feasible generalized least squares regression that incorporates the direct effects of country-level variables. We also specify an endogeneity-adjusted two-stage least squares model and estimate it with an embedded technology adoption function in a simultaneous equation model. This permits the analysis of the relevance of IT infrastructure, as well as reverse causality between e-commerce growth and Internet-based selling technology. We test these models using archival data for four different regions, based on either 24 or 42 countries around the world, depending on the data requirements of the models. Our empirical tests evaluate quasi-production environmental inputs, in which technology determines the environment of production of e-commerce services. Our main finding is that both endogenous variables (e.g., Internet user penetration, capital invested in telecommunication) and exogenous variables (international openness) drive the GDP-normalized level of B2C e-commerce revenues over time. A second main finding is that it is useful to include an embedded technology adoption function in a modeling specification for growth, since growth is founded on the availability of relevant IT infrastructure that is made possible by the availability of venture capital. In addition, B2C e-commerce revenue growth and venture capital also contribute to the adoption of Internet-based selling technology. We discuss our overall approach for the interpretation of the strength of our main findings, as well as the policy implications, and why our hybrid growth theory approach is useful.

**Keywords** Cross-model inference · E-commerce · Economic analysis · Empirical research · Endogenous growth · Exogenous growth · Growth theory · Hybrid growth model · ICT · Internet-based selling technology adoption

S.-C. Ho (✉)
National Kaohsiung Normal University, Kaohsiung, Taiwan, ROC
e-mail: sch@nknu.edu.tw

R. J. Kauffman
W. P. Carey School of Business, Arizona State University, Tempe, AZ 85287, USA
e-mail: rkauffman@asu.edu

T.-P. Liang
College of Management, National Sun Yat-sen University, Kaohsiung, Taiwan, ROC
e-mail: tpliang@mail.nsysu.edu.tw

T.-P. Liang
City University of Hong Kong, Hong Kong SAR, China

## 1 Introduction

The development of information and communication technology (ICT) has opened up opportunities for e-commerce and new economic growth worldwide. However, ICT infrastructure and e-commerce growth still is somewhat limited to the more developed countries. The

available evidence on productivity gains related to the use of ICT suggests that they are still highly concentrated in a small group of developed countries, led by the US, and in selected emerging economies, such as Singapore, South Korea and China. According to Baumol [9], the world is divided into distinct groups of countries with their own common trends—something that we also expect to see in the e-commerce context. This unbalanced development also occurs with technology adoption and innovation diffusion due to barriers that are known to exist in less developed countries and are weaker in more developed countries [68]. Technological innovations are only adopted and diffused in countries that have high productivity levels, for the most part [89]. In developing countries, technology adoption and diffusion lags far behind. The disparity across countries in technology adoption and e-commerce is the subject of high research interest for academicians and practitioners (e.g., [1, 91, 92]). The current lack of country-level data, measurement approaches, and appropriate theory bases has led to a greater challenge for understanding the relationship between technology and e-commerce growth.

International organizations such as the United Nations and the Organization of Economic Cooperation and Development (OECD) have endeavored to help the developing countries to build up their ICT infrastructure and e-commerce environment by providing financial support, policy advice, and legal frameworks. They have found that investments in ICT infrastructure result in higher national competitiveness, and motivate e-commerce growth [62, 82]. E-commerce also has collateral effects, for example, on the growth of communications, finance, retail trade, education, health, and government, which account for about 50% of GDP in developed countries [66]. Since e-commerce growth impacts many sectors in a national economy, the investigation of the determinants of e-commerce growth at the country level will be useful to support a deep managerial and policy-related understanding.

Our objective is to apply a *hybrid growth theory* to explain the determinants of B2C e-commerce revenue growth across countries. We are specifically interested in how a macro-level growth theory can explain the relationship between Internet-based selling technology and B2C e-commerce growth. We aim to answer the following questions, while demonstrating our new theoretical perspective and some innovative methods that can be used to understand them. What are the factors that drive B2C e-commerce revenues at the country level? What role does Internet-based selling technology adoption play in country-level B2C e-commerce revenue growth? Does B2C e-commerce revenue growth affect Internet-based selling technology adoption? Is there a feedback loop between Internet-based selling technology adoption and B2C e-commerce revenue growth, indicating reverse causality? Can we provide rich empirical evidence of the efficacy of the theory through a cross-model inference approach-based empirical analysis?

The remainder of this article is laid out as follows. We review the available studies on e-commerce in different countries and the economic theory of growth in Sect. 2. Section 3 presents our theoretical perspective and discusses the development of our primary hypotheses. Section 4 further discusses our data collection, variables, and empirical models and analysis approach, and main results. Section 5 interprets our findings and assesses the appropriateness of our models, inquiry and cross-model inference approach. Section 6 concludes with the contributions and limitations of this research.

## 2 Theoretical background

This section reviews prior research on e-commerce growth in different national settings. We also discuss the background on growth theory in economics. We also evaluate the potential exogenous and endogenous variables that drive economic growth, and the related variables that are likely to affect e-commerce growth.

### 2.1 National-level e-commerce studies

The development of e-commerce across nations has drawn considerable research interest in the past decade [37, 60, 62, 67, 90]. The prior research adopted different theoretical perspectives and explored different levels of analysis. They include e-commerce adoption at the individual level, the firm level, and the country level. Xu et al. [87], Zhu et al. [91, 92], and Kraemer et al. [54] applied the elements of the technology-organization-environment framework of Tornatzky and Fleischer [78] to identify inhibitors and facilitators of firm-level e-business adoption across countries. In other related work, Meso et al. [64] used archival data to examine the relationships among national information infrastructure, governance, and socio-economic development for a number of developing countries. In addition, Martinez and Williams [62] applied institutional theory and entrepreneurship theory to examine the impact of ICT adoption in e-commerce across countries. We summarized these the studies in Table 1.

At the aggregate level of the economy, a number of different factors are likely to lead to impacts on e-commerce growth. Because e-commerce affect different economic sectors, it is valuable to investigate the impacts of these factors at the macro-level. Studies of technology that examine different countries typically suffer from limited availability and constrained access to the appropriate national statistics. Often, as a result, there are no perfect data sets that will fit a single study of different countries'

**Table 1** E-commerce adoption and diffusion studies across different countries

| Authors | Research theme | Theory or framework | Level of analysis | Countries | Explanatory variables |
|---|---|---|---|---|---|
| Mahmood et al. [60] | Online shopping experience across countries | Online shopping framework | Individual-level, secondary data | 26 | Economic condition<br>Educational level<br>Technological savvy<br>Trust |
| Kraemer et al. [55] | Globalization, e-commerce growth, firm performance | Conceptual framework | Firm-level, surveys | 10 | Firm globalization<br>Firm performance |
| Zhu and Kraemer [90] | Value of e-business by organizations | Technology-organization-environment (TOE) framework | Firm-level, survey | 10 | Technology competence<br>Firm size<br>International scope<br>Financial commitment<br>Competitive pressure<br>Regulatory support |
| Zhu et al. [92] | E-business adoption | TOE, theory of innovation assimilation | Firm-level, survey | 10 | Technology readiness<br>Technology integration<br>Firm size, global scope<br>Managerial obstacles<br>Competition intensity<br>Regulatory environment |
| Ho et al. [37] | Macro-level of western European countries e-commerce growth | Hybrid growth theory | Country-level, secondary data | 17 | Credit card availability<br>Educational level<br>Internet penetration<br>Telecom investment intensity<br>Venture capital |
| Meso et al. [64] | Information infrastructure, governance and socio economic development | Conceptual model | Country-level, secondary data | 144 | Telephone density, Internet density, personal computer density, television density, radio density, newspaper circulation density, effectiveness of central government, regulatory quality, rule of law, corruption control, voice and accountability, political stability, GDP_PPP, purchasing power parity index, life expectancy index, education index |
| Martinez and Williams [62] | Global ICT adoption | Institutional theory, entrepreneurship theory | Country-level, secondary data | 80 | Institutional quality<br>Intensity of new business creation<br>Entrepreneurship |

experience. Language differences also constrain the accessibility of archival data. Country-level studies that apply secondary data from different sources, in contrast, permit researchers to offer different perspectives and they may get around some of the constraints associated with the lack of access to data. Nevertheless, the diverse sources and measurement approaches that are applied in different countries also create some issues with the comparability of their data. So it isn't always likely to be easy to test the relevant theories that seem appropriate. Given the constrained availability of country-level data and the lack of common measurement approaches, there are significant challenges for conducting effective country-level studies of e-commerce growth.

### 2.2 The exogenous and endogenous growth theory perspectives

Growth theory has been widely applied to study the economic performance of different countries. *Exogenous growth theory* accounts for economic growth based on sustained technological advances, a constant capital-output ratio and labor share, and stable interest rates on capital [44]. It assumes that technological change is *exogenous*—externally-led, and not produced within an economy—so the same technological opportunities are available everywhere, and that countries have closed economic systems. Economic growth, from this viewpoint, is the result of

forces that affect a country from outside of its economic system. Exogenous technological progress is a key determinant of long-term per capita output growth.

On the other hand, *endogenous growth theory* argues that economic growth is the endogenous outcome of an economic system, instead of the result of external factors [72, 73]. Endogenous growth means that output growth is more responsive to factors that occur within an economy than those outside it, although exogenous factors also may play some role in contributing to the growth rate of output. Endogenous growth theory has been applied in different multiple country-level studies that involve the effects of technological diffusion on economic growth [5, 35, 71]. These studies show that differences in policies and preferences may lead to permanent differences in growth rates of per capita output. Endogenous growth theory suggests that technological innovations are driven by the profit motives of agents within an economy, and government policies on technological innovation can affect long-run growth [2, 3, 35, 58]. Further, endogenous technology progress based on the relevant input factors suggests that economic growth is a two-way interaction between technology and the economy.

A key feature of Internet-based technology and e-commerce is that they permit business to overcome geographical barriers. Thus, we anticipate that e-commerce growth will not be driven by factors that are internal to a country only; exogenous factors, and especially those that reflect external impacts from technological progress also should be important [26, 27]. The hybrid perspective that we will offer on exogenous and endogenous growth provides an alternative explanation for economic productivity across countries, and also serves as an appropriate theoretical base for explaining e-commerce growth at the country level.

### 2.3 The role of Internet-based selling technology adoption

Previous literature has indicated a number of possible variables associated with economic growth and e-commerce growth. The most important ones are technological innovation and ICT adoption. Economists view technological innovations as a stimulus to production without necessitating increased levels of input in the production function. A series of studies identified and modeled technology innovation and adoption relative to economic performance [8, 11, 13, 32, 62, 89]. Researchers have used different variables to measure the impact of technology adoption and diffusion at the country level of economic performance [19, 32]. Since e-commerce is built on technology infrastructure, technology investments of different kinds by firms, ICT investments at the country, and other factors are likely to play a role in driving e-commerce growth [62]. In this context, *installed computing capacity* and *Internet access* are alternative measures of technology adoption because people cannot utilize e-commerce without such infrastructure. There are different kinds of technology and infrastructure investments that can be made, so it's a challenge to measure the impact on economic performance.

Technology investments across countries and the consequent impacts on the global information economy have generated interest among researchers and policy-makers [7, 25, 67, 70, 80, 81]. However, challenges related to how such technology adoption works and the evaluation and measurement of its impacts on the economy remain. There is a lack of consensus about how measurement should be carried out, as well as issues with the comparability of data [25, 79]. International organizations, meanwhile, have promoted the growth potential of ICT to the international community [79]. For example, the United Nations has used Internet and mobile phone penetration, the trade of ICT-related goods, and e-commerce transactions as ICT adoption indicators at the country level.

In the B2C e-commerce growth setting, technology adoption applies to two different levels: individuals and firms. Computers per capita, Internet user penetration, broadband penetration, and mobile phone penetration are primary indicators for Internet technology adoption at this level. Previous research indicates that developing countries can benefit from globalization if they are able to successfully encourage technology diffusion and build the requisite skill levels of their domestic labor force [78]. The potential growth of Internet users encourages the additional development of Internet technology and e-commerce infrastructure. This is because the number of Internet users reflects the size of the market in which B2C e-commerce transactions occur. On the other hand, the number of secure servers may be a useful way to represent or proxy for Internet-based selling technology adoption, reflecting firm-level efforts to supply online services to the market [66]. Online stores, online banking and financial services, and other online service providers use secure socket layer (SSL) sites to ensure that there are encrypted connections between servers and browsers. Secure servers ensure that sensitive information such as credit card and personal information can be encrypted and transmitted in a secure way over the Internet [66]. Secure servers grew in number from just 20,000 in 1998 to more than 664,000 worldwide in 2008, and they provide a ready means to measure the growing installed based of relevant Internet technology. Meanwhile, Internet user penetration and secure server penetration have increased every year and share similar growth patterns. Meanwhile, worldwide Internet user penetration reached 24.4% in 2008, a fourfold increase of the number since 2001. See Table 2.

To further understand Internet-based technology adoption from the demand and supply sides, we will look into it

**Table 2** Internet user and secure server penetration rates, by country in 2008

| Internet user penetration (42 Countries/Regions) | | | | Secure server penetration (24 Countries/Regions) | |
|---|---|---|---|---|---|
| Country | Penetration % | Country | Penetration % | Country | Penetration % |
| Netherlands | 87.1 | Czech | 52.7 | US | 1.13 |
| Norway | 87.0 | Poland | 49.7 | Netherlands | 0.97 |
| Denmark | 84.8 | Italy | 49.4 | Denmark | 0.96 |
| Finland | 82.2 | Portugal | 41.8 | Switzerland | 0.93 |
| Sweden | 82.2 | Brazil | 40.1 | New Zealand | 0.91 |
| UK | 79.7 | Colombia | 36.6 | Australia | 0.90 |
| South Korea | 77.1 | Chile | 32.5 | Canada | 0.87 |
| Switzerland | 76.2 | Greece | 32.4 | UK | 0.84 |
| Germany | 76.0 | Argentina | 28.1 | Norway | 0.78 |
| Canada | 74.9 | Venezuela | 25.8 | Sweden | 0.72 |
| US | 72.4 | Vietnam | 25.5 | Finland | 0.63 |
| Australia | 70.8 | Russia | 24.7 | Germany | 0.51 |
| Japan | 70.7 | Thailand | 23.4 | Austria | 0.45 |
| New Zealand | 70.4 | China | 22.6 | Japan | 0.44 |
| Belgium | 70.0 | Mexico | 21.6 | France | 0.16 |
| Singapore | 68.3 | Indonesia | 12.7 | Spain | 0.16 |
| Taiwan | 66.0 | India | 8.4 | Czech | 0.14 |
| Ireland | 64.6 | Philippines | 6.6 | Portugal | 0.10 |
| Malaysia | 61.2 | | | Korea | 0.10 |
| Austria | 59.3 | | | Italy | 0.09 |
| Hong Kong | 59.0 | | | Hungary | 0.07 |
| Spain | 58.1 | | | Poland | 0.07 |
| France | 54.8 | | | Greece | 0.06 |
| Hungary | 54.8 | | | Mexico | 0.01 |

Data sources are ITU [40] and OECD [66]. The Internet user penetration data cover 42 countries and regions. Due to limitations with data assess, we only obtained 24 countries for the secure server penetration statistics. To eliminate country scale effects, we divided Internet user penetration by population. Secure server penetration is stated in terms of percent per 1,000 population. *Internet user penetration* refers to the potential market size of B2C e-commerce in a country. *Secure server penetration* shows the supply side of Internet technology environment in a country

penetration rates in the different countries that we sampled in 2008. Internet user penetration rates are much higher than secure server penetration rates, for example. The highest level of secure server penetration is in the U.S., and this matches its intensive e-commerce activities. Some countries, such as Mexico, Greece, Poland, and Hungary, have less than 0.1% penetration, which limits their capacity to develop B2C e-commerce. The diversity of secure server penetration levels across different countries suggests different degrees of national infrastructure, and that there are abundant opportunities for growth for all but a handful of countries. In terms of Internet user penetration rates, several Western European countries ranked in the top five in 2008. When a country ranks high on both Internet user penetration and secure server penetration, e-commerce activities have the potential to be in growth mode. Overall, Internet user penetration and secure server penetration represent the indicators for the demand and supply side of market in e-commerce [7, 38, 56].

## 3 Theory development

We next introduce a high-level conceptual model that will serve as the primary theoretical basis for this research. We conceptualize a *country* as an economic system within which e-commerce growth occurs. We start by establishing a hybrid growth model that examines the primary factors of B2C e-commerce growth. After that, we introduce a related model and another embedded technology adoption function. We estimate a simultaneous equation model to examine the possibility of a two-way interaction between Internet-based selling technology adoption and B2C e-commerce growth that represents reverse causality.

Some studies intentionally use different kinds of models to show the robustness of their results (e.g., [16, 21, 27]). Using a hybrid growth perspective, our intention is to leverage alternate models to provide evidence for the effects that the theory suggests should be present. Instead of identifying a "best" model, our approach will be to report the

results of the different models. Why? Each of the empirical models that we will use is founded on a different information structure for the error terms, and on a different representation of causality, especially unidirectional causality versus reverse causality. Thus, our approach is not to "cherry pick" the model that offers the best fit for the variables. Instead, we intend to see what can be learned from each of the models. We will elaborate on this evaluative perspective as we discuss the process of analyzing the data with each of the models.

## 3.1 A growth-theoretic modeling approach for e-commerce growth

### 3.1.1 Conceptual model

*B2C e-commerce revenues* are the value of products and services purchased by consumers on the Internet [39]. When we consider *endogenous variables* in e-commerce growth, it is appropriate to compare how different theories of economic growth represent them. In growth theory, labor and capital are key inputs in the production function. In the B2C e-commerce context, we will not use physical inputs in the production of revenue growth. Instead, we consider *environmental variables* that affect B2C e-commerce growth. The *endogenous variables* are Internet user penetration, telecommunication investment, education level, online payment readiness and secure server penetration. The *exogenous variables* are international openness, and population density. Figure 1 shows our conceptual model and hypotheses, and provides a preliminary reading on the results that we obtain from the analysis we will conduct. Table 3 summarizes the key constructs, variables, and definitions.

### 3.1.2 A quasi-production function model

Our model is built from three separate elements: a set of *quasi-production endogenous variables*, a set of *quasi-production exogenous variables*, and a representation of te*chnology adoption* within an economy that is relevant to e-commerce activities. Our model's general form is similar to a production function:

$$Y = f\left(\alpha, X^{ENDOG}, X^{EXOG}\right)$$

We have suppressed the subscripts in this representation to focus on the main elements of the model. Country-level B2C e-commerce revenues, $Y$, are produced in the presence of a vector of endogenous variables, $X^{ENDOG}$, and a vector of exogenous variables, $X^{EXOG}$. The specification also contains a time-specific parameter, $\alpha$. There also will be effects of omitted variables and measurement imprecision, reflecting our inability to capture all the details of the relationship. One typically represents this with an error term in regression.

### 3.1.3 Exogenous variables

In empirical studies of growth theory, there are a number of different exogenous variables related to growth that are often discussed. These include international openness, geographic differences, climate differences, and population density. *International openness* refers to the degree to which a country is open to business and economic influences through trade activities. Grossman and Helpman [35] have defined international openness an exogenous and external force that captures knowledge spillovers from countries that have a positive impact on the technological progress of the participating countries. Coe and Helpman [22], Coe et al. [23] and Keller [50] consider trade as a carrier of knowledge. They assessed the importance of imports in introducing foreign technology into domestic production and spurring total factor productivity. Rivera-Batiz and Romer [71] also view trade as a channel for the transfer of technological knowledge.

This exogenous variable explains the knowledge spillover effect among countries, which also represents technology diffusion among countries. We intend to capture the flow and impacts of ideas, innovations, and business models of e-commerce among countries. Since there is no direct measure for e-commerce knowledge spillovers, we will use international openness as a proxy variable. The degree of international openness can be measured based on the *ratio of exports plus imports to gross domestic product* (GDP) [6, 20, 77]. Since e-commerce diminishes the force of geographical boundaries, international openness provides a meaningful measure of the degree of interdependence and knowledge spillover of e-commerce activities and innovations among countries. We use international openness as a proxy variable to examine the knowledge spillover effects of e-commerce activities and innovations among countries. Thus, the degree of international openness is an exogenous influence on B2C e-commerce growth that has the potential to capture knowledge spillovers across different countries:

**Hypothesis 1** (*The International Openness Hypothesis*) The degree of international openness in a country has a positive effect its B2C e-commerce growth.

Except for international openness, geographical characteristics may also act as exogenous factors that influence e-commerce development [54, 84]. *Population density* is another exogenous variable in our model because urbanization may be related to B2C e-commerce revenue. It refers to the number of people in a geographic area,

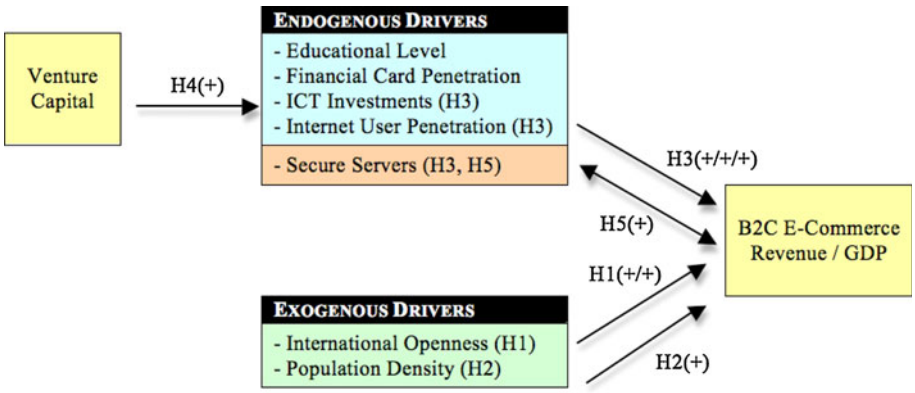


**Fig. 1** Conceptual model and hypotheses with a preview of the empirical results. The plus signs in the parentheses after each numbered hypothesis indicates the number of positive and significant coefficient estimates, as predicted by the hypotheses, obtained from the three models that we discuss later in this article. In particular, the FGLS model yielded positive and significant coefficient estimates for variables associated with Hypotheses 1, 2 and 3. The endogeneity-adjusted model, simultaneously estimated with an embedded technology function, yielded similar results for the variables that represented the assertions of Hypotheses 1 and 3. Finally, the simultaneous equation estimation produced positive and significant coefficient estimates for the variables associated with Hypotheses 3, 4 and 5. Although some estimated coefficients related to the different models that we estimated were not significant, there were no coefficients that had the wrong sign and were significant. We will provide a fuller overview and explanation of the results in Table 9 at the end of our discussion of empirical results in this article

**Table 3** Constructs, variables and definitions

| Constructs | Variables | General description |
|---|---|---|
| Dependent variable | | |
| E-commerce revenue growth | B2C e-commerce revenue growth | The value of products or services purchased by individuals by clicking an order button on the Internet. |
| Endogenous variables | | |
| Financial infrastructure | Financial card penetration | The financial infrastructure readiness for e-commerce transactions. |
| Educational level | Adult literacy | The capability of people to conduct online transactions. |
| ICT infrastructure | Telecommunications investment | ICT infrastructure and e-commerce environment readiness. |
| Market size for B2C e-commerce | Internet user penetration | Internet users prompt the development of Internet technology and e-commerce infrastructure. Internet users also contribute to the growth of e-commerce transactions. |
| Supply side of Internet technology adoption | Secure server penetration | Internet technology adoption from the online service supply perspective at the firm level. Secure servers ensure that encrypted sensitive information such as credit card and personal information can be transmitted in a secure way on the Internet. |
| Exogenous variables | | |
| International openness | International openness | The degree to which a country is open to business and economic influences through trade activities. |
| Geographic environment | Population density | Population per square kilometer |
| Embedded technology adoption variable | | |
| Venture capital | Venture capital availability | Opportunities for business to develop new businesses models and technological innovations for e-commerce |

which also is likely to be correlated with the infrastructure of that environment. When an area is more congested, the cost of the infrastructure (including public libraries, roads, and telecommunication infrastructure) will be proportionately less than the size of the population [4]. Governments also tend to allocate higher budgets to the more urbanized areas. Thus, population density is a measure that is correlated with the commercialization and industrialization of a country [76]. For example, countries such as Singapore and Germany, with high population densities and high wealth per capita, have well-developed ICT infrastructures [55]. Calem and Carlino [18] indicated that urban areas typically

have greater infrastructure and economies of scale. The degree of urbanization, measured in terms of the percentage of the population living in urban areas [86], has also been used as a ceiling parameter in models to explain global cellular telephone adoption and diffusion [26]. As a result, the more urbanized area will have higher B2C e-commerce growth because the relevant infrastructure is well developed. This leads to our second hypothesis:

**Hypothesis 2** (*The Population Density Hypothesis*) The population density in a country has a positive effect on its B2C e-commerce growth.

#### *3.1.4 Endogenous variables*

There are several potential endogenous variables. First, the number of Internet users is an important indicator of Internet connectivity and e-commerce access and demand. Human capital is recognized as a key input to country R&D, which generates new ideas and products associated with technological progress [10, 36]. Similar to the role of human capital from a supply perspective, Internet users create value via network externalities from their use of B2C e-commerce mechanisms. Second, prior studies demonstrate that the average level of education [52] and the quality of human capital [19] are influential influences on individual technology adoption. Level of education is positively related to the capability of people to use Internet and be involves in the e-commerce activities. Third, financial card penetration represents the adequacy of financial infrastructure to enable online transactions. The adequacy of financial resources that consumers can bring to e-commerce is a supply-side variable that has been proven to have direct effects in shaping diffusion [84]. Financial cards are one of the alternative payment tools that facilitate B2C e-commerce growth. Among the endogenous variables, we also are interested in testing Internet technology adoption in the model as an influence on the growth of e-commerce.

We use *Internet user penetration* to represent the market size of B2C e-commerce. Second, *capital invested in ICT* typically represents ICT infrastructure and the readiness of the environment to support the growth of e-commerce. Third, *educational level* is important, since it represents the human capital abilities of people in a country to create the innovations needed to build e-commerce and digital business model capabilities. Fourth, we further view *online payment capabilities* as a relevant variable; it proxies for national-level financial infrastructure readiness for e-commerce transactions. Finally, we specify whether Internet-based selling technology adoption contributes to e-commerce revenue growth. We will use the installed base of *secure servers* as a proxy variable for the degree of Internet-based selling technology adoption.

### 3.2 An embedded Internet-based selling technology adoption model

Internet-based technology adoption has different kinds of effects on e-commerce growth in a country. To understand how technology adoption creates the impetus for the growth of e-commerce, it is necessary to identify and understand some additional underlying influences. These variables will impact the e-commerce development that is observed in a country, but will be more distant from the creation of e-commerce revenues. They will have *indirect effects* through Internet-based selling technology adoption, passing their influence through the e-commerce infrastructure to e-commerce revenues, based on the extent of infrastructural development they are associated with. For example, the growth of secure servers may result in higher e-commerce transactions because of the availability of secure on-line transactions. There also may be other Internet-based selling technology-related factors that contribute to the growth of secure servers. Venture capital availability, for example, supports the online transactional infrastructure in a country, since it is directed to entrepreneurial projects that lead to high-technology development.

The direct and indirect effects of Internet-based selling technology adoption can be represented with simple quasi-production functions. First, the direct effect of Internet-based selling technology adoption endogenously influences e-commerce growth in a country. Also, an embedded technology adoption function captures the installed base of relevant Internet-base selling technology adoption in a country, and the indirect effects of ventures capital that supports its creation, in an indirect relationship with e-commerce growth. We represent these relationships as follows

$$\begin{aligned} \textit{E-commerce growth} &= f(\textit{Constant}, X, g(\bullet), \varepsilon) \\ &= f(\textit{Constant}, X^{\textit{ENDOGENOUS}}, X^{\textit{EXOGENOUS}}, \\ &\quad \textit{Internet-based selling technology adoption}, \varepsilon) \end{aligned}$$

Here, *Internet-based Selling Technology Adoption* = $g$ (*Constant*, *Venture Capital,* $\gamma$), with $X^{ENDOGENOUS}$ representing the endogenous variables, $X^{EXOGENOUS}$, representing the endogenous variables, and $\varepsilon$ and $\gamma$ as error terms in the estimation model. The dependent variable, *secure servers*, of the embedded Internet-based selling technology adoption function is used to represent the effect of relevant technology infrastructure on e-commerce growth, as best we can gauge it from the data that are available for this research design. Our approach to establishing an interpretation of the results of this "model within a model" explanation for e-commerce growth will be based on cross-model inference with several different models, each of which represents a piece of the

overall set of relationships, rather than a unified path analysis or the estimation of a single empirical model.

#### 3.2.1 Internet-based selling technology adoption

There are three technology-related variables in our model: capital investment in telecommunication, Internet users, and secure servers. Capital investment in telecommunication serves as a measure for ICT infrastructure, and Internet users serves as a measure of the market size of e-commerce, as well as Internet technology adoption at the individual level. However, we need to further consider the relevant technology infrastructure on the supply side of e-commerce. We use secure servers as a proxy for Internet-based selling technology adoption in the B2C online transaction setting, since it supports online transactions [66]. E-commerce websites typically use secure servers to ensure throughput of encrypted credit card transactions in the online payment process. This limits transaction risk and increases trust between vendors and buyers [61]. Secure servers act as a foundation for e-business infrastructure as well. We will evaluate the role of secure server penetration as a readily measurable proxy for Internet-based selling technology adoption in our model. We assert:

**Hypothesis 3** (*The Internet-Based Selling Technology Adoption Hypothesis*) The adoption of Internet-based selling technology in a country has a positive effect on its B2C e-commerce growth.

#### 3.2.2 Venture capital

It is widely recognized that the availability of venture capital has resulted in the development of e-commerce-related technologies around the world [34, 56]. If a market has more venture capital available for business, there ought to be more opportunities for developing new businesses models, start-ups, and technological innovations as a result [88]. Many B2C e-commerce startups were developed primarily on the basis of venture capital funding [33, 59, 79, 88]. According to UNCTAD [79], the US represented nearly two-thirds of the global private equity and venture capital market in 2001. This led to the creation of new firms, innovative technology applications, as well as new innovations on the part of traditional firms that migrated to bricks-and-clicks business models. Western European countries have been relative followers in the global venture capital market. The uneven distribution of venture capital offers a basis for the disparity of Internet-based selling technology adoption in countries. Based on the previous studies, we argue that venture capital contributes to the adoption of Internet-based selling technology. We argue that venture capital is the one of the driving forces in support of the development of e-business and online stores, which support the production of e-commerce revenues. Thus, venture capital serves as an indirect effect through Internet-based selling technology adoption and further contributes to B2C e-commerce. The availability of venture capital is a proxy measure of innovation in Internet-based selling technology related to B2C e-commerce, and represents private equity capital provided to early-stage and high-potential companies. We propose:

**Hypothesis 4** (*The Venture Capital Hypothesis*) A higher level of venture capital availability in a country is associated with a higher level of Internet-based selling technology adoption.

### 3.3 Simultaneous effects of Internet-based selling technology adoption and B2C E-commerce

When there are more online shops and a more secure online transaction mechanism is available, people will be more willing to shop online, which should results in more B2C e-commerce revenues growth. This implies that the adoption of Internet-based selling technology ought to stimulate more e-commerce transaction revenues. Similarly, the growth of e-commerce transactions will attract more venture capital to support start-ups and creation of online stores. We argue that e-commerce transactions and Internet-based selling technology adoption interact with one another to create a "virtuous cycle."

In this vein, Zhu et al. [92] found that consumer readiness results in greater intent among businesses to adopt e-business practices. Consumer readiness also supports the growth of market transactions, and will determine the extent to which business process, product and service innovations will result in higher profits. More Internet-based selling technology adoption, thus, is likely to lead to higher B2C e-commerce revenues over time. These variables are likely to exhibit a *feedback loop*. When there are more B2C e-commerce transactions, there also should be more investment and adoption of Internet-based selling technologies that support B2C e-commerce. Thus, there is a role for the estimation of a simultaneous equation model, with the dependent variable in one equation acting as an explanatory variable in another equation [43, 51]. We propose:

**Hypothesis 5** (*The Simultaneity Hypothesis*) There will be positive simultaneous effects between Internet-based selling technology adoption and B2C e-commerce growth.

## 4 Data, methods and empirical analysis

This section discusses our research methodology and cross-model inference approach, the sources of our data, the

operational definitions of the variables we have selected, our empirical analysis. Our intention is not to demonstrate a single "best" model, but instead to see what can be learned from different models. We will use feasible generalized least squares (FGLS) and an instrumental variable endogeneity-adjusted model to assess the effects of Internet-based selling technology adoption and B2C e-commerce growth. We will employ a simultaneous effects model to capture the indirect effect of venture capital through Internet-based selling technology adoption on B2C e-commerce revenues, and to evaluate the potential of a reverse causal relationship between B2C e-commerce growth and relevant IT infrastructure. Our inquiry approach is different from the usual approach, which emphasizes the development a single unified empirical model, where the specific values of the coefficient estimates that are obtained are of greatest interest to the analyst. Figure 2 includes a flowchart of the sequence of our model estimation and inference approach as a means to evaluate the efficacy of our hybrid growth theory to explain the overall relationships that are present in the data.

### 4.1 Data collection and variables

To empirically test the model, we collected secondary data from the International Telecommunications Union (ITU), the United Nations, the International Monetary Fund (IMF), the United Nations Educational, Scientific and Cultural Organization (UNESCO), and the OECD. Our approach uses national-level archival data to examine the relationship between e-commerce growth and aggregate-level variables. We also obtained access to proprietary databases, including IDC, Jupiter Research, and the *IMD World Competitiveness Yearbooks*. The sample size is constrained by the data set available across various secondary sources. The Internet user penetration and adult literacy rate data are from the ITU, which covers 198 counties. The data represent four regions, including fifteen Western European, two Eastern European, three Americas, and four Asia Pacific countries from 2001 to 2008. Thus, our overall data set includes only 42 countries. (See the Appendix.) We have only 42 countries with data on e-commerce revenues, and 24 countries with data on secure servers though. We validated the values of the variables by checking them against different sources wherever possible. Archival data have limitations since they are dependent on the assumptions that underlay the original data collection [41]. We will address these assumptions when we discuss the results of the different modeling approaches. (See Table 4 for information on our variables and the data sources.) We ran our data with STATA 9.0 for the empirical tests of the time-series and cross-sectional secondary data. (See Table 5 for descriptive statistics.)

### 4.2 Model diagnostics

The collected secondary data reflect differences between observations and countries, and differences within observations or countries over time. Time-series and cross-sectional observations introduce the potential problems of *heteroscedasticity* due to the different sectors and *serial correlation* between the successive years of the data. A separate issue is *endogeneity*, which is common in industry and country analysis. We performed a number of diagnostic tests for multicollinearity and heteroscedasticity. First, we did a pair-wise correlation analysis to ensure that no two variables were too highly correlated, rendering both of them ineffective as regressors. The pair-wise correlation coefficients between the explanatory variables were all lower than 0.7. (See Table 6 for the correlations and significance levels.)

Second, the mean of the *variance inflation factors* (VIF) was 1.81 and the VIFs of all explanatory variables all were less than 3. The results indicate that multicollinearity is not

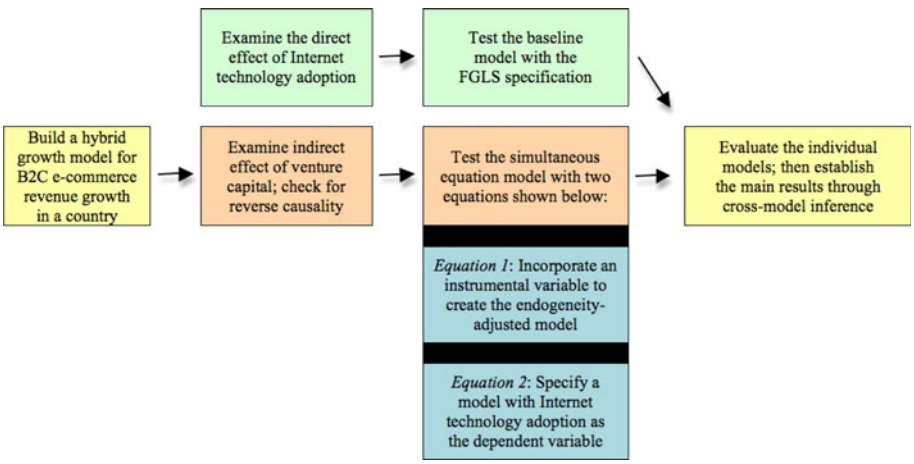


**Fig. 2** Empirical analysis flowchart

**Table 4** Modeling variables, operational definitions and data sources

| Variable | Operational definition | Data source |
|---|---|---|
| *ECExpendRatio*[a] | B2C e-commerce expenditure/GDP. B2C ecommerce is defined as the value of products or services purchased by individuals by clicking an order button on the Internet. | IDC, United Nations |
| *NetUserRatio* | Total number of Internet users/Population aged 15–64 | Jupiter Research |
| *CardPenetr* | Number of financial cards in circulation/Population aged 15–64 | IMF |
| *IntlOpenness* | (Exports + Imports)/GDP | IMF, United Nations |
| *Education* | Adult literacy rate | UNESCO, national stats |
| *TelcInv* | Total capital investment in telecommunications/GDP | ITU |
| *PopDensity* | Population per square kilometer | United Nations, National statistical offices |
| *VCapital* | Venture capital availability for business development, measured on a 1 (low) to 10 (high) scale | *IMD World Competitiveness Yearbook* |
| *Servers* | Number of secure servers/Population aged 15–64 | www.netcraft.com, OECD |

[a] We could easily include B2B e-commerce expenditures or B2C plus B2B expenditures to construct this variable for the ration of B2C e-commerce expenditures to GDP. However, since B2C and B2B expenditures are correlated, choosing any of the three—B2C or B2B expenditures alone, or their sum—will yield the same estimation outcome. Thus, we chose to go with B2C expenditures, which had relatively more complete data, and made sense in our context

**Table 5** Descriptive statistics

| Variables | Mean | Min | Max | SD |
|---|---|---|---|---|
| *ECExpendRatio* | 0.440 | 5.45e-07 | 39.974 | 3.458 |
| *NetUserRatio* | 0.503 | 0.004 | 1.317 | 0.354 |
| *CardPenetr* | 2.785 | 0.001 | 13.021 | 2.534 |
| *IntlOpen* | 0.583 | 0.000 | 3.344 | 0.601 |
| *Education* | 0.949 | 0.601 | 1.317 | 0.068 |
| *VCapital* | 4.944 | 1.230 | 8.619 | 1.524 |
| *Servers* | 0.302 | 0.002 | 1.481 | 0.322 |
| *TelcInv* | 0.767 | 4.24e-06 | 56.155 | 5.961 |
| *PopDensity* | 92,291.6 | 2,950.8 | 1,321,290 | 237,520 |

**Table 6** Correlations between the main variables in the study

| Variables | *Education* | *NetUser Ratio* | *CardPenetr* | *TelcInv* | *IntlOpen* | *PopDensity* | *Servers* | *VCapital* |
|---|---|---|---|---|---|---|---|---|
| *Education* | 1.000 | | | | | | | |
| *NetUserRatio* | 0.582*** | 1.000 | | | | | | |
| *CardPenetr* | 0.310*** | 0.476*** | 1.000 | | | | | |
| *TelcInv* | −0.006 | 0.096* | 0.117** | 1.000 | | | | |
| *IntlOpen* | 0.147*** | 0.023*** | −0.141*** | 0.021*** | 1.000 | | | |
| *PopDensity* | −0.015*** | 0.015*** | 0.639** | 0.004 | −0.323*** | 1.000 | | |
| *Servers* | 0.429*** | 0.617*** | 0.454*** | −0.100 | −0.047 | 0.227*** | 1.000 | |
| *VCapital* | 0.468*** | 0.510*** | 0.330*** | −0.078** | 0.198*** | −0.040*** | 0.540*** | 1.000 |

Signif.: * $p < 0.10$, ** $p < 0.05$, and *** $p < 0.01$. There are no pair-wise correlations that exceed the level of 0.80, as discussed by Kennedy [51] as a criterion for omitting variables due to the overlap of the information that they provide

a problem. We further examined *panel-wise heteroscedasticity*. Heteroscedasticity is a potential problem because the size of the different countries varies in the pooled data. Although the exact relative error variances cannot be determined, it is commonly assumed that they vary inversely with the size of the sector [17]. The Breusch and Pagan [14] test, in addition, showed no problems ($\chi^2 = 1.19$, $p < 0.28$).

### 4.3 Feasible generalized least squares (FLGS) estimation

The estimation equation is an extended Cobb-Douglas production function, restated in logarithmic form, with two-sided errors $v$ and $\varepsilon$, and a lagged telecommunications investment variable for country $i$ at time $t$:

$$\begin{aligned}\ln ECExpendRatio_{it} = \ln\ & \alpha_1 + \beta_1 \ln NetUserRatio_{it} \\ & + \beta_2 \ln Education_{it} \\ & + \beta_3 \ln CardPenetr_{it} \\ & + \beta_4 \ln IntlOpen_{it} \\ & + \beta_5 \ln TelcInv_{i,t-1} \\ & + \beta_6 \ln PopDensity_{it} + \ln v_i + \ln \varepsilon_{it}\end{aligned}$$

Time-series and cross-sectional empirical research model designs often violate the standard OLS assumptions. We performed two post-estimations beyond our baseline model to test for *serial correlation*, and *contemporaneous correlation* for the same 42 countries. *First-order serial correlation* refers to correlation of the errors of the same analysis unit over successive time intervals. Errors in one time period will be correlated directly with errors in the next time period. Serial correlation does not affect the unbiasedness or consistency of the OLS estimators, but it does affect their efficiency [69]. We used the Wooldridge [85] test for autocorrelation in the panel data model. The results ($F = 22.80$, $p < 0.01$) indicated there is first-order autocorrelation in the residuals. *AR(1) autocorrelation* occurs when the error term in one time period is proportional to the disturbance in the previous time period, plus a spherical disturbance [51]. This is reasonable because some variables such as the Internet user penetration, the adult literacy rate, and the population density may exhibit co-movement over time.

Since there is autocorrelation in the residuals, we chose *feasible generalized least squares* (FGLS) regression to eliminate the serial correlation of the errors. FGLS regression assumes that the errors are serially correlated, usually as an AR(1) process. It also assumes that the variance–covariance matrix of the errors is unknown. The Parks-Kmenta approach consists of two FGLS transformations. First, it eliminates serial correlation of the errors. Second, it eliminates the contemporaneous correlation of the errors, and corrects for any panel heteroscedasticity (See Table 7).

In the FGLS regression analysis, we tested the following six explanatory variables: Internet user penetration (*NetUserRatio*), education level *(Education)*, credit card penetration (*CardPenetr*), international openness (*IntlOpen*), telecommunication investment intensity (*TelcInv*), and population density (*PopDensity*). The results show that both the endogenous and the exogenous variables have

**Table 7** FGLS regression results

| Variables | Coefficients | Standard errors | *Z*-values |
|---|---|---|---|
| *NetUserRatio* | 1.205 | 0.173 | 6.96*** |
| *Education* | 3.603 | 1.314 | 2.74*** |
| $TelcInv_{t-1}$ | 0.137 | 0.029 | 4.67*** |
| *PopDensity* | 0.276 | 0.099 | 2.78*** |
| *CardPenetr* | −0.060 | 0.106 | −0.57 |
| *IntlOpen* | 0.295 | 0.026 | 11.18*** |

Model: FGLS with homoskedastic errors. Correlation: panel-specific AR(1) (PSAR1). 328 observations, 42 countries from 2001 to 2008. Dependent variable: B2C e-commerce revenues divided by GDP. Model fits statistics are given by: Wald $\chi^2(6) = 367.85$***, and log likelihood = −375.58***. The significant levels are: *** $p < 0.01$

direct impacts on B2C e-commerce revenue growth. First, Internet user penetration (*NetUserRatio* = 1.205, $p < 0.001$) has a positive impact on a country's e-commerce growth. Although not all Internet users shop online, the Internet population is the potential market base of B2C e-commerce, so this makes sense. They contribute to e-commerce activities by using the Internet and creating Web contents. Thus, a larger number of Internet users in a country should predispose it to have higher e-commerce revenues. Second, the coefficient of *Education* is positive and significant (*Education* = 3.603, $p < 0.01$), which supports our argument about the relationship between the quality of human capital and e-commerce activities.

Third, one-year lagged telecommunication investment intensity ($TelcInv_{t-1}$ = 0.137, $p < 0.001$) in a country is positively related to B2C e-commerce growth. More capital invested in telecommunication infrastructure contributes to the creation of a solid foundation of relevant e-commerce infrastructure. Fourth, population density (*PopDensity* = 0.276, $p < 0.001$) is also positively related to B2C e-commerce growth. Higher population density in a country captures the effects of a larger market size and a more advanced technology infrastructure, which result in more potential and network traffic, creating the possibility that B2C e-commerce activities can be efficiently produced. Fifth, we found that the exogenous variable, international openness, also was positively related to e-commerce growth (*IntlOpen* = 0.295, $p < 0.001$). This implies that the more trade interactions that occur among countries, the higher B2C e-commerce growth should be. The related flow of new ideas, technologies, and innovative business models for e-commerce activities also should play a role in accelerating e-commerce growth in a country through its international trade.

Countries can imitate and learn about innovative e-commerce activities from other leading countries. We proposed international openness as an exogenous influence on e-commerce growth to capture knowledge spillovers

from e-commerce activities across the different countries. It reflects the intensity of trade interactions among countries, and the extent of knowledge spillovers through the sharing of business ideas and the related innovations.

The penetration of financial payment cards was not significant in our estimation model. We note that there may be inaccuracies in the data that come from the sources or that were introduced by the methods we used for data collection. For example, some data elements needed a degree of judgment on our part to measure, particularly the penetration of financial cards.

To sum up, the results of the FGLS regression support the International Openness Hypothesis (H1), the Population Density Hypothesis (H2) and the Internet-Based Selling Technology Adoption Hypothesis Hypothesis (H3). The reader should recall that this model does not address the other two hypotheses (H4 and H5). Although we argue that it is appropriate to present these results as a set of baseline findings, to give the reader a more insightful understanding of the nature of the relationships that we have modeled, it is appropriate to further explore the data and evaluate what else we can learn about the evidence that alternative estimations can produce. We next will examine an alternative estimation approach permits reverse causality to be evaluated.

### 4.4 Incorporating an instrumental variable and assessing simultaneity in two more models

The assumptions of a panel data model to produce unbiased estimates of the parameters and the standard errors are similar to those from ordinary least squares (OLS): the error term must be uncorrelated with the regressors and homoskedastic in the cross-section. The assumption that the error term is orthogonal to the regressors is potentially an issue. If the explanatory variables are measured with error, the orthogonality assumption also may be violated. The direction of the bias of the coefficients from measurement error is dependent on both the correlation among the variables, as well as the correlation among the measurement errors. Regardless of its source, it is possible to correct for potential bias using instrumental variables and two-stage least squares (2SLS) methods. This offers another way of probing what our data can tell us beyond the baseline model, as a means to further understand the basis for the growth of B2C e-commerce over time.

Another modeling assumption, that the error terms are uncorrelated with the independent variables, is potentially a problem in a panel data model, and one that deserves further consideration and analysis. If causality between e-commerce growth and Internet-based selling technology adoption were reversed, this assumption will be violated [53]. Secure server penetration also may give rise to endogeneity within our model, due to correlation of an independent variable with the error term. An endogenous explanatory variable may result in problems for interpreting the statistical relationships of interest because of the possibility of biased results. To correct for the potential bias, it is necessary to test whether there is endogenity with respect to the explanatory variable in the following model, once again representing country $i$ at time $t$:

$$\begin{aligned}\ln ECExpendRatio_{it} = {} & \ln \alpha_1 + \beta_1 \ln NetUserRatio_{it} \\ & + \beta_2 \ln Education_{it} \\ & + \beta_3 \ln CardPenetr_{it} \\ & + \beta_4 \ln IntlOpen_{it} + \beta_5 \ln TelcInv_{i,t-1} \\ & + \beta_7 \ln Servers_{it} + \ln \varepsilon_{it}\end{aligned}$$

We dropped the *PopDensity* variable when we estimated this model. When the number of countries fell from 42 to 24 in this analysis, we lost the capability to obtain stable estimates. This is often the case for a model with this many parameters and a relatively small number of observations [51]. It is also common in research that involves the country and regional levels of analysis, since there are a limited number of countries available for analysis [45, 49]. We accept this limitation, since it is natural for the context that we are studying. We will comment further at the end of this article on the implications of this limitation.

We performed the Durbin-Wu-Hausman test of exogeneity for *Servers*. The result ($F = 0.98$, $p = 0.324$) provided some preliminary evidence that Internet-based selling technology adoption was not endogenous. We further checked whether there is endogeneity in the e-commerce growth equation which, in contrast, showed evidence of endogeneity ($F = 12.57$, $p = 0.001$). The residual for the estimation of B2C e-commerce growth (*ECExpendRatio*) is significantly different from zero based on the small $p$-value. Thus, OLS does not produce consistent parameter estimates. Instrumental variables and 2SLS regression, on the other hand, will produce consistent and efficient estimators [69].

To address the possibility of endogeneity—even though we only obtained partial evidence of its presence, we replaced $Servers_{it}$ with an instrumental variable, in order to create a stronger basis for effective cross-model inference about the efficacy of the proposed hybrid growth theory this setting. Several considerations are necessary involving the selection of an instrumental variable. The first property is *instrument-regressor correlation*, which indicates that the instrument should be relatively highly correlated with the regressor. The second property, *instrument-error term non-correlation*, is that the correlation of the proposed instrument with the model error term should be as low as possible. The third property, *regressor orthogonality*,

indicates that the proposed instrument should not unduly overlap or be correlated with other variables in the set of regressors in the model.

We faced relatively strict limitations with the data available for doing this. A workable technical accommodation is to introduce a lagged version of the endogenous regressor [43]. This ensures that the first and third properties are met, and it will break the endogeneity link between the endogenous regressor and the error term in the model. Our approach is to utilize a lagged value of secure server penetration, $Servers_{i,t-1}$, a predetermined variable that cannot be caused by $Servers_{it}$. This approach, which we refer to as the endogeneity-adjusted model, solves the problem in spite of the limitations of our data set.

Along with the endogeneity-adjusted model, we estimated a function for embedded technology adoption in a simultaneous equation model. The estimation model's dependent variable is the logarithm of servers in country $i$ at time $t$:

$$\ln Servers_{it} = \alpha_2 + \beta_8 \ln VCapital_{it} + \beta_9 \ln ECExpendRatio_{it} + \ln \varepsilon_{it}$$

The results of each model are presented in Table 8.

The coefficient for $Servers_{i,t-1}$ in the endogeneity-adjusted model is not significant ($Servers_{i,t-1} = -0.483$, $p > 0.10$). Thus, the results do not appear to support the Internet-based Selling Technology Adoption Hypothesis (H3). The results support the International Openness Hypothesis (H1) though ($IntlOpen = 0.264$, $p < 0.01$). Estimation of the simultaneous equation model shows that an increase in e-commerce growth also results in higher Internet-based selling technology adoption ($ECExpendRatio = 0.579$, $p < 0.01$). In addition, an increase in venture capital results in higher Internet-based selling technology adoption ($VCapital = 2.378$, $p < 0.01$). This supports the Venture Capital Hypothesis (H4) and the Simultaneity Hypothesis (H5).

To wrap up this section, Table 9 summarizes our results, with an overview of the hypotheses that we tested, the results that we obtained on them from the different estimation models (where applicable), and our comments on the nature of the evidence related to the efficacy of our use of growth theory as a means of explaining e-commerce growth across different countries.

## 5 Discussion

We will assess the appropriateness of hybrid growth theory and the embedded technology adoption function to model e-commerce growth at the national level. We also will further evaluate the effectiveness of the FGLS and 2SLS regression analyses.

### 5.1 Assessment of findings relative to the proposed theory

Growth theory is generally associated with the set of models, explanations, and predictive frameworks that characterize the aggregate factors that drive a country's economic growth. The hybrid exogenous and endogenous growth model that we have proposed provides a different

**Table 8** Endogeneity-adjusted and simultaneous equation model estimation results

| Variables | Endogeneity-adjusted B2C EC revenues model (Dep. Var.: *ECExpendRatio*) | | | Simultaneous equation Internet-based selling technology adoption model (Dep. Var.: *Servers*) | | |
|---|---|---|---|---|---|---|
| | Coefficient | Standard errors | *t*-value | Coefficient | Standard errors | *t*-value |
| *NetUserRatio* | 4.546 | 0.542 | 4.70*** | | | |
| *Education* | −9.051 | 7.649 | −1.18 | | | |
| $TelcInv_{t-1}$ | 0.235 | 0.053 | 4.38*** | | | |
| $Servers_{t-1}$ | −0.483 | 0.300 | −1.61 | | | |
| *CardPenetr* | 0.506 | 0.183 | 2.76*** | | | |
| *IntlOpen* | 0.259 | 0.059 | 4.33*** | | | |
| *ECExpendRatio* | | | | 0.579 | 0.088 | 6.53*** |
| *VCapital* | | | | 2.378 | 0.335 | 7.10 *** |
| Model fit | $F(6, 187) = 23.60$***, Adj. $R^2 = 0.38$ | | | $F(2, 191) = 85.52$***, Adj. $R^2 = 0.31$ | | |

These models are estimated with 2SLS; 192 obs., 24 countries, 2001–2008. The dependent variables in the endogeneity-adjusted model is *ECExpendRatio*, similar to the FGLS model we estimated before. The simultaneous equation model is a reduced-form, reverse causality-focused model that uses *VCapital* as the dependent variable in one equation and *ECExpendRatio* in the other equation. This modeling choice reflects our effort to build evidence on the basis of somewhat different empirical model structures to obtain a richer picture of the underlying relationships. As we have noted in the text, no single model is perfect to represent the structure of the estimations that we carried out. Because only 24 countries have data available for *Servers*, the results are restricted to 24 countries in the 2SLS analysis. Because of the reduction of sample size, we only include *IntlOpen* as the only exogenous factor in 2SLS analysis. Signif.: * $p < 0.10$; ** $p < 0.05$; *** $p < 0.01$

**Table 9** Summary of the main results of this research

| Hypotheses | Results from the estimation models | Comments |
|---|---|---|
| **Hypothesis 1** (*The International Openness Hypothesis*). The degree of international openness in a country has a positive effect on its B2C e-commerce growth. | (1) FGLS: H1 is supported based on the positive and significant coefficient on *IntlOpen*.<br>(2a) Endogeneity-adjusted: H1 also supported by a positive and significant coefficient on *IntlOpen*.<br>(2b) Simultaneous equation: This relationship is not modeled with *Servers* as a function of *VCapital* and *ECExpendRatio,* so no additional evidence is provided. | (1) The baseline FGLS model provides the expected support for H1 through the targeted variable, in a panel-specific AR1 formulation.<br>(2) The endogeneity-adjusted model's results match those of the FGLS model, which increases our confidence about the evidence of the effect that is proposed by H1. We have been able to show its presence in two representative empirical modeling formulations. |
| **Hypothesis 2** (*The Population Density Hypothesis*). The population density in a country has a positive effect on its B2C e-commerce growth | (1) FGLS: H2 is supported based on the positive and significant coefficient on *PopDensity.*<br>(2a) Endogeneity-adjusted: *PopDensity* variable dropped due to collinearity concerns with introduced variable, $Servers_{t\text{-}1}$, though some support for the effect is retained through the alternate measure.<br>(2b) Simultaneous equation: This relationship is not modeled with *Servers* as a function of *VCapital* and *ECExpendRatio,* so no more evidence is given. | (1) The outcome for the baseline FGLS model is similar: we found the expected support via the targeted variable, *PopDensity* under the PSAR1 model structure.<br>(2) The overall evidence that we have is somewhat weaker though, since the endogeneity-adjusted model doesn't focus on trying to building evidence for the exact same effect, but instead shifts to focus on the role of relevant infrastructure. |
| **Hypothesis 3** (*The Internet-Based Selling Technology Adoption Hypothesis*). The adoption of Internet-based selling technology in a country has a positive effect on its B2C e-commerce growth. | (1) FGLS: H3 supported by the positive and significant coefficients of *NetUserRatio* and $TelcInv_{t-1}$. The variable $Servers_{t-1}$ is not included in the FGLS model, so it provides no direct evidence on its effect on the dependent variable, *ECExpendRatio*.<br>(2a) Endogeneity-adjusted: H3 is similarly supported based on the positive and significant coefficients of *NetUserRatio* and $TelcInv_{t-1}$. The $Servers_{t-1}$ variable was not significant though.<br>(2b) Simultaneous equation: H3 is supported by the positive and significant coefficient of the variable, *ECExpendRatio*. | (1) Our modeling approach offered three different variables that we argued ought to have an association with the effect of relevant technology on the growth of B2C e-commerce across countries: investments in telecommunications, Internet users (indicating the relevant technologies at home), and secure server infrastructure.<br>(2) In the endogeneity-adjusted model, we included three variables that might potentially bear the hypothesized effects: *NetUserRatio*, $TelcInv_{t-1}$, and $Servers_{t-1}$. Although we were unable to establish the expected separable and positive effect for $Servers_{t-1}$, which was not significant, the other two variables still were significant and positive. The simultaneous equation model also provided additional information. This strengthened the evidence that we obtained in support of H3, since we were able to do so under an alternate estimation model. |
| **Hypothesis 4** (*The Venture Capital Hypothesis*). A higher level of venture capital availability in a country is associated with a higher level of Internet-based selling technology adoption. | (1) FGLS: *VCapital* is not included in the FGLS model, so no evidence related to H4 was produced.<br>(2a) Endogeneity-adjusted: Again, no evidence related to H4 was created, since *VCapital* was not included in this model.<br>(2b) Simultaneous equation: H4 is supported by the positive and significant coefficient on *VCapital* as an explanatory variable for *Servers.* | (1) Two of the three models did not include the key independent variable, *VCapital.* Instead, it was only included in the final simultaneous equation model, so there was just one chance to show evidence to support H4.<br>(2) The evidence suggests that the availability of venture capital in a country has an important association with its ability to build relevant infrastructure to support the growth of B2C e-commerce. So the result is as we hypothesized it would be, based on the theory that we applied. |

**Table 9** continued

| Hypotheses | Results from the estimation models | Comments |
|---|---|---|
| **Hypothesis 5** (*The Simultaneity Hypothesis*). There will be positive simultaneous effects between Internet-based selling technology adoption and B2C e-commerce growth in a country. | (1) FGLS: This model does not consider the possibility of simultaneous effects and reverse causality, so it cannot product any relevant evidence for H5.<br>(2a) Endogeneity-adjusted: H5 is not supported by this model's estimation because the coefficient of $Servers_{t-1}$ is not significant.<br>(2b) Simultaneous equation: H5 is supported by the positive and significant coefficient of *ECExpendRatio* as an explanatory variable for *Servers.* | (1) Only two of the three models that we estimated include both of the variables *ECExpendRatio* and *Servers*. The FGLS model does not give us the ability to test H5.<br>(2) The evidence of simultaneity is mixed, based on the estimations of the endogeneity-adjusted model and the simultaneous equation model. The first of these indicates that the relevant variable, $Servers_{t-1}$ is not significant, while in the simultaneous equation model it is positive and significant.<br>(3) Although the evidence provided is not as strong as what was predicted, we nevertheless obtained a useful reading on simultaneity and reverse causality through this estimation approach. |
| **Overall Results** (*Efficacy of Hybrid Growth Theory, and the Embedded Technology Adoption Function*). Our central idea is that exogenous and endogenous factors drive national B2C e-commerce growth. A related assertion is that it is useful to represent relevant IT infrastructure as an embedded technology adoption function to explain growth but is driven by venture capital investments. | (1) Overall, our findings and cross-model inference analysis bear out the combined importance of the various exogenous and exogenous factors in the estimation results for the FGLS and the endogeneity-adjusted models that we tested.<br>(2) In addition, it is possible to draw a preliminary conclusion about the efficacy of the embedded technology adoption function and the role of *Servers* (and $Servers_{t-1}$) from this research, although the we had some disagreement in the findings of the endogeneity-adjusted model and the simultaneous equation model, as described in (2a) and (2b) for Hypothesis 3 above. | (1) The research approach that we used in this work was to prefer to obtain multiple sources of evidence using models with different representations of the underlying relationships that the various theoretical perspectives suggested might be important.<br>(2) This method of inquiry in the study of technology adoption contrasts with the development and presentation of one unified empirical model, where the focus is on the specific values of the coefficient estimates that are obtained. Refinement of such models might proceed with the inclusion of interactions between variables, adjustments to the statistical model (e.g., additive separable vs. multiplicative regression, or observable variable vs. latent variable models, etc.). The latter approach may be more appropriate when the analyst is focused on the relative importance of specific variables in the model, and not the holistic ability of a theoretical perspective to explain real-world observations. |

theoretical lens to explain e-commerce growth at the country level. To anchor economic growth theory in the e-commerce context, we employed variables that explain macro-level e-commerce revenue growth across countries. This set up our test of the direct effects of the endogenous variables related to e-commerce growth within a country. It also allowed us to evaluate the explanatory capacity of exogenous variables that influence e-commerce revenue growth.

Previous economics studies have suggested that economic growth involves a two-way interaction between technology and life [2]. From an economic growth perspective, technological innovation creatively destroys the existing economic systems that make it possible, while economic growth fosters further technology progress the builds up new market capabilities [2]. To capture the complexity of these different roles of Internet-based selling technology adoption, we examined the simultaneous effects of Internet-based selling technology adoption and national level e-commerce growth.

### 5.2 In retrospect: a comparative discussion of the empirical models and methods used

We next discuss the efficacy of the empirical modeling and cross-model inference methods that we have used. This research conceptualized the creation e-commerce revenue growth at the country level from 2001 to 2008 in *environmental production* terms. We applied a quasi-production function to model e-commerce revenue growth driven with exogenous and endogenous variables. To empirically test our proposed model, we used an FGLS panel data model as a

baseline to evaluate e-commerce revenue growth. Applying FGLS regression eliminated the statistical problems with the serial and contemporaneous correlation of the error terms. It captured the basic hypothesized relationships, and enabled us to validate the proposed hybrid e-commerce growth model. The FGLS model results provided a reading of the effects of Internet user penetration, credit card penetration, and Internet-based selling technology adoption on e-commerce revenue growth.

To further deal with the possible problems of endogeneity in the base model, we identified an appropriate instrument to replace Internet-based selling technology adoption. Venture capital met the technical requirements for being a valid instrument, and the results showed its usefulness. Compared to FGLS regression, the simultaneous estimation of an embedded technology adoption function coupled with an endogeneity-adjusted model helped us to further understand the connection between Internet-based selling technology adoption and e-commerce revenue growth. The results demonstrated that Internet-based selling technology adoption is associated with a higher level of B2C e-commerce revenues.

## 6 Conclusion

To explore the diversity e-commerce revenue growth among nations, this research has proposed a hybrid growth model to explain whether revenue growth is driven by endogenous variables, exogenous variables, or a combination of both. Our research objective was to further explore the role of Internet based-selling technology adoption on B2C e-commerce revenue growth. We collected secondary data from different sources to empirically examine the proposed hypotheses and find major determinants of national e-commerce growth.

The theoretical contributions are as follows. Our hybrid growth theory model explained the mechanism of e-commerce revenue growth at the national level from a new perspective. Second, the theory helped us to understand the role of Internet-based selling technology adoption in e-commerce revenue growth. The results showed a positive feedback relationship: increases in e-commerce revenue growth were associated with growth in secure servers, and the increase of Internet-based selling technology adoption tended to accelerate e-commerce revenue growth. Reaching this conclusion required the combination of results from different empirical estimation models.

Overall, growth theory adds to our knowledge of B2C e-commerce growth settings in the IS discipline by providing an understanding beyond some of the traditional theories of economic growth that are founded on other more general theoretical models of technology adoption and diffusion. One example of them is *trickle down diffusion theory*, which posits that countries which are more developed will be the first to produce and adopt new technologies, resulting in growth in the affected sectors, and only later will the less developed by able to do achieve the same things [19, 24, 75]. There will be some lag time until adoption is possible, as the technology "trickles down" from stronger to weaker economies. The result is that growth in the affected sectors also will be slower. Another well-known perspective is the *innovator-imitator theory* of technology adoption. The idea is that the leading economies tend to be the innovators. The less developed countries are forced to be followers because their costs of imitation are higher, which also create a lag in time to adoption [5, 31]. This, in turn, will slow down growth. Neither of these theories explores the roles of exogenous versus endogenous factors that may be important.

In terms of methodological contributions, we demonstrated the benefits from going through a cycle of empirical estimation with multiple models, and then doing an additional assessment of what we learned through a cross-model inference approach. The typical approach is to start with a simple representation, such as linear and separable ordinary least squares regression. Our FGLS model was not able to capture the relationships that can be represented by more sophisticated models though. So we used an alternative approach, 2SLS estimation, to further examine the interactions between Internet-based selling technology adoption and e-commerce growth. Overall, analysis of alternative models created a pattern of results—an *analytical gestalt*—that helped us to learn more about the empirical regularities in the data that could be explained with a new and useful theoretical perspective. Our cross-model inference, which is different than what might be done with an analysis that involves just one empirical model emphasizes the method of "evidence triangulation" that has been developed in other research in different domains (e.g., the economic analysis of the appropriability of technology investments in the airlines' computerized reservation systems [29]. Other meta-research approaches that are similar in spirit have been applied to evaluate the relative efficacy of multiple theories as a more holistic means of explaining firm behavior in different settings, without trying to exclude any specific theories from consideration (e.g., in the economic literature on price rigidity and price flexibility [12, 47].

We expect that a similar methodological approach may be useful to study other technology adoption phenomena that may lead to economic growth in specific sectors of business. One example during the past 20 years that has been interesting to watch, but which has not been targeted by researchers as a basis for evaluating the related economic growth in IT services, IT outsourcing and IT offshoring—each of which seems to had its own adoption and diffusion trajectory in different parts of the world. The

most recent variant on these themes is cloud computing, which appears to have been rapidly adopted and now represents one of the premier forces for IT sector growth and development in many economies around the world. We believe that our methodological approach will be helpful to support researchers and analysts to conceptualize a joint exogenous factors-endogenous factors model that will permit them to understand the role of the key influences on IT services and cloud computing growth.

Our findings yield insights for policy-makers in three ways. First, the results show that greater Internet user penetration generally accelerates e-commerce growth. Governments can make ICT policies to support Internet user penetration, such as preferential treatment for Internet services providers and mobile telecommunication services companies. For example, a well-known approach that governments have used over the past 50 years is to support *infant industries* [30], which they view as potential future growth industries and major variables that influence economic national development. Some examples that come to mind in which governments have played a strong hand are the electronics and semiconductor industries in Malaysia and Singapore [42, 63], the flat panel monitor industry and other high-technology industries in Taiwan [65, 74], and the software and IT services industry in India [46, 57].

Second, support for the development of venture capital for technology-related businesses also should stimulate technology and economic development. Government policies that specifically promote the development of venture capital should accelerate e-commerce growth. A shining example, as we have noted, is India, which saw a nascent software industry in the mid-1980s grow into a booming global IT services industry by the early 2000s, due to the involvement of the Indian government's effort to retool its legal and tax environment to encourage the inflow of capital from the diaspora of wealthy and successful Indian ex-patriots [28]. Israel's high-tech boom in the 2000s is also a product of existing intellectual capital matched with the government's efforts to create an institutional and economic infrastructure for the promotion of technological innovations and the formation of financial capital. For example, the government initiated the creation of six incubators to build R&D and entrepreneurship capabilities through the Ministry of Industry Trade and Labor. It also created the Yozma Program, which consisted of ten investment funds in which the government took a 40% funding share, while foreign investors took the remaining 60% [15].

Finally, our results suggest that capital investments, other interorganizational, and international relationships in telecommunications also may predispose a country to grow its relevant technological infrastructure, which ought to be a precursor of e-commerce revenue growth. A case in point is the formation of mobile telephony infrastructure, which serves as a basis for the future growth of mobile commerce revenue growth. Recent research has shown that, similar to Yozma's case in Israel, domestic sources of capital are important, but so is foreign involvement in the relevant technological infrastructure and technology services. Kauffman and Techatassanasoontorn [48] have pointed out the web of foreign direct investments that occurred leading up to the mid-2000s in the Asia Pacific, Europe, and Middle East regions. Some examples include Hong Kong's Hutchison Telecom, which received capital investment from Japan's NTT Docomo, the leading telecommunications in that geographic region. At the same time, however, Hutchison Telecom was itself investing relational assets in Chinese telecommunication infrastructure by offering training to China Unicom, while it funded Hutchison Telecom Australia. Similar foreign investments were also undertaken by Singapore's SingTel to create SingTel Opus Australia, while the Australian telecommunication services provider Telstra invested in CSL Hong Kong. Meanwhile, in Europe and the Middle East, mobile telephony industry leader, Vodaphone, was implementing a "Partner Network" strategy that included Estonia's Radiolinja, Lithuania's Bite GSM, Croatia's VIPNet, Cyprus's Cytamobile, and MTC in Bahrain and Kuwait.

There are several limitations to our research. First, we recognize the challenge of the generalizing from what we learned in this research. Because the data that we collected are primarily from developed countries over a specific period of time, this limited in our ability to generalize the findings. For some variables, we were not able to collect complete data, and missing data constrained our ability to include some countries and certain years. Collecting more data continues to be a major obstacle. Second, there also are possible errors from the measurement of the data since they are from different international organizations and consulting firms. Also, different organizations may use different measurement approaches, and different periods of time to collect data. This may make it hard to compare different variables across different countries and years. Besides, collecting data at different times of a year (e.g., different fiscal year ending dates) may make it problematic for the analyst to fully leverage the value of the data—another source of bias and error.

Third, this research used proxy variables to represent key constructs of interest in the hybrid growth model. For example, secure server penetration is a proxy variable to represent Internet-based selling technology adoption, although other variables provided related proxy measures. In addition, financial card penetration is a proxy variable that represents the financial environment readiness of B2C e-commerce. The use of proxy variables is always an accommodation in empirical research. Some of the proxy variables, we admit, are not perfect, but our choices are

supported by the literature and make sense in our research context, especially in view of the limited data. A final consideration is that the hybrid growth model does not consider the impacts of various government policies, which Watson and Myers [83] have shown may be especially important to consider in promoting technology industry development and success in smaller countries. Some the related government policies include issues such as taxes on e-commerce transactions, the promulgation of telecommunications and Internet access standards, and beneficial measures to control the incidence of Internet fraud. These issues are worthwhile to pursue in future research.

**Acknowledgments** We appreciated input from Nelson Granados, Kunsoo Han, Dongwon Lee, Jae-Kyu Lee, Hsiangchu Lai, Kalle Lyytinen, Michael Myers, Sajda Qureshi, Fred Riggins, Ryan Sougstad, Shariffah Zamoon, Bruce Weber, Ping Wu, and the reviewers and participants who read our paper in the JAIS Theory Workshop and the Hawaii International Conference on Systems Science, where the earliest versions of this work was present. We also thank the participants at the 2006 Information System Research Symposium at National Sun Yat-sen University. We further acknowledge the anonymous reviewers of this article when it was submitted to *Information Technology and Management*, and Angsana Techatassanasoontorn for her guidance and developmental support with refining some of the ideas. Shu-Chun Ho thanks the National Science Council in Taiwan for support under Grant #NSC97-2410-H-017-034-MY2. T.P. Liang thanks the support of "Aim for the Top University Plan" by Ministry of Education, Taiwan, and National Sun Yat-sen University. Rob Kauffman acknowledges the MIS Research Center of the University of Minnesota, the E-Commerce Research Center of National Sun Yat-sen University, and the W.P. Carey Chair and the Center for Advancing Business through Information Technology at Arizona State University for generous support.

## Appendix

See Table 10.

**Table 10** The 42 countries represented in the study

| Regions | Number | Countries in the region |
|---|---|---|
| Asia Pacific | 14 | Australia, China, Hong Kong, Indonesia, India, Japan, Malaysia, New Zealand, Philippines, Singapore, South Korea, Taiwan, Thailand, Vietnam |
| Central America | 1 | Mexico |
| Eastern Europe | 4 | Czech Republic, Hungary, Poland, Russia |
| North America | 2 | Canada, United States |
| South America | 5 | Argentina, Brazil, Chile, Colombia, Venezuela |
| Western Europe | 16 | Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Netherlands, Norway, Portugal, Spain, Sweden, Switzerland, United Kingdom |
| Total | 42 | |

## References

1. Agarwal R, Animesh A, Prasad K (2009) Social interactions and the 'digital divide': explaining variations in Internet use. Inf Syst Res 20(2):277–295
2. Aghion P, Howitt PA (1992) A model of growth through creative destruction. Econometrica 60(2):323–351
3. Aghion P, Howitt PA (1999) Endogenous growth theory. MIT Press, Cambridge, MA
4. Alesina A, Wacziarg R (1998) Openness, country size and government. J Pub Econ 69(3):305–321
5. Barro R, Sala-i-Martin X (1997) Technological diffusion, convergence and growth. J Econ Growth 2(1):1–26
6. Barro RJ, Sala-i-Martin X (2004) Economic growth. MIT Press, Cambridge, MA
7. Bassanini A, Scarpetta S (2002) Growth, technological change, and ICT diffusion: recent evidence from OECD countries. Oxford Rev Econ Policy 18(3):324–344
8. Basu S, Weil DN (1998) Appropriate technology and growth. Quart J Econ 113(4):1025–1054
9. Baumol WJ (1986) Productivity growth, convergence, and welfare: what the long-run data show. Am Econ Rev 76(5):1072–1085
10. Benhabib J, Speigel MM (1994) The role of human capital in economic development: evidence from aggregate cross-country data. J Monet Econom 34(2):143–173
11. Besley T, Case A (1993) Modeling technology adoption in developing countries. Am Econ Rev 83(2):396–402
12. Blinder AS, Canetti ERD, Lebow DE, Rudd JB (1998) Asking about prices: a new approach to understanding price stickiness. Russell Sage Foundation, New York, NY
13. Boldrin M, Levine DK (2002) Factor saving innovation. J Econ Theory 105(1):18–41
14. Breusch TS, Pagan AR (1979) A simple test for heteroscedasticity and random coefficient variation. Econometrica 47(5):1287–1294
15. Buchwald D (2008) Israel's high-tech boom. Infocus 2(2). Available at www.jewishpolicycenter.org/infocus/2008-06. Accessed on 15 Jan 2011
16. Brynjolfsson E, Kemerer CF (1996) Network externalities in microcomputer software: an econometric analysis of the spreadsheet market. Manage Sci 42(12):1627–1647
17. Brynjolfsson E, Malone TW, Gurbaxani V, Kambil A (1994) Does information technology lead to smaller firms. Manage Sci 40(12):1628–1644
18. Calem PS, Carlino GA (1991) Urban agglomeration economics in the presence of technical change. J Urban Econ 29(1):82–95
19. Caselli F, Coleman WJ (2001) Cross-country technology diffusion: the case of computers. Technol Adopt Econ Growth 91(2):328–335
20. Chandrasekaran D, Tellis GJ (2008) Global takeoff of new products: culture, wealth, or vanishing differences? Mark Sci 27(5):860–884
21. Chen PY, Hitt LM (2002) Measuring switching costs and the determinants of customer retention in Internet-enabled businesses: a study of the online brokerage industry. Inf Syst Res 13(3):255–274
22. Coe D, Helpman AW (1995) International R&D spillovers. Eur Econ Rev 39(5):859–887
23. Coe D, Helpman AW, Hoffmaister E (1997) North–South R&D spillovers. Econ J 107(1):134–149
24. Comin D, Hobijn B (2003) Cross-country technology adoption: making the theories face the facts. Staff Report No. 169, Economic Research, New York Federal Reserve Bank, New York, NY

25. Daveri F (2002) The new economy in Europe. Oxford Rev Econ Policy 18(3):345–362
26. Dekimpe MG, Parker PM, Sarvary M (1998) Staged estimation of international diffusion models. Technol Forecast Soc Change 37(1–2):105–132
27. Dewan S, Kraemer KL (2000) Information technology and productivity: evidence from country-level data. Manage Sci 46(4): 548–562
28. Dossani R, Kenney M (2002) Creating an environment: developing venture capital in India. BRIE working paper no. 143. Berkeley round table on the international economy, University of California, Berkeley, CA
29. Duliba KA, Kauffman RJ, Lucas HC Jr (2001) Appropriating value from computerized reservation system ownership in the airline industry. Organ Sci 12(6):702–728
30. Easterly W, King R, Levine R, Rebelo S (1994) Policy, technology adoption, and economic growth. In: Solow RM, Pasinetti LL (eds) Economic growth and the structure of long-term development. St. Martin's Press, New York, NY, pp 3–21
31. Eeckhout J, Jovanovic B (2002) Knowledge spillovers and inequality. Am Econ Rev 92(5):1290–1307
32. Forman C (2005) The corporate digital divide. Manage Sci 51(4):641–654
33. Fortune (2000) Venture sweepstakes: faced with a new market reality, investors look for opportunities at the nexus of business and the Internet. Fortune 142(12):202–207
34. Gibbs J, Kraemer KL, Dedrick J (2003) Environment and policy factors shaping global e-commerce diffusion. Inf Soc 19(1):5–18
35. Grossman GM, Helpman E (1991) Innovation and growth in the global economy. MIT Press, Cambridge, MA
36. Grossman GM, Helpman G (1994) Endogenous innovation in the theory of growth. J Econ Perspect 8(1):23–44
37. Ho SC, Kauffman RJ, Liang TP (2007) A growth theory perspective on B2C e-commerce growth in Europe: an exploratory study. Electron Commer Res Appl 6(3):237–259
38. Ho SC, Kauffman RJ, Liang TP (2008) A growth-theoretic empirical analysis of simultaneity in cross-national e-commerce development. In: Sprague R, Waikoloa HI (eds) Proceedings of the 41st Hawaii international conference on systems science. IEEE Computing Society Press, Los Alamitos, CA, pp 410–419
39. IDC (2008) Digital marketplace model and forecast, version 1.0. Framingham, MA
40. ITU (International Telecommunications Union) (2009) Library and archives service (Geneva, Switzerland). Available at www.itu.int/library. Accessed on 1 Dec 2010
41. Jarvenpaa SL (1991) Panning for gold in information systems research: second-hand data. In: Nissen HE, Klein H, Hirschheim R (eds) The information systems research arena of the 1990s: challenges, perceptions and alternative approaches. North-Holland, Amsterdam, pp 63–80
42. Jomo KS, Felker G, Rasiah R (eds) (1999) Industrial technology development in Malaysia: industry and firm studies. Routledge, London, UK
43. Judge GG, Griffiths WE, Hill RC, Lutkepohl H (1985) The theory and practice of econometrics, 2nd edn. Wiley, New York, NY
44. Kaldor N (1961) Capital accumulation and economic growth. In: Lutz FA, Hague DC (eds) The theory of capital. St. Martin's Press, New York, NY
45. Kauffman RJ, Kumar A (2008) Impacts of communication and information technologies on country development: accounting for area relationships. Int J Electron Commer 13(1):11–58
46. Kauffman RJ, Kumar A (2008) Mapping the multi-tiered impacts on the growth of IT industries in India: a combined scale-and-scope externalities perspective. J Inf Technol Dev 14(3):225–252
47. Kauffman RJ, Lee DW (2010) A multi-level theory approach to understanding price rigidity in Internet retailing. J Assoc Inf Syst 11(6):303–338
48. Kauffman RJ, Techatassanasoontorn A (2005) Is there a global digital divide for digital wireless phone technologies? J Assoc Inf Syst 6(12):338–382
49. Kauffman RJ, Techatassanasoontorn A (2009) Understanding early diffusion of digital wireless phones. Telecommun Policy 33:432–450
50. Keller W (1998) Are international R&D spillovers trade-related? Analyzing spillovers among randomly matched trade partners. Eur Econ Rev 42(8):1469–1491
51. Kennedy P (2003) A guide to econometrics, 5th edn. MIT Press, Cambridge, MA
52. Kiiski S, Pohjola M (2002) Cross-country diffusion of the Internet. Inf Econ Policy 14(2):297–310
53. Kmenta J (1986) Elements of econometrics, 2nd edn. Macmillan, New York, NY
54. Kraemer KL, Dedrick J, Melville N, Zhu K (eds) (2006) Global e-commerce: impacts of national environments and policy. Cambridge University Press, Cambridge, UK
55. Kraemer KL, Gibbs J, Dedrick J (2005) Impact of globalization on e-commerce use and firm performance: a cross-country investigation. Inf Soc 21(5):324–340
56. Kshetri N, Dholakia N (2002) Determinants of the global diffusion of B2B e-commerce. Electron Mark 12(2):1–10
57. Lateef A (1997) Linking up with the global economy: a case study of the Bangalore software industry. DP/96/1997, International Institute of Labor Studies (Geneva, Switzerland). Available at www.ilo.org/public/english/bureau/inst/papers/1997/dp96/ch1.htm. Accessed on 1 Dec 2010
58. Lucas RE (1988) On the mechanics of economic development. J Monet Econ 22(1):3–42
59. Lucking-Reiley D, Spulber DF (2001) Business-to-business electronic commerce. J Econ Perspect 15(1):55–68
60. Mahmood MA, Bagchi K, Ford TC (2004) On-line shopping behavior: cross-country empirical research. Int J Electron Commer 9(1):9–30
61. Manchala DW (2000) E-commerce trust metrics and models. IEEE Comput 4(2):36–44
62. Martinez CA, Williams C (2010) National institutions, entrepreneurship and global ICT adoption: a cross-country test of competing theories. J Electron Commer Res 11(1)
63. Mathews JA, Cho DS (2000) Tiger technology: the creation of the semiconductor industry in East Asia. Cambridge University Press, Cambridge, UK
64. Meso P, Musa P, Straub D, Mbarika V (2009) Information infrastructure, governance, and socio-economic development in developing countries. Eur J Inf Syst 18(1):52–65
65. Murtha TP, Lenway SA, Hart JA (2001) Managing new industry creation: global knowledge formation and entrepreneurship in high technology: the race to commercialize flat panel displays. Stanford University Press, Stanford, CA
66. OECD (Organization for Economic Cooperation and Development) (2009) Communications outlook: information and communications technologies. Zurich, Switzerland
67. Okoli C, Mbarika VWA, McCoy S (2010) The effects of infrastructure and policy on e-business in Latin America and Sub-Saharan Africa. Eur J Inf Syst 19(1):5–20
68. Parente SL, Prescott EC (1994) Barriers to technology adoption and development. J Polit Econ 102(2):298–321
69. Pindyck RS, Rubinfeld DL (1998) Econometric models and economic forecasts, 2nd edn. McGraw Hill, New York, NY
70. Pohjola M (2003) The adoption and diffusion of ICT across countries: patterns and determinants. In: Jones DC (ed) The new economy handbook. Elsevier, New York, NY

71. Rivera-Batiz LA, Romer PM (1991) Economic integration and endogenous growth. Quart J Econ 106(2):531–555
72. Romer PM (1986) Increasing returns and long run growth. J Polit Econ 94(5):1002–1037
73. Romer PM (1994) The origins of endogenous growth. J Econ Perspect 8(1):3–22
74. Saxenian AL (2007) The new argonauts: regional advantage in a global economy. Harvard University Press, Boston, MA
75. Saxonhouse G, Wright G (2004) Technological evolution in cotton spinning, 1878–1933. In: Farnie DA, Jeremy DJ (eds) The fibre that changed the world. Oxford University Press, Oxford, UK
76. Stern DI, Common MS, Barbier EB (1996) Economic growth and environmental degradation: the environmental Kuznets curve and sustainable development. World Dev 24(7):1151–1160
77. Tellis GJ, Stremersch S, Yin E (2003) The international takeoff of new products: the role of economics, culture and country innovativeness. Mark Sci 22(2):188–208
78. Tornatzky LG, Fleischer M (eds) (1990) The process of technological innovation. Lexington Books, Lexington, MA
79. UNCTAD (United Nations Conference on Trade and Development) (2001–2005) E-commerce and development report. New York, NY
80. UNCTAD (2006) ICT for e-business development. Trade and Development Board, Commission on Enterprise Business Facilitation and Development, Geneva, Switzerland
81. UNCTAD (2007) Information economy report—2007–2008 science and technology for development: The new paradigm of ICT. New York, NY, and Geneva, Switzerland
82. UNCTAD (2009) Information economy report, 2009: trends and outlook in turbulent times. New York, NY, and Geneva, Switzerland
83. Watson R, Myers MD (2001) IT industry success in small countries: the cases of Finland and New Zealand. J Global Inf Manage 9(2):4–14
84. Wolcott P, Press L, McHenry W, Goodman S, Foster W (2001) A framework for assessing the global diffusion of the Internet. J Assoc Inf Syst 2(6):1–50
85. Wooldridge JM (2002) Econometric analysis of cross section and panel data. MIT Press, Cambridge, MA
86. World Bank (1999) World development indicators. Washington, DC
87. Xu SK, Zhu K, Gibbs J (2004) Global technology, local adoption: a cross-country investigation of Internet adoption by companies in the United States and China. Electron Mark 14(1):13–24
88. Zacharakis AL, Shepherd DA, Coombs JE (2003) The development of venture-capital-backed Internet companies: an ecosystem perspective. J Bus Ventur 18(2):217–231
89. Zeira J (1998) Workers, machines, and economic growth. Quart J Econ 13(4):1091–1117
90. Zhu K, Kraemer KL (2005) Post-adoption variations in usage and value of e-business by organizations: cross-country evidence from the retail industry. Inf Syst Res 16(1):61–84
91. Zhu K, Dong S, Xu SX, Kraemer KL (2006) Innovation diffusion in global contexts: determinants of post-adoption digital transformation of European companies. Eur J Inf Syst 15(6):601–616
92. Zhu K, Kraemer KL, Xu S (2006) The process of innovation assimilation by firms in different countries: a technology diffusion perspective on e-business. Manage Sci 52(10):1557–1576