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A growth theory perspective on B2C e-commerce growth in Europe: An exploratory study

Shu-Chun Ho [a,*], Robert J. Kauffman [b,1], Ting-Peng Liang [c,2]

[a] Department of Information Management, Shu-Te University, Kaohsiung, Taiwan, ROC
[b] Carlson School of Management, 321, 19th Avenue South, University of Minnesota, Minneapolis, MN, USA
[c] Department of Information Management, National Sun Yat-Sen University, Kaohsiung, Taiwan, ROC

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Abstract

Information and communication technologies (ICTs) continue to have a profound effect on the economies and societies where they are used. In this article, we propose three related theories to describe the underlying mechanism for growth in e-commerce revenues at the national level. *Endogenous growth theory* posits that the primary drivers of e-commerce growth are internal to a country. *Exogenous growth theory* suggests that the primary drivers of e-commerce growth are external to an economic system, and reflect the forces of the regional economy. A blend of these, a *mixed endogenous–exogenous growth theory*, incorporates drivers from both the economy and the region of a country. We test a number of hypotheses about e-commerce growth in the context of these theories. The key variables include Internet penetration, telecommunication investment intensity, venture capital and credit card availability, and education level. The data are drawn from 17 European countries over a five-year period from 2000 to 2004, and are analyzed using panel data regression with robust error terms, a variant of weighted least squares. The results show the differential efficacy of internal and external drivers as endogenous and exogenous precursors of e-commerce growth across the countries for a number of different modeling specifications. We conclude with a discussion of alternative approaches to model e-commerce growth in a country. The results also suggest the appropriateness of exploring models of regional contagion for e-commerce growth.

Keywords: Contextual production; Economic analysis; E-commerce; Empirical research; Endogenous growth; Exogenous growth; Growth theory; Theory-building research

1. Introduction

The productive capacity of societies and standard of living of nations are primarily determined by the evolution of technology, and the related information and knowledge are critical components of economic growth [17,89]. The emergence of Internet-based business has radically transformed the global economic and social landscape over the past decade [87]. E-commerce experienced a boom-and-bust business cycle in its transition from the dotcom bubble in 2000 and 2001 back to an economy with more modest expectations for technology-led value. More recently, it has been achieving steady growth in the global setting. The development of e-commerce and related technologies so far has mostly been limited to developed countries and has been relatively slower in the rest of the world [13,23,29,35,36,47]. Recent issues of the *E-Commerce and Development Report* by the United Nations Conference on Trade and Development [114,115] suggest that the majority of developing countries face limitations for the advancement of their digital economies. These limitations stem largely from low income levels, low literacy rates, a lack of payment systems that can support online transactions, and cultural resistance to online transaction-making.

* Corresponding author. Fax: +886 7 615 8000x3099.
E-mail addresses: sch@mail.stu.edu.tw (S.-C. Ho), rkauffman@csom.umn.edu (R.J. Kauffman), tpliang@mail.nsysu.edu.tw (T.-P. Liang).
[1] Fax: +1 612 626 1316.
[2] Fax: +886 7 525 4504.

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UNCTAD has proposed these constraints on cross-national e-commerce growth; however, they have not yet been examined empirically. The lack of empirical results highlights the importance of investigating macro-level factors affecting cross-national e-commerce growth.

Prior studies have explored the facilitating and inhibiting factors for e-commerce growth and diffusion across countries [73,125,126]. However, an appropriate theory is needed to explain the different observed levels of e-commerce growth and diffusion [67,128]. This research presents complementary macroeconomic growth theories for interpreting business-to-consumer (B2C) e-commerce growth in the cross-national context. We will explore the macro-drivers of B2C e-commerce growth across countries.[3]

We seek answers to the following research questions:

- Is growth theory useful for investigating B2C e-commerce growth and diffusion across countries? What does it offer beyond current theories?
- How do endogenous growth theory and exogenous growth theory help to organize our thinking about the mechanism for B2C e-commerce revenue growth? What new explanatory capabilities do the theories offer?
- To what extent do the growth theories explain the extent to which growth is driven internally or externally across countries? Does a mixed model further inform us?

This research will permit us to understand the extent to which the growth of B2C e-commerce is driven by factors that are internal or external to the countries in our data set. We specifically employ a *growth theory perspective* from macroeconomics and developmental economics as the basis for eliciting answers to the research questions. We map this perspective to a preliminary and exploratory empirical analysis that involves an illustration of the roles of endogenous and exogenous drivers of e-commerce growth across a set of 17 European countries. The results suggest the potential of variables such as Internet user penetration, telecommunications investment, education level, venture capital availability, and credit card penetration in support of online transaction-making in explaining B2C e-commerce growth. These vary in strength as endogenous drivers of growth when they are from the country for which growth estimation is being performed, and as exogenous drivers of growth when they are from other countries and explain the e-commerce growth of other countries.

The remainder of the article is laid out as follows. Section 2 reviews the development of e-commerce across countries. In Section 3, we introduce the theories of exogenous and endogenous growth and illustrate why they are appropriate to apply to national-level e-commerce growth. In Section 4, we present research hypotheses that we will empirically test to gauge B2C e-commerce growth among 17 European countries. Section 5 lays out the variables and data sources used in this research. Section 6 presents the details of our empirical models (including modeling diagnostics, model formulation and functional form, full and reduced models) and the exploratory empirical results. We conclude in Section 7 with the contributions and limitations of this research.

2. Background: global e-commerce growth

We next define e-commerce to specify what we study and model in this research. We further discuss the background of global Internet diffusion, e-commerce growth, and assess the main thrust of empirical research to date on international aspects of e-commerce.

2.1. Definition of e-commerce

Although there are a number of definitions of e-commerce that are currently available in the literature [61,127,112,94,60,103,50,67], the discussion of e-commerce definitions intends to give idea of our application of growth theory and deliver new knowledge. Zwass [127, p. 3] defines e-commerce as "the sharing of business information, maintaining business relationships, and conducting business transactions by means of telecommunications networks." Treese and Stewart [112, p. 5] define e-commerce as "the use of the global Internet for purchase and sale of goods and services, including services and support after the sale." Kalakota and Whinston [61, p. 3] define e-commerce as "the delivery of information, products/services, or payments via telephone lines, computer networks or any other means." They do not limit their coverage to just Internet-based means. Kauffman and Walden [67, p. 3] emphasize "the Internet as a medium for enabling end-to-end business transactions." Their definition "applies equally well in dot-com [and] Internet-only business settings, as well as more traditional business settings where the new channel of the Internet is being used alongside existing channels."

We seek to identify an appropriate definition for e-commerce that emphasizes the B2C side of e-commerce. This is because our measurement approach is focused on growth in consumer expenditures relative to transaction-making on the Internet—in other words, the revenues of Internet-based sellers. With this in mind, we use a B2C-focused version of Treese and Stewarts' and Kauffman and Walden's definitions: B2C electronic commerce is the use by business and consumers of the global Internet for the sale and purchase of goods and services, including business services and support after the sale to consumers. Similar to Kauffman and Walden [67], we note that the present definition emphasizes the Internet as a medium for end-to-end B2C

[3] We do not include consumer-to-consumer (C2C) e-commerce, since information is tracked by the national agencies that collect data on the digital economy, in spite of the fact that this may constitute an interesting aspect of the actual commerce that is being transacted. In addition, we do not treat the growth of business-to-business (B2B) e-commerce, which would require different modeling and variables to provide an effective interpretation. We also do not emphasize technology adoption as a precursor of e-commerce growth.

transactions. Their definition also applies to Internet only and bricks-and-clicks settings in which businesses and consumers share information and make transactions.

2.2. The related role of Internet diffusion

The effect of computing progress on productivity has been widely examined by researchers [43,1,86,14]. The increasing power of computerization and declining prices of computing are known contributors to a country's productivity [14]. The effects of declining prices of networking and hardware technologies have had a marked and positive influence on Internet technology adoption for the purpose of conducting e-commerce. Declining prices make the factors of production for e-commerce cheaper, accelerating adoption of Internet technologies and e-commerce business models.

According to a recent white paper published by the International Telecommunication Union (ITU), nearly 676 million people—about 11.8% of the total population of the world—had access to the Internet by the end of 2003 [115]. The distribution and growth of Internet users in different regions, however, are uneven (see Table 1).

Internet users from the developed countries contribute to 58% of the share of global Internet users and those from developing countries accounted for more than 36% by the end of 2003. The developing countries' share of global Internet users was nearly 50% in 2000 and 2003, but the users were concentrated in a few nations (e.g., China, Republic of Korea, India, Brazil and Mexico, which accounted for nearly 62% of Internet users in the developing world).

Nevertheless, the surge in worldwide Internet usage does not necessarily correlate directly with observed growth in the volume of e-commerce transactions or revenues. Internet users often investigate what they should buy, but their actual purchases may be made in physical stores. This is the "look-to-book" phenomenon that we saw towards the end of the 1990s in the United States, when air travelers searched for attractive airfares on the Internet, but actually booked through traditional bricks-and-mortar travel agencies [20].

2.3. Cross-country e-commerce research

In recent years, various researchers have sought to understand factors that affect e-commerce or e-business adoption across countries [40,54,74,78,117,121,126]. These cross-country e-commerce studies focus on three different levels: the *individual level* [78], the *firm level* [40,121,126] and the *country level* [54,74]. Xue et al. [121], Zhu et al. [126] and Gibbs et al. [40] provide valuable insights on firm-level e-business adoption across countries. They applied a technology–organization–environment framework to identify facilitators and inhibitors of firm-level e-business adoption across countries. The above discussion suggests that adoption and use of e-business technologies is an active research area in the information systems (IS) discipline [108]. However, based on the current state of the research, very little is known about the *aggregate level* of national economies relative to B2C e-commerce growth. Our intention is to explore aggregate-level drivers of B2C e-commerce growth across countries.

2.4. Identifying drivers of global e-commerce growth

Since there are few studies of aggregate level e-commerce growth, no definitive list of the drivers of B2C e-commerce growth across countries exists. To begin to identify the drivers of B2C e-commerce growth, we reviewed the literature on cross-national technology adoption and the diffusion of innovations [25,40,51,70,96,109]. These studies focus on technology and innovation adoption, and so they are not specialized or tuned for capturing

Table 1
Internet users by region and by level of development, 2000–2003 (thousands)

Countries	2000 Users	Percent growth	2001 Users	Percent growth	2002 Users	Percent growth	2003 Users
Regions of the world							
Africa	4559	34	6119	63	9988	21.38	12,123
Asia	109,257	38	150,535	40	211,202	15.25	243,406
Europe	110,824	30	143,584	23	176,232	7.24	188,997
Latin America	17,673	65	29,224	45	42,439	4.19	44,217
North America	136,971	14	156,823	12	175,110	12.7[a]	197,389[a]
Oceania	8248	16	9601	21	11,607	1.88	11,825
Total	387,532		495,886		626,578[b]		697,957
Developed, developing and other countries							
Developed	285,480	19	339,427	15	388,746	7.79	419,033
Developing	94,352	48	139,317	50	209,556	17.53	246,290
Others	7700	123	17,142	65	28,277	15.41	32,634
Total	387,532	27.96	495,886	23.36	626,579[b]	11.39	697,957

Source: UNCTAD (2004).
[a] Data source ITU (2003).
[b] Small differences due to rounding errors.

growth. Nevertheless, these determinants give us a picture of the potential drivers. They include GDP per capita, geographic and demographic characteristics, urbanization, information infrastructure, cost to shop on the Internet, adequacy of economic and financial resources, cosmopolitanism, education, and human capital (see Fig. 1). We next discuss some of these studies to identify specific variables that will help us in modeling B2C e-commerce growth and diffusion across countries.

We will first consider the potential link between national wealth and e-commerce growth. Various studies have suggested that GDP per capita [31,40,51,81–83,109], and the related gross national product (GNP) per capita [25,63–65] are indicators or drivers of national wealth. They are likely to affect the extent of observed new product or technology development in a country. The reader should recognize that GDP per capita internal to a country is likely to be an endogenous driver of growth. However, it is also possible that high levels of GDP per capita in neighboring countries may encourage some spillover effects for the adoption and diffusion of e-commerce.

Second, geographic and demographic characteristics may act as indirectly enhancing or constraining conditions for e-commerce development [40,119]. Countries such as Singapore and Germany, with high population densities and high wealth per capita, have well-developed ICT infrastructures [40]. However, high population density also may explain the well-developed traditional retailing networks that are observed such as in France and Taiwan. These countries have efficient convenient traditional retailing channels that reduce the need for online shopping [40].

Third, the availability of information infrastructure also has been demonstrated as an enabler of B2C e-commerce diffusion [40] and other technologies within nations [19,21,22,120]. People cannot shop online if they do not have telephone lines. The same is true if they do not have reasonably quick Internet access.[4] ICT infrastructure is a prerequisite for e-commerce growth. Thus, we expect that a well-developed ICT infrastructure within a country should be associated with faster e-commerce growth.

Fourth, adequacy of economic and financial resources will have direct effects in shaping e-commerce diffusion [119]. The cost of Internet access is a critical factor that affects e-commerce development. High costs for Internet access or availability of alternative technologies (like mobile phones) are likely to hamper e-commerce development at the level of the economy. People will access the Internet more often when the connection costs and the technology costs are relatively low. Online transaction costs, as a result, also may affect e-commerce growth. The relevant costs include access fees and transaction costs associated with privacy, risk and e-security issues on the Internet [45,70,110]. Privacy, transaction cost, and e-security issues are critical micro-level factors that may affect people's intentions to shop online. The availability of online payment infrastructure capabilities, such as credit cards and other online shopping payment support, is likely to accelerate online transaction-making in e-commerce.

Fifth, the average level of education [70] and the quality of human capital [16] within a country also may be influential. Technological knowledge that is necessary for the creation and effective usage of e-commerce-related activities may not be available in countries with poorly educated populations [38]. High levels of educational attainment are proven to be critical in the extent of computer technology adoption in a country [16]. In addition, human capital is widely recognized as a key input to the R&D sector in a country, which usually generates the new ideas and products associated with technological progress. Educational capabilities and human capital resources within a country, rather than outside of it, are most likely to influence the growth of e-commerce in the country.

Last, Calem and Carlino [15] have shown that urban areas typically have greater infrastructure and economies of scale. As a result, the penetration potential for various kinds of technologies will be higher in countries with higher levels of urbanization. The degree of urbanization has also been used as a ceiling parameter in models to explain global cellular telephone adoption [25,29]. Other authors offer somewhat different and contrasting interpretations based on *global village theory*, which posits that isolated establishments will be earlier adopters of innovative technologies, and *urban leadership theory*, which suggests that density creates beneficial externalities in support of earlier adoption of new technologies in cities [39].

Although we are not able to include all the above variables in this exploratory research, they nevertheless give us some initial ideas about the variety of potential considerations that must be made to bring together a more comprehensive understanding of cross-country B2C e-commerce growth. Similarly, we need to better understand the patterns in which B2C e-commerce growth occurs across countries. Such patterns of growth will provide us with the raw data from which we can make deductions about the underlying mechanisms that are at work that

[4] We should point out that the effects of Internet access are likely to be subtle in this research. It probably is not appropriate to characterize Internet access alone as being sufficient for the creation of online shopping expenditures. We know, for example, that access speeds for the Internet have gotten faster, while the cost of such access has fallen. In other words, this variable has not exhibited *stationarity* over time; instead, there has been a time-wise drift so that with the passage of time Internet access has become less of an issue. As one reviewer of this paper suggested, it might be interesting to consider the issue of Internet access in another way—by price. However, there is no consistent international source of data to capture either access speeds by country by year, or access prices by country by year. Finally, within the European data set that we use, we actually do not expect there to be so many dramatic differences in access speeds across countries. Compared to other regions of the world, the European countries tend to share more similar telecommunications infrastructures. This might be of more interest to us if our data set covered multiple continents and regions, such as Europe, Asia, North America, etc. There are other noteworthy differences in the European context though, so we believe it is worthy of exploratory study.

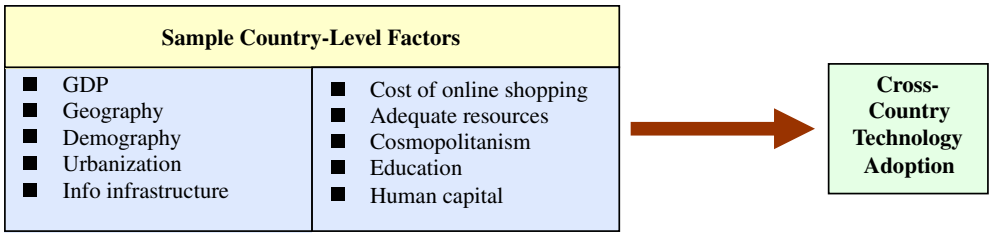

Fig. 1. Sample country-level factors affecting cross-country technology adoption. *Note*: The country-level drivers can be classified in terms of *economy* (e.g., adequate resources, GDP), *environment* (e.g., geography, demography, urbanization, cosmopolitanism), *people* (e.g., education, human capital), and *technology* (e.g., cost of online shopping, information infrastructure).

lead to the observed outcomes. This is where growth theory comes in.

3. Theoretical explanations for B2C e-commerce growth

We next provide a theoretical perspective with the nation as the primary unit of analysis. This permits us to develop insights on the underlying mechanisms for B2C e-commerce growth, and the manner in which we can estimation their outcomes.

3.1. Theories of economic growth

Growth theory provides a theoretical vantage point to observe and interpret e-commerce development in the global economy. *Growth theory* is generally associated with models, mechanisms, explanations and predictive frameworks that characterize what drives a country's economic growth. The most fundamental proposition of growth theory is that there is continuous exogenous technological progress. The related advances take the form of new goods, new markets, and new processes to sustain a positive growth rate of output per capita in the long run. This proposition in technology-led economic growth matches the context of digital economy growth. Internet technologies create the basis for continual advances with respect to new goods, new markets and new business models in the digital economy, which provide the basis for e-commerce development. On the other hand, it also widens the gap of e-commerce development among countries. The increasing gap in cross-national e-commerce development highlights the importance of understanding what factors drive growth. We focus on investigating the key determinants of B2C e-commerce growth across countries.

There have been many attempts to identify the factors that drive economic growth and performance, and to provide suggestions to policymakers to lessen the gap between developed and developing countries [24,71,92,102]. The increasing availability of standardized data sets has led to a burgeoning empirical literature on cross-country growth. Many of these articles have examined whether economic growth is converging relative to the United States and what the forces are that may lead to convergence [7,8,10,26,27,79,100]. A variety of different variables, including labor, land, capital, infrastructure and technology, have been measured and evaluated in terms of their contribution to the international difference of productivity. We next examine one variant of growth theory more closely, exogenous growth theory, as a means to begin our exploration of where the key drivers of e-commerce growth are likely to be operative and how they work.

3.2. Exogenous growth theory

During the 1950s, Solow [104] and Swan [107] constructed the first general equilibrium model of economic growth—the *Solow–Swan model*—which is most representative of *exogenous growth theory*. Today, this body of knowledge is known as *neoclassical growth theory*. The exogenous growth theory assumes technological progress as an exogenous component in the production function. Since technology change is constrained to be exogenous and costless in the model, national-level technology policy cannot affect the long-term growth rate of per capita income (even though it may not be logical to view the process this way). In the neoclassical growth model, per capita output grows in the long run only due to exogenous technological progress.[5] This model demonstrates that the effects of diminishing returns to capital investments will cause economic growth to slow or stop without technological progress. One implication is that capital accumulation and population growth are insufficient to explain continuing increases in per capita incomes, and that government policy will not affect long-term per capita growth.

[5] Exogenous technological progress is often referred to in economics as *disembodied technical change*. This occurs when the production frontier exogenously shifts over time, without any specific or identifiable source or factor of production bearing the responsibility for causing this [88]. In contrast, *embodied technical change* occurs when a production frontier endogenously shifts in response to improvements in the design or quality of capital goods, or in the presence of more effective intermediate inputs, which can be incorporated in a production function as specific factors of production [88]. The move to digital economy business processes and new economy business models is made possible by a number of technologies and knowledge spillovers that have changed the production frontier for the related business services. We can look at this issue in the context of a given economy, and attempt to gauge the specific impacts of aggregate Internet technology or digital wireless phone services infrastructure investments on the growth of e-commerce or mobile commerce sector production, for example. For additional background on embodied and disembodied technical change, see Jorgenson [55].

The Solow–Swan model of economic growth typically is expressed in the Cobb–Douglas production function format with aggregate output at different points in time, a measure of the degree of exogenous technological progress, a measure for capital stock, an indicator for the labor supply, and a productivity parameter. Output grows at a rate equal to the sum of the growth rate of the population and the exogenous component of technology progress [105]. According to Mankiw et al. [79], the Solow–Swan model does well in explaining the cross-country distribution of growth in per capita income, and the convergence rates of countries to their steady state growth rates.

However, there are some issues with exogenous growth theory that need to be considered. For example, consider labor as human capital or knowledge. In the knowledge economy, labor is human capital because knowledge from employees can be accumulated within a firm and stored within the systems of a firm. Another issue with exogenous growth models is that they tend to treat the key engine of growth, technological change, as a "black box," and are not able to offer policymakers with workable controls. Another weakness of exogenous growth theory is that it does not address some of the complicated issues that arise in the economic analysis of the production and the diffusion of technology, knowledge, and information [2]. Finally, Solow's original model does not consider that countries are likely to differ in the amount of technology that they use, which might help to explain international differences in income and social welfare over time.

Although there are arguments about the limitations of exogenous growth theory in explaining long-term growth, recent empirical cross-country studies have tried to identify exogenous variables that are explanatory of international differences in economic output [49,90,99,101,123]. These studies have demonstrated that variables such as geography, resource endowments, infrastructure, and political regime cause much of the international productivity differentials. The exogenous variables in some of these studies are similar to the factors that affect technology adoption and the diffusion of innovations in cross-country studies in marketing and IS. We now turn to a discussion of a contrasting perspective, endogenous growth theory, which has a different fundamental assumption about the role of technological progress in the production function.

3.3. Endogenous growth theory

Endogenous growth theory was developed in the mid-1980s in response to criticisms of the neoclassical growth model associated with exogenous growth. *Endogenous growth theory* argues that economic growth is an internally-driven outcome of an economic system, instead of the result of forces and factors that impinge from outside [97,98]. The main theme of endogenous growth theory is that economic growth involves a two-way interaction between technology and economic life: technological progress transforms the very economic system that creates it [3]. Lucas [76], Grossman and Helpman [46], and Aghion and Howitt [2] have provided guidance on how to endogenize technological changes to create new explanations for economic growth, for example, that technological innovations are driven by the profit motives of agents within an economy, and government policies on how technological innovation can affect long-run growth.

A key characteristic of endogenous growth models is the absence of diminishing returns to capital. The simplest version of a production function (without restrictions on the returns, e.g., diminishing, constant or increasing) is one in which output is a function of a positive constant that reflects the leverage on economic growth that the technology creates, labor and capital. Endogenous growth also means that, on balance, output growth is more responsive to factors that occur within an economy than outside it. This implies that exogenous factors also play some role in contributing to the growth rate of output. We can leverage the understanding that endogenous growth theory has established for the links between technological knowledge and various economic and social structural characteristics, and how such interactions result in economic growth.

Endogenous growth theory has been widely applied in different cross-national studies that involve the effects of technological diffusion on economic growth. Grossman and Helpman [46] and Rivera-Batiz and Romer [95] assess the effects from diffusion of knowledge under the condition of steady-state growth. Barro and Sala-i-Martin [8] construct a model that combines elements of endogenous growth with convergence of growth across economies by considering the role of technology innovation. They claim that the rate of international economic growth is driven by discoveries that occur in the leading technological economies, and the following countries converge toward the leaders because technological imitation tends to be cheaper than technological innovation.

These endogenous growth models have the characteristic that cross-country differences in policies and preferences may lead to permanent differences in growth rates of per capita output. Several of the endogenous growth models also can be interpreted as models of technology adoption, because they recognize that there is an accumulation of intangible capital. Endogenous growth theory further predicts positive externalities and spillover effects within a country from the development of a high value-added knowledge economy [3,45]. However, there also is a weakness: endogenous growth theory loses predictive ability for growth convergence, where there is an allowance made for the heterogeneity of economies and their different growth trajectories toward a steady-state level of growth [8].

The growth theories discussed so far provide us with different and useful perspectives on the underlying mechanisms for B2C e-commerce growth across countries.

Exogenous growth theory has proven to be powerful in accounting for the patterns of economic development. In contrast, endogenous growth theory assists our understanding of the growth in global knowledge transfer and the transition of global economy.

3.4. Assessment of production models with contextual factors

To make an effective case for how the growth theories that we have discussed can be leveraged to build empirical models that will provide useful insights in our research context, we need to consider two related issues.

We must consider the extent to which the models we will assess are production models. The estimation of parametric models involving input–output correspondences is standard in production economics [55,57], and has led to a number of key contributions in the economic literature involving IT impacts [30,31,56,58]. The typical approach that these works take is to assess "true" input–output production, in which the inputs are viewed as being consumed in the production of outputs (e.g., energy, labor and materials in manufacturing production, for example).

This is also true for non-parametric production function assessment approaches, in particular data envelopment analysis (DEA). However, the literature on DEA also treats other circumstances in which inputs are not controllable or consumed. Banker and Morey [5] proposed a method that recognizes the role of *exogenously-fixed inputs* (e.g., population or income levels in a sales territory, or the existing level of Internet users among potential e-commerce shoppers, etc.)— *non-discretionary input variables* that would not be consumed in production in the usual sense. Banker and Natarajan [6] further note the role of *contextual variables,* which may explain productivity outcomes. The DEA literature examines production outcomes and the reasons causing it via two-stage methods involving DEA then explanatory regression. Xue et al. [122] also point out that DEA models have used objective and perceptual inputs, both of which may not be consumed or physically-produced (e.g., customer effort in self-service Internet-based selling, and perceptions of customer satisfaction with Web site use for purchasing goods and services). Several recent studies that use DEA also apply this general approach to examine the performance of alternative Web site designs in Internet-based selling [48] and the co-production of retail services by the firm and its consumers [122].

For the present research, we conceptualize our study of e-commerce growth in contextual production terms. *Contextual production* means the estimation of production outcomes or outputs in the presence of exogenously-fixed variables or contextual variables that have some effect on production, but are not themselves consumed. As the reader will see later in this article as we discuss data collection, it is difficult to acquire the typical kinds of data for the study of a true input–output correspondence for e-commerce growth (e.g., related technology capital, non-technology capital, e-commerce-related labor and so on). We will examine how to apply growth theory thinking when the production of B2C e-commerce growth is not based on the consumption of inputs, but on the mapping of factors that influence production outcomes in a given context (as with both exogenously fixed variables and contextual variables).

We also need to conceptualize the differences so that it is clear what we can do to establish meaningful empirical results. In operationalization terms for empirical models of e-commerce growth, this means that we must identify internal and external drivers—as influences on production—and determine how they relate to one another and to e-commerce growth. Some prior studies have examined the contextual characteristics that are associated with higher levels of development in developing countries and regressed those on key indicators and performance measures. For example, Ngwenyama et al. [84] did this for the United Nation's Human Development Index (HDI), which they estimated in terms of national-level investments in health, ICT and education. We also see similar issues being studied in the context of input–output production correspondences, where the inputs are not necessarily consumed physical inputs. Two examples are Mahlberg and Obersteiner [77], who estimated national efficiency levels in the production of different countries HDI, and Depotis [28], who did this for countries in the Asia and Pacific region. Another example that provides useful guidance in our context is Ngwenyama et al. [85]. The authors assessed a DEA model whose outputs are different HDI dimensions and whose inputs are population, and investments in healthcare, education and ICTs. The authors also refer to these as non-discretionary input variables, as Banker and Morey [5] did earlier. These prior perspectives in the literature are helpful to establish a solid basis for the exploratory modeling and analysis we will be reporting on in this article.

4. Development of research hypotheses

We next discuss a series of hypotheses that frame the empirical determinants of e-commerce growth across countries, according to the theoretical perspectives we have developed.

4.1. Preliminaries and definitions

We conceptualize a *country* as an economic system, within which e-commerce growth may be driven by factors that are either from inside (internal forces) or outside of the economic system (external forces) of that country. In other words, there are both *internal forces* (e.g., Internet users, information and telecommunication infrastructure, availability of online payment systems, venture capital, and education level) and *external forces* (e.g., e-commerce

development in other influential countries in the region) which affect a country's e-commerce growth and diffusion. In this study, we define *e-commerce growth* as *online shopping expenditures per capita in a country*.[6] If e-commerce growth is primarily generated within a country's domestic economy, the internal factors of that economic system will dominate the country's e-commerce growth. On the other hand, there may also be external forces that affect a country's e-commerce growth. They may be result from e-commerce development in one or a number of influential countries—"leading" countries—in a region, which is representative of knowledge and other kinds of spillover effects. In the production economics terms in which growth theories are often framed, these external factors can be thought of as production influences or "inputs" to e-commerce growth that are based on interactions with the other countries and occur outside of a country's economic system.

4.2. Endogenous growth model: pure internal effects specification

An endogenous explanation of e-commerce growth suggests that the primary forces of e-commerce growth are internal to an economic system. Our starting point for an *endogenous growth model of e-commerce* is a cross-country regression of the general form $y_{it} = f(\alpha, X_{it}, \beta, \varepsilon)$. In this expression y_{it} represents e-commerce growth in a country i at time t, X_{it} is a vector of explanatory variables of the same country i with estimated parameters β, α is regression constant, and ε is an error term that may reflect omitted variables.

Since we intend to measure the macro-level of e-commerce growth in an economy, we have argued that the e-commerce growth drivers in this model should include economy-level variables. They are Internet user penetration, the intensity of telecommunications investments, the educational level of adults, the availability of online payment tools, and the availability of venture capital. We identified these economy-level factors from an UNCTAD study [114], verified them with prior cross-country studies by Gibbs et al. [40], Wolcott et al. [119] and Kiiski and Pohjola [70]. In our endogenous e-commerce growth model, we will view all of these drivers as internal to the country and responsible for its e-commerce growth.

In economic growth theory, labor is an important input for production; in fact, it is one of the key resources in the economic system. Research in service operations management and service marketing also consider customers' involvement in service production and delivery processes are critical in a firm's production [18,75,124]. Customers' involvement in the service and delivery processes can be regarded as an input to the service production, even though they are never consumed [80]. In B2C e-commerce growth, we argue that Internet users are an analogous critical resource that can be thought of as an input because Internet users are co-producers of the service. Internet users create value, such as positive network externalities, for the growth in scale size of e-commerce. Although not all of the Internet users in a country may shop online, they are still potential shoppers, a likely demand-side driver for a country's e-commerce development. This leads to our first hypothesis:[7]

- **Hypothesis 1A (Endogenous Internet User Penetration Hypothesis)**. *The ratio of Internet users to total population within a country is a driver of its e-commerce revenue growth.*

Investment in telecommunications infrastructure has been shown to lessen the gap between computer and Internet usage [19]. In addition, there is evidence that the availability of information and telecommunication technologies is an enabler for e-commerce adoption and diffusion [40,91,74]. E-commerce development is only possible in the presence of a well-developed information and telecommunications infrastructure. Without the basic telecommunications infrastructure and accessibility of the Internet, e-commerce will not easily develop and grow. Thus, information and telecommunications investment have great potential impact on the growth of e-commerce. This leads us to assert:

- **Hypothesis 2A (Endogenous Telecommunications Investment Hypothesis)**. *The intensity of telecommunications investment within a country is a driver of its e-commerce revenue growth.*

According to UNCTAD [113], venture capital funding is primarily an American phenomenon because the United States accumulates nearly two-thirds of the global private equity and venture capital market. European countries are relative followers in the global venture capital market. The United Kingdom represents around 12% and Ger-

[6] Based on other research conducted by Kauffman and Techatassanasoontorn [63–65], we know that it is necessary to look at consumer expenditures and digital wireless phone operator revenues as the dependent variables for economic growth in the digital wireless marketplace. If we only count the number of cell phones or the number of service providers, we only will have a measure of the extent of the adoption of this technology.

[7] We initially hypothesized that the raw number of Internet users would provide a good basis for predicting e-commerce growth in a country. However, we learned during our analysis that the degree of co-movement and expansion of Internet users across countries made it difficult to achieve sufficient variation in a main effects variable so as to yield meaningful econometric estimates. Gauging the extent of Internet user penetration in a country in terms of the larger demographic setting seemed to be a richer proxy for human involvement with the Internet, and permits us to link growth to both Internet users *and* the overall population. Still though, this is a proxy for the number of Internet users.

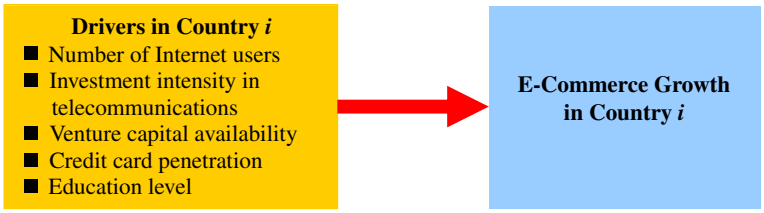

Fig. 2. An endogenous growth theory model for e-commerce growth. *Note*: The emphasis in the endogenous growth theory model is that the drivers of e-commerce growth in country *i* also originate in country *i*. Such a view, relative to the suggested variables, is consistent with a *contextual production view* of the growth of e-commerce consumer expenditure and online shopping revenues that we put forth earlier. The production of e-commerce growth occurs in the presence of the identified drivers, but no consumption of those drivers occurs, as with a standard input–output production correspondence.

many and France about 3% of the global venture capital. Asia has a much smaller share of the global venture capital funding, and within that area, Taiwan and Hong Kong account for about half of venture capital funding. Venture capital infusion into the technology sector paved the way for the growth of e-commerce, via the creation of innovative business models and technologies.[8,9] This leads us to assert:

- **Hypothesis 3A (Endogenous Venture Capital Hypothesis).** *The availability of venture capital within a country is a driver of its e-commerce revenue growth.*

The adequacy of financial resources is a supply-side driver that has been proven to have direct effects in shaping e-commerce diffusion [46,119]. The payment process is an important part of the larger business processes that support transaction-making. We argue that online payment is a critical portion of online transaction. Among the variety of electronic payment tools, credit cards play a special role in online transactions:

- **Hypothesis 4A (Endogenous Credit Card Penetration Hypothesis).** *The extent of the availability of credit cards within a country is a driver of its e-commerce revenue growth.*

The average level of education [70] and the quality of human capital [16] within a country are influential drivers for technology adoption, although they tend to represent the demand side, rather than the supply side. Adult literacy is necessary for the creation of e-commerce activities which may not be available in countries with poorly-educated populations [38]. High levels of educational attainment are proven to be critical in the extent of computer technology adoption in a country [16]. In addition, human capital is widely recognized as a key input to the R & D sector in a country, which usually generates the new ideas and products associated with technological progress. We argue that educational capabilities influence e-commerce growth:

- **Hypothesis 5A (Endogenous Education Level Hypothesis).** *The degree of education within a country is a driver of its e-commerce revenue growth.*

We summarize the endogenous growth theory model in Fig. 2.

4.3. Exogenous growth model: a base case for e-commerce growth

A second case of e-commerce growth occurs when the drivers are from another influential country in the region—a *leading country*—instead of the country itself. To represent this perspective, we can use a simple version of the Solow–Swan model to model e-commerce growth. The model posits that there is a technological progress factor that is exogenous: it only depends on time and does not depend on other factors that result from aspects of the internal economy, for example, government policy, domestic capital formation, etc. A modified *exogenous growth theory explanation* of e-commerce growth in a given country *i* is that there are forces affecting growth that emanate from another country *j*.

When a country is viewed regionally as a leader in some aspect of e-commerce (e.g., Japan and Hong Kong in Asia, and the United States in the Americas), other follower countries may be observed to imitate aspects of e-commerce business development that lead to their own e-commerce development. Also, human capital and financial capital may flow across their borders. This influence is an *exogenous regional contagion effect* whose source is a leader country and which is transmitted to the follower country, resulting in co-movement in e-commerce growth [68,111]. We model this with variables that represent the drivers of e-commerce growth in the leading country (see Fig. 3).

[8] We thank an anonymous reviewer for noting that that besides market forces associated with venture capital and other kinds of investment markets, government intervention and national-level policies also are likely to drive e-commerce growth. These are potential omitted variables in the analysis which follows. South Korea is a leading example, especially in terms of the support that was offered by the government to its country's corporations to undertake massive investments in digital wireless telecommunication. This led to business innovation, and growth in mobile commerce and e-commerce. Singapore offers another similar example.

[9] Another potentially confounding factor is the relatively free flow of venture capital in Europe. This may make it more difficult to maintain the argument that an endogenous effect of venture capital.

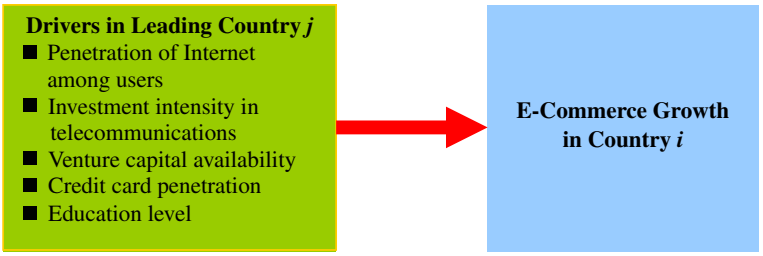

Fig. 3. Exogenous growth model. *Note*: The general case involves a number of countries, $j = 1, \ldots, J$, that may have some influence on a country's e-commerce growth. In addition, there is no particular requirement that the exogenous drivers in the leading country in the exogenous model need to be the same as the endogenous drivers in the endogenous model. In fact, this is a fairly restrictive case, although it is appropriate for our initial exploratory and illustrative purposes in this paper. Finally, we only consider a single country j as a leading country for any country i. Again, we recognize that his may be a restrictive assumption, but it is appropriate for this exploratory theory-building research.

To illustrate this perspective in the empirical analysis that follows, we will select one *leading country j* for each *following country i* that is being analyzed.[10] We used a modified Delphi interviewing process to determine the leading countries for each of the countries in our data set (see Table 2). We also evaluate related variables to see if they are drivers of the growth of e-commerce. The form of the exogenous growth model is $y_{it} = f(\alpha, X_{jt}, \beta, \varepsilon)$, where y_{it} represents e-commerce growth in a country i at time t, X_{jt} is a vector of explanatory variables of leading country j ($i \neq j$) with their estimated parameters, α is regression constant, and ε is an error term.

The hypotheses associated with the exogenous model relative to the drivers that we discussed previously are as follows, reflecting the extent to which regional contagion may be possible:

- **Hypothesis 1B (Exogenous Internet User Penetration Hypothesis)**. *The ratio of the number of Internet users to total population in a leading country is a driver of e-commerce revenue growth in a country that feels its influence.*
- **Hypothesis 2B (Exogenous Telecommunications Investment Hypothesis)**. *The intensity of telecommunications investment in a leading country is a driver of e-commerce revenue growth in a country that feels its influence.*
- **Hypothesis 3B (Exogenous Venture Capital Hypothesis)**. *The availability of venture capital in a leading country is a driver of e-commerce revenue growth in a country that feels its influence.*
- **Hypothesis 4B (Exogenous Credit Card Penetration Hypothesis)**. *The extent of the availability of credit cards in a leading country is a driver of e-commerce revenue growth in a country that feels its influence.*
- **Hypothesis 5B (Exogenous Education Level Hypothesis)**. *The level of education in a leading country is a driver of e-commerce revenue growth in a country that feels its influence.*

Although these exogenous growth hypotheses illustrate the theoretical perspective, it is necessary to evaluate the extent to which any similar exogenous external driver can achieve a greater impact than the same exogenous external variable.

Table 2
Leading countries for European countries included in this study

Leading country	Affected countries
Finland	Norway, Sweden
France	Belgium, Italy, Spain
Germany	Austria, Denmark, Luxembourg, Netherlands, Switzerland
Italy	Greece
Spain	Portugal
Sweden	Finland
United Kingdom	France, Germany, Ireland
United States	United Kingdom

Note: The method we used to determine leading countries was a *modified Delphi interviewing process*, involving four people who are knowledgeable about the global diffusion of IT and e-commerce and have experience with cross-national research. The country relationships that we have specified are primarily based on geographical proximity, language similarities, the timing of domestic Internet diffusion, and international trade considerations. We settled on a *reflexive* leading-and-affected country relationship between Finland and Sweden in our data, based on geographical proximity and what we know about digital wireless phone diffusion. The United States was considered as a possible leading country for all e-commerce growth in Europe. However, the model that we used did not permit us to test this. As a result, the only instance of the United States is as a leading country for the United Kingdom, which has close ties. The reader should recognize this decision making process for specifying the details of the model as a possible source of error in the models that we test. We also note that the leading country may change over time. However, we did not try to accommodate this nuance in our illustration.

[10] The leading country does not have to be the same for all of the countries that we are studying. Instead, there may be regional differences, economic system similarities, cultural connections and other reasons that a country looks to the experience of another country in the e-commerce growth context. For example, we will argue that the United Kingdom is the leading country for Ireland, while Spain is the leading country for Portugal based largely on their geographical proximity, and linguistic and cultural similarities.

4.4. A mixed effects endogenous–exogenous growth model

We also will consider a third model that shows a mix of exogenous and endogenous drivers of e-commerce growth in a country. Again, for the purposes of simplicity and illustration, we will assume that it is possible to identify the external drivers are from the leading country associated with a country in that region. In this mixed endogenous and exogenous growth model, we can again represent this with a function, $y_{it} = f(\alpha, X_{it}, \beta, X_{jt}, \phi, \varepsilon)$, with y_{it} as the growth of e-commerce in country i at time t. X_{it} is a vector of production inputs for e-commerce growth in country i. But now X_{jt} reflects the fact that exogenous growth drivers from the leading country $j \neq i$ impact the production mapping that results in e-commerce growth in country i. As before, α is a constant, the β's are regression parameters on the endogenous variables, and ε is an error term. We add other regression parameters, ϕ's, to represent leading country exogenous driver effects.

A simple example that appears to fit the story is the development of e-commerce in Canada in the late 1990s. The impetus for growth—beyond the basic domestic production process of the country involving indigenous labor and capital—came largely from the U.S., where the e-commerce revolution was occurring. The reader should imagine that e-commerce growth in country i—Canada in this case—might possibly be driven by external forces from a subset of factors from the leading country. If the U.S. were the object of our model, we could include the various hypothesized drivers in the base endogenous model, supplemented with similar variables, only from another country (or more generally, from other countries). The mixed effects growth model is shown in Fig. 4.

5. Study variables and data

We next specify the explanatory variables in the models and their operationalizations. In addition, we explain the data sources and data collection of the scope of our study.

5.1. Study variables

We have identified five unique drivers for B2C e-commerce growth. Some endogenous drivers may also be exogenous drivers in association with the leading country in a region, where it is possible to establish a connection to e-commerce growth in a specific context. To analyze what drives e-commerce growth across countries, we will use *per capita online shopping expenditures* in a country as the dependent variable in all of our estimation models (or *PerCapitaECExpenditures*). This revenue-focused measure is a relatively direct means to represent e-commerce growth. For the explanatory variables, we use the following five constructs: the ratio of Internet users to total population, GDP share of capital investment in telecommunications, venture capital availability, credit card penetration, and adult literacy. We will refer to these as *NetUserRatio, TelcInv*, *VCapital*, *CardPenetr*, and *Education*. We selected these variables from the literature [40,70,74,91], and the policy press [114,115]. Because of difficulties with data collection, we omitted some variables, such as the degree of national urbanization, the availability of e-security provisions, and the role of various government policies. Table 3 summarizes the variables, their definitions and the data sources.

All of these variables are based on archival data. In addition, all are factual data with the exception of one:

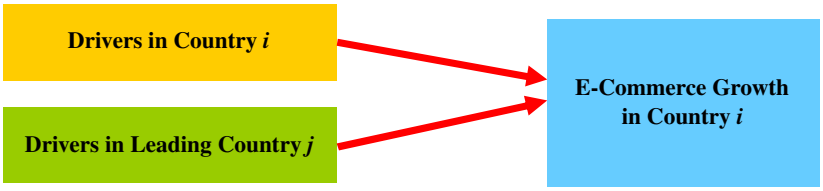

Fig. 4. Mixed effects growth model for e-commerce growth

Table 3
Definitions of variables and sources of data

Variable	Operationalization	Data sources
$PerCapitaEC\ Expenditures_t$	Online shopping expenditures$_t$/Population 15–64$_t$	Jupiter Research
$NetUserRatio_t$	Total number of Internet users$_t$/Population 15–64$_t$	Jupiter Research
$TelcInv_{t-1}$	Total capital investment in telecommunications$_{t-1}$/Gross domestic product$_{t-1}$	International Telecommunications Union (ITU)
$CardPenetr_t$	(Visacards + Mastercards held)$_t$/Population 15–64$_t$	Visa International, Mastercard, United Nations (UN)
$VCapital_t$	Venture capital availability for business development$_t$—measured on a 1 (low) to 10 (high) scale	*IMD World Competitiveness Yearbook*
$Education_t$	Level of education of the adult population$_t$	UNESCO, National Statistics

Note: Among the independent variables, only *TelcInv* is lagged for one year, since there is likely to be some latency between telecommunications investments and the new e-commerce business capabilities they permit. In the exogenous and mixed growth models, we will use the same endogenous drivers from a leading country as exogenous drivers.

Table 4
Descriptive statistics and correlations for 17 European countries (2000–2004)

Variables		Mean	Min	Max	Std. Dev.
Descriptive statistics					
PerCapitaECExpenditures ($)		84.32	1.75	335.79	73.43
NetUserRatio (%)		0.57	0.14	0.96	0.19
TelcInv (telecom investment/GDP) ($)		0.01	$3.60e^{-6}$	0.07	0.01
VCapital (1–10 scale)		5.62	3.17	7.95	1.06
CardPenetr (%)		98.86	92.22	99.90	1.64
Education (%)		1.55	0.45	3.42	0.62
	$NetUserRatio_t$	$TelcInv_{t-1}$	$VCapital_t$	$CardPenetr_t$	$Education_t$
Correlations					
NetUserRatio	1				
TelcInv	−0.0285	1			
VCapital	0.3048	0.0400	1		
CardPenetr	0.3020	−0.2369	0.3390	1	
Education	0.0056	0.3098	−0.0221	0.0545	1

Note: $N = 85$ for all variables, covering 2000–2004. *PerCapitaECExpenditures* and *TelcInv* (which is lagged one year) are measured by international dollars with purchasing power party.

venture capital availability, *VCapital*. This variable is subjective and refers to the relative availability of venture capital for business development in a country, as estimated in the *IMD World Competitiveness Yearbook* (www01.imd.ch/wcc/). We used lagged values for one variable, capital investment in telecommunications adjusted for population, *TelcInv*. This is a common practice in studies of IT value, where there is a need to represent the latent value that arises after IT adoption and usage are observed [41,72]. This modeling choice also enables us to avoid problems with contemporaneous determination and endogeneity. The approach of using lagged values of potentially endogenous variables is discussed by Judge et al. [59]. They offer a number of ways to logically rule out the possibility of endogeneity based on the structure of the empirical model. Moreover, most analysts would agree that capital investment in telecommunications infrastructure will only affect e-commerce development after some period of time.

5.2. Data sources and data collection

Our data cover the period from 2000 to 2004, a critical time for e-commerce growth. To illustrate our approach, we chose 17 developed European countries, for which it was possible to collect the appropriate data. Table 4 provides descriptive statistics. Our pre-empirical analysis showed that there was heterogeneity in Internet technology adoption and the take-off of e-commerce shopping expenditures across Europe, in spite of the fact that most observers would agree that the countries are developed countries with relatively advanced economies. The Appendix shows the patterns of e-commerce growth among the 17 European countries from 2000 to 2004 in terms of online shopping expenditures (Fig. A1) and online shopping expenditures per capita (Fig. A2). Norway had the maximum per capita e-commerce expenditures in 2004, while Greece had the minimum expenditures in 2000. Although per capita e-commerce expenditures increased dramatically among these 17 countries in 2000–2004, we nevertheless can see the differences in the levels of e-commerce expenditures among these countries, especially per capita and per Internet user. Appendix shows online shopping expenditures per Internet user (Fig. A3), and, average online shopping expenditures per purchase (Fig. A4).

Although one may think of the European countries as being very similar in terms of their wealth levels and investments in e-commerce, this actually is not the case. There is considerable variation even among these more advanced industrialized countries. For example, we note a large range and standard deviation for *PerCapitalECExpenditure,* as demonstrated by Norway, which had e-commerce expenditures of US$355.79 per capita in 2004, and Greece, which had only US$1.75 in e-commerce expenditures per capita. Some additional comments about our decision to use European data only for this study are also in order.

For empirical research, the availability of data is a significant concern, as is the length of the time-series for each country that can be obtained. In spite of the fact that e-commerce growth began in some European countries prior to 2000, related data from international organizations were not available for years other than those for which we have collected it. However, in terms of the time-series length and up-to-date nature of the data, our data set is more inclusive than most of the available cross-country e-commerce studies [74,78]. Earlier studies simply have not been able to use much more data. The reality is that no agencies of national governments or international organizations were well enough organized for the study of e-commerce to be tracking this kind of data across the many countries. Further, the Asian countries' governments were slow to capture all the kinds of data that we need for our model. Thus, we are limited in both the length of the time-series we can

collect, as well as the number of countries that we can cover—even in the 2000–2004 time frame.[11]

6. Empirical models and results

We next discuss the development and estimation of our empirical models and the related results on e-commerce growth.

6.1. Empirical modeling preliminaries

Our analysis approach involved a series of steps that led to the specification of an appropriate set of empirical models and illustrative results. The following discussion briefly considers the related issues of correlation, multicollinearity, heteroskedasticity, functional form, and model estimation approaches.

6.1.1. Correlation and multicollinearity

We performed diagnostic checks of pairwise correlations in the data, and identified variables for which the degree of correlation made it impossible to use them in raw form across the multiple models. This led us to respecify several raw variables in terms of their intensity relative to population or GDP in a country, while still matching our interpretation of the theory. In addition, we identified multicollinearity with the inclusion of *Education* for leading countries in the mixed growth models through assessment of *variance inflation factors* (VIFs) [69]. The VIFs for the explanatory variables were small in all models, except the two mixed models, where the endogenous effects and exogenous effects *Education* variables had VIFs in excess of 10 but less than 20. The latter is the typical criterion value for problems with multicollinearity [69]. In contrast, the Belsley, Kuh and Welch test [11] test suggested multicollinearity was absent in all models. To be cautious with this conflicting information, we modified the set of variables associated with the various leading countries in the two mixed effects models. The set from the endogenous model was retained, but we excluded *Education* as an exogenous effect. This eliminated the problem.

6.1.2. Functional form

A natural starting point for determining how to estimate global e-commerce shopping expenditures growth is to consider the issue of functional form. The linear model has restrictive assumptions for linear and separable effects. So we chose the more flexible multiplicative functional form, with a constant, several main effects variables, main effects exponent parameters and a multiplicative error term, as our main model to support the hypothesis tests.[12] We estimated the model in log-linear form, and checked whether it matches the standard assumptions for ordinary least squares (OLS) estimation. We next consider the possibility of unequal error variances.

6.1.3. Heteroskedasticity and a regression with robust standard errors

Heteroskedasticity occurs when an estimated model exhibits error terms with different variances [12]. A common approach to resolving the problem of heteroskedasticity is to use *regression with robust standard errors*, as discussed by Stock and Watson [106] and Greene [42].[13] Since the data we are analyzing come from countries and economies of different sizes with various cultures and traditions in mercantile exchange, a reasonable entering assumption is to expect that the classical linear regression model will be inappropriate as a means for yielding best least unbiased estimators of the main effects [42]. The Breusch–Pagan test [12] is restrictive, since it only checks for linear forms of heteroskedasticity. We used the more general White's test [118] to check for these and other non-linear forms of heteroscedasticity (e.g., in the squares and cross-products of the independent variables). We found test evidence to reject the null hypothesis of homoskedastic errors in all models except the exogenous growth model.

[11] This is not to say that it is not possible to do meaningful research with the data that are available. The point we wish to make is that it will necessarily require a somewhat modified research design or the passage of time for the appropriate data to be obtained before we can instantiate the proposed model on a broader global basis. We are currently exploring other models of e-commerce growth that involve less constraining requirements for the explanatory variables, and which permit the inclusion of more countries for the longest feasible time-series.

[12] The reader should note that we do *not* use a Cobb–Douglas model, which is typically specified in log-linear form for econometric estimation in growth theory applications and for the estimation of production frontiers. See Dewan and Min [32] for economy-level cross-country analysis of the productivity effects of IT, and Grilliches [44] for coverage of other applications, including R&D, patents and technology innovations. In the IT productivity assessment context, this modeling approach typically involves a true input–output production correspondence that relates non-IT capital, IT capital, labor and other factors of production to some appropriate output [116], for example, GDP at the level of a country. The approach carries with it a number of assumptions and restrictions that are of questionable value in an intertemporal and cross-national IT context. For example, Cobb–Douglas functional form, in the aggregate national evaluation context, assumes that a nation's IT capital stock should result in a constant share of GDP in the country over time [90]. If this assumption is held for e-commerce, then it will not be possible to reflect the impacts of increasing technology adoption or to capture the effects of unobserved complementarities on GDP.

[13] The idea is to make adjustments in the estimates that account for the information structure in the data—especially cross-error term correlation and unequal error term variances. This generalized least squares (GLS) approach is a variant of weighted least squares (WLS). It yields estimates of Huber–White standard errors [52,118], "which have been adjusted for specific assumed-and-estimated correlations of error terms across observations" [34]. The estimation process iteratively re-weights the ordinary least squares (OLS) estimates to determine both the regression coefficients and the standard errors. It returns the same coefficients as the OLS equivalent model, but its standard errors eliminate heteroskedasticity and potential non-normality of the errors.

Table 5
Results for several full and reduced e-commerce growth models

Variables	Endogenous (full GLS)	Endogenous (reduced GLS)	Exogenous (full OLS)	Mixed effects (full GLS)	Mixed effects (reduced GLS)
Endogenous domestic economy effects variables					
NetUserRatio	1.97*** (0.12)	1.91*** (0.13)		0.99*** (0.18)	1.01*** (0.19)
TelcInv	0.09** (0.03)	0.07*** (0.02)		0.03 (0.03)	–
VCapital	−0.64 (0.42)	–		−0.38 (0.33)	–
Education	17.12*** (3.95)	14.71*** (3.26)		15.09*** (3.45)	10.78*** (2.19)
CardPenetr	0.14 (0.13)	–		0.00 (0.12)	–
Exogenous leading country effects variables (assuming only one leading country)					
NetUserRatio			2.58*** (0.14)	1.65***(0.22)	1.70*** (0.21)
TelcInv			0.22*** (0.03)	0.07* (0.04)	0.02 (0.03)
VCapital			−0.91** (0.31)	−0.42 (0.31)	–
Education			19.50*** (2.94)	(a)	–
CardPenetr			−0.37*** (0.10)	−0.18* (0.10)	−0.09 (−0.07)
Model performance descriptors					
F-Statistic	69.34***	88.83***	96.96***	46.85***	62.25***
R^2 (%)	78.8	77.1	86.8	89.8	89.0

Notes: Data: 17 European countries over 5 years, from 2000 to 2004, $N = 85$ in panel data set. Dependent variable = *PerCapitaECExpenditures*. Model: Multiplicative functional forms with OLS in one model and GLS in four other models reflect quasi-production function representations from growth economics. The variable TelcInv is lagged one period. Correlation/multicollinearity diagnostics: High correlation between *Education* in domestic effects and leading country effects variables groups did not permit leading country *Education* variable to be included in Mixed Factors models. Other variables had pairwise correlations of less than 70% and variable inflation factors (VIFs) of less than 3 for all pairs of right-hand side variables. Heteroskedasticity: Detected via White's test and corrected via regression with robust standard errors. Results in each cell are coefficient estimate/significance level (robust standard error). All estimations were made with STATA 8.0. Significance levels: *** = $p < .01$, ** = $p < .05$, * = $p < .10$. R^2 and adjusted-R^2 values exhibited few differences in the regressions, so we only report R^2 values. We caution the reader not to conclude that the best quality model is the one with the highest R^2 value. Note that the difference between the exogenous model's R^2 values of 86.8% and the mixed effects model's R^2 of 89.8% is only 3%. (a) Due to the high correlation between the endogenous and exogenous effects *Education* variable, we decided to only include it once in the model among the endogenous effects.

6.1.4. Estimation procedures

Based on our correlation and multicollinearity diagnostics, and the unequal error term variance adjustments, we determined that it was necessary to perform GLS estimations for four of the models and OLS for just one. (Our findings will be presented in the estimation results table in the following subsection.) In addition, we found that it was appropriate to carry over what we learned from one model to the next. Initially, we learned which variables were significant for the endogenous and exogenous growth models separately. After that, we estimated reduced models, leaving the insignificant variables out. As a result, the estimation of mixed model includes subsets of the endogenous and exogenous growth variables.

6.2. Estimation results

The results of estimations of multiple models are shown in Table 5.

The second and third columns from the left show the results of the endogenous growth model, in full and reduced form. The middle column shows the exogenous model's results. Finally, the two rightmost columns show the estimation results for the mixed endogenous–exogenous model in both full and reduced form. The reported results are for a multiplicative model run in log-linear form. (For comparison purposes, we also ran more restrictive linear models. However, they did not perform as well in model fit and consistency of findings, though some basic relationships were retained.)

6.2.1. Endogenous growth model results

Our estimation of the log-linear endogenous growth model had a reasonable fit for both the full (f) ($F_f = 69.34$, $R^2_f = 78.8\%$, $p_f < 0.01$) and the reduced (r) versions ($F_r = 88.83$, $R^2_r = 77.1\%$, $p_r < 0.01$).[14] We also found that the ratio of Internet users to total population within a country is a driver of e-commerce growth (full model: $NetUserRatio_f = 1.97$, $SE_f = 0.12$, $p_f < 0.01$; reduced model: $NetUserRatio_r = 1.91$, $SE_r = 0.13$, $p_r < 0.01$). These findings support the Endogenous Internet User Penetration Hypothesis (H1A).

The GDP share of telecommunication investment within a country is also an influence on e-commerce growth ($TelcInv_{t-1,f} = 0.09$, $SE_{t-1,f} = 0.03$, $p_{t-1,f} < 0.05$; $TelcInv_{t-1,r} = 0.07$, $SE_{t-1,r} = 0.02$, $p_{t-1,r} < 0.01$), which supports the Endogenous Telecommunications Investment Hypothesis (H2A). Education level within a country also

[14] In our presentation of the results for the endogenous growth model for e-commerce (and the others as well) we will suppress the subscript for time, t, when the year of the dependent variables and the independent variables match. The only exception to this, as a reminder to the reader, is that *TelcInv* is marked to represent its one-year lag, $t - 1$, with $TelcInv_{t-1}$. We subscript all study variables' coefficient estimates with either f to indicate estimation of a full model or r to indicate estimation of a reduced model.

shows a positive and significant effect in driving e-commerce growth ($Education_f = 17.12$, $SE_f = 3.59$, $p_f < 0.01$; $Education_r = 14.71$, SE_r 3.26, $p_r < 0.01$), and this result is consistent across all our models. This supports the Endogenous Education Level Hypothesis (H5A), and also offers a useful perspective that e-commerce is a "knowledge economy" phenomenon. Thus, in the endogenous growth model, Internet user penetration, telecommunication investment, and education level of a country had the expected effects, and were significant drivers of e-commerce growth within a country.

6.2.2. Exogenous growth model results

Our estimation of the exogenous growth model (full model only) also exhibited good statistical fit ($F_f = 96.96$, $R_f^2 = 86.8\%$; $p_f < 0.01$). All five exogenous factors have significant results, but they are not all supportive of the hypotheses that we proposed. Based on our estimation the number of Internet users in a leading country is associated with e-commerce growth in a country that feels its influence ($NetUserRatio_f = 2.58$, $SE_f = 0.14$, $p_f < 0.01$), which supports the Exogenous Internet Users Hypothesis (H1B). The share of telecommunications investment of GDP in a leading country is also a driver of e-commerce growth in a country that feels its influence ($TelcInv_f = 0.22$, $SE_f = 0.03$, $p_f < 0.01$). This supports the Exogenous Telecommunications Investment Hypothesis (H2B). Contrary to our expectations, however, availability of venture capital in a leading country had a negative association with e-commerce growth in a following country ($VCapital_f = -0.91$, $SE_f = 0.31$, $p_f < 0.05$). This runs counter to our Exogenous Venture Capital Hypothesis (H3B), which suggested a positive effect, and so we reject this hypothesis.

Our estimation results show that the level of education in a leading country is also a driver of e-commerce growth in a follower country ($Education_f = 19.50$, $SE_f = 2.94$, $p_f < 0.01$), as proposed in the Exogenous Education Level Hypothesis (H4B). The reader may question whether this result is plausible as a "true" effect—as we have—or if it is an anomaly due to correlated variables. We believe that the argument for an endogenous effect is the more convincing argument that can be made. This result may be due to the relative similarity of educational levels of these 17 European countries we studied. All of them have educational levels that ensure literacy in excess of 90% of their populations. Credit card penetration in a leading country, however, has a negative sign—opposite to what we expected to see ($CardPenetr_f = -0.37$, $SE_f = 0.10$, $p_f < 0.01$). So we rejected the Exogenous Credit Card Penetration Hypothesis (H5B). Thus, in the exogenous growth model, only Internet users, telecommunications investments and educational level in a leading country are critical drivers of e-commerce growth in a country that feels its influence. Venture capital availability and credit card availability appear to have the opposite effects.

6.2.3. Mixed effects growth model results

Our mixed effects growth model also yielded strong statistical fit, which is to be expected based on the separate "pure effects" models' results ($F_f = 46.85$, $R_f^2 = 89.8\%$, $p_f < 0.01$; $F_r = 62.25$, $R_r^2 = 88.0\%$, $p_r < 0.01$). There also are generally concordant results across the models. The results show the blend of endogenous and exogenous effects that illustrate the theoretical perspective of the mixed effects growth model. For example, endogenous Internet users adjusted for population ($NetUserRatio_f = 0.99$, $SE_f = 0.18$, $p_f < 0.01$; $NetUserRatio_r = 1.01$, $SE_r = 0.19$, $p_r < .01$) and endogenous education level ($Education_f = 15.09$, $SE_f = 3.45$, $p_f < 0.01$; $Education_r = 10.78$, $SE_r. = 2.19$, $p_r < 0.01$) are significant drivers of a country's e-commerce growth with the hypothesized positive effects. In addition, there are three significant effects among the exogenous variables, although only two are in the predicted direction across the full and reduced mixed effects models, and only one is strong. They include: the leading country's number of Internet users adjusted for population ($NetUserRatio_f = 1.65$, $SE_f = 0.22$, $p_f < 0.01$; $NetUserRatio_r = 1.70$, $SE_r = 0.21$, $p_r < .01$), its telecommunication infrastructure investments ($TelcInv_f = 0.07$, $SE_f = 0.04$, $p_f < 0.10$; $TelcInv_r$ not significant), and its credit card penetration ($CardPenetr = -0.18$, $SE_f = 0.1$, $p_f < 0.10$; $CardPenetr_r$ not significant). Overall, although the mixed effects model provides an exploratory illustration of the potential for discovering e-commerce growth contagion effects from other regional economies, the results are not especially strong.

6.3. Discussion: the efficacy of growth theory for e-commerce growth

We now turn to some additional discussion of the estimation results that we have obtained. In particular, we are interested to know: What is the efficacy of growth theory as a means to explain the underlying mechanism for B2C e-commerce growth in Europe? The first observation that we can make about the empirical results is that our models seem to be able to capture the basic hypothesized relationships that are present in the data. The argument we made with respect to an explanation of endogenous drivers of e-commerce growth in country is a reasonable one: Internet user penetration, the intensity of telecommunication investment, and education within a country seem to be associated with the outcomes. On the other hand, our illustration was less successful in showing the role of an identical set of exogenous growth drivers. We found that drivers from a leading country, including Internet user penetration, the intensity of telecommunication investment and education level, that seem to have positive effects on e-commerce growth in a country that is influenced by the leader.

Some of the other results that we did not expect bear further consideration, especially when the signs of the estimated effects ran counter to our expectations. We did what we could to eliminate the statistical problems that arise

with respect to correlated variables, multicollinearity, omitted variables, heteroskedasticity. However, beyond this, it is appropriate to evaluate whether a set of exogenous growth regressors that is identical to the endogenous growth regressors (selected based on the prior theory and research) can provide the same fidelity of explanation of e-commerce growth. We noted, for example, that availability of venture capital and card credits in some leading countries was associated with lower growth in other countries that we thought might be influenced. One possible problem, of course, is that our leading countries may have been misspecified. A second possibility is that e-commerce growth in one country is driven more diffusely by a number of countries in a region. A third possibility is that the exogenous regressors are simply inappropriate, and give an incorrect reading on e-commerce growth.

It is plausible to observe a negative relationship for venture capital in a leading country relative to another country that we may propose should feel beneficial effects. Why? First, we have not measured the extent to which the available capital in a leading country is actually made available to a country that is influence in other ways by another country. Second, it may be that the true association is between e-commerce growth in a country and the cumulative amount of venture capital that is available within a region, so there is no implied dependency on the cross-border funding of a single country. From this point of view, our single leading country exogenous growth variable modeling specification may not be appropriate. We will be exploring other means to handle exogenous growth effects, other than the time-dependent growth in technology capabilities. Finally, it is possible that venture capital only has a latent effect: when other countries in the region begin to be influenced by the drivers of e-commerce growth in another country (including capital), the capital may be committed already for other things, even though an external observer might rate the availability of capital as high in the leading country. To examine this possibility, we ran the exogenous model and the mixed model again, only with lagged values for venture capital. The results were largely unchanged, which diminishes the likelihood that our alternative conjecture about latent effects is true. We will leave the other issues for future research.

Another apparent anomaly in our estimation results is that the potential exogenous effect of credit card penetration in a leading country has a negative coefficient for e-commerce growth on another selected country in the European region. Our working hypothesis is that credit card penetration reflects the presence of a well-developed payment system for e-commerce. Again, it is possible that we have chosen inappropriate leading countries. We will be exploring the data to see if there are patterns for leading countries and other countries' association with them in terms of e-commerce growth. The counter-intuitive results also may suggest a relative or comparison-based effect: that people in the following country may compare their own transaction-making capabilities on the Internet with the online payment systems capabilities that are available in the leading country. When they see a difference (i.e., very favorable credit card penetration outside their own country but not within it), they may hesitate to shop online in their own country. We can also learn from the case of Canada: people there learned to shop on the Internet by shopping on the Internet in the U.S. So this also may be the case for Western Europe, only with the leading countries' Internet firms as the "shopping destinations" for consumers in other countries in the region.

To close out this discussion, we want to sensitize the reader to what our models have to say about the variance of the dependent variable, *PerCapitaECExpenditures*, as it has been explained by the endogenous, exogenous and mixed effects models that we estimated. We note that all of the models have relatively high levels of variance explained in terms of the values of R^2 and the related *F*-statistics. The R^2s in the endogenous models range from 77% to 79%, while in the exogenous model it is about 87% for the endogenous model. The mixed effects model yields a higher R^2, but the reader should keep in mind that the increasing number of variables causes a slight reduction in adjusted R^2. The net effect is that the performance of the exogenous and mixed effects models is not very different. Since our goal in this exploratory research was to illustrate the different modeling approaches, we decided that it was appropriate to present the results from all of them for the reader to come to their own conclusion.

7. Conclusion

The primary objective of this research has been to examine the efficacy of growth-theoretic explanations of the macro-level determinants of B2C e-commerce growth across countries. This objective is in line with Castells' [17] call for understanding the historical and current forces at work in the global transformation to a post-industrial information economy. We positioned our exploration with respect to growth theory in economics because of the potentially new and interesting insights it offers for understanding B2C e-commerce growth. We analyzed a newly-constructed data set that includes online shopping expenditures at the country level as a means to measure B2C e-commerce revenue growth. We also proposed three theoretical models: an endogenous growth model, an exogenous growth model, and a mixed effects endogenous–exogenous growth model. The endogenous growth model states that B2C e-commerce growth in a country primarily results from internal drivers within the country. The exogenous growth model argues that B2C e-commerce growth in a country is primarily driven by external drivers from a leading country or multiple leading countries. As an exploratory step, we tested the case of one leading country, in lieu of a set of them, to capture any contagion effects that may be present. The mixed effects model posits that a blend of internal and external factors may be at work, and a key issue is the relative strength of the regional con-

tagion effects on B2C e-commerce growth in a country. We also made a case for viewing our analysis as an assessment of contextual production, which includes output measures for B2C e-commerce growth with a set of explanatory variables that characterize the national economic environments in which such growth is observed. We were careful to contrast our methodological approach in the analysis in this article to the analysis of "true" input–output production correspondences, for which different kinds of evaluative models may be used.

7.1. Contributions

We studied 17 Western European countries during 2000–2004, a five-year period. The data were drawn from another much larger cross-national data set that we have been constructing. These panel data are more inclusive than most available cross-country e-commerce studies. But building data sets that cover cross-national settings involving IT and e-commerce is not easy. The difficulties result from the differences in data capture practices at the national level and the time lags for reporting the data that occur between the country level and the international institution level. Our experience in this and other related cross-sectional research [62–65] suggests that effective data collection is often a key innovation that makes it possible to study interesting problems involving global technology diffusion patterns.

We empirically tested three models (and a number of relevant sub-models and alternative formulations) and obtained interesting findings related to the efficacy of the theorized relationships, as well as the underlying modeling perspective. Our empirical analysis was conducted using ordinary least squares regression and regression with robust error terms.

Our findings are as follows. In the endogenous growth model, the results show that Internet user penetration, telecommunications investment intensity, and education levels within a country have significant impacts on a country's B2C e-commerce revenue growth. In contrast, the results of the exogenous growth model produced five significant external determinants. In other words, there appear to be variables from a leading country which may be associated with e-commerce growth in a given country. These include the extent of Internet user penetration in a country, the intensity of telecommunications investment, the availability of venture capital, education level, and the degree of credit card penetration in the economy. Since we specified the exogenous model as a second base case, we must point out that the model is testing for "pure" exogenous effects. This modeling formulation precludes the possibility that there may be a blend of endogenous and exogenous effects.

Our intent with the mixed endogenous–exogenous growth model is to assess whether there are simultaneous influences on a country's e-commerce growth—both from within its economic system and across its region of the world. However, we have only permitted single countries—what we call *leading countries*—to express their effects. The results of the mixed effects model suggest that B2C e-commerce growth within a country is driven by internal drivers and also affected by external factors associated with other leading countries. Thus, our model has yielded some exploratory evidence that there may be regional contagion effects associated with other countries' e-commerce growth.

The contributions of this research can be concluded in both theoretical and practical perspectives. Leading up to this work, we observed that there has been a lack of theory applied at the aggregate level of the economy in cross-national studies of e-commerce-related phenomena. When we identified growth theory as a basis for exploration in this study, we did so with the knowledge that theoretical thinking would be fresh and new, and be able to offer opportunities for refinement and application in the e-commerce context. The exogenous growth and the mixed effects growth models also provide a conceptual basis for exploring how regional contagion effects work in e-commerce growth. For business and policy makers, the practical contribution of this research is to provide some reading on the various factors that are associated with the growth of B2C e-commerce. Although our results only identify the average effects of the study variables across European countries, they nevertheless can be used to gauge the extent to which changes in some underlying factors will produce greater or lesser growth effects for e-commerce in different countries. These results will also provide international organizations (e.g., the United Nations) and non-governmental organization policy makers (e.g., technology standards or industry groups) with greater insight into the dynamics of e-commerce growth across countries. Our findings will help government policy makers and practitioners to learn more about the nature of the global B2C e-commerce growth, and encourage the development of telecommunications and Internet infrastructure, and the related complementary capabilities from which they can reap benefits.

We believe that this work will inform ongoing research on the growth and diffusion of e-commerce in other contexts. For example, the growth theory perspectives that we have explored can be also applied to assess the underlying mechanism for economic growth in the digital wireless phone industry cross-nationally, as discussed in the recent research of Kauffman and Techatassanasoontorn [63–66]. This series of papers examines reasons why multiple domestic standards may hold back the pace of digital wireless phone adoption and diminish the value of any given standard in a country in the minds of consumers [63], endogenously impacting the economic growth that occurs around digital wireless phone. In related papers, the authors [64,65] identify drivers for adoption of digital wireless phone across a series of technology adoption life cycle stages, and the extent to which regional contagion occurs across countries. They also model the cross-national commonalities in the growth curves of digital wireless phone adoption around the world [66]. A basic premise of their

work is that growth in adoption of digital wireless phones ought to be an embedded function in the revenue growth of digital wireless services. These, in turn, lead to expenditures by consumers and businesses, resulting in revenues for the providers of digital wireless services and economic growth in that sector of the economy of a country.

7.2. Limitations and other issues

7.2.1. Association vs. causality

At this stage of our research, we hesitate to state that our empirical results are entirely consistent with causality. Instead, we have explored the efficacy of endogenous, exogenous and mixed effects growth theory as a means to characterize the association between a set of hypothesized drivers and our observations of B2C e-commerce revenue growth outcomes. We believe that it is appropriate to argue in favor of "association" rather than "causality". Such first steps in research always require follow-up steps: additional theoretical, modeling and data refinements; greater consideration of alternative explanations and competing theories; more complete concordance in modeling e-commerce growth on the basis of the growth of national economies; and further analysis of other related issues. For example, there may be reasons for rejecting the possibility of identical sets of regressors for the country that is being analyzed and other countries that may produce exogenous effects [9].

7.2.2. Omitted variables bias and complementary technologies

Other issues include omitted variables (especially the availability of e-security provisions, government intervention and policies, online taxes and urbanization, as we alluded to earlier in this article), more complex interaction effects, the simultaneous production of related economic outcomes (e.g., the growth of businesses that are involved in Internet-based selling technology adoption and e-commerce) and expanding data collection. Still another issue is the possibility of complementary factors and technologies impacting the value of economic growth that is released by adoption of Internet technology and e-commerce business models [91]. Dewan and Kraemer [31, p. 581] suggest the possibility of *experience curves* for capital investments, which require countries to "first build their ordinary capital stocks before investments in information technology become productive." This may occur to a greater extent in developed countries in comparison with developing countries. The implication is that Internet adoption may be higher where there already are significant infrastructures of network technologies and many PCs in use, including countries such as Finland, the United States, Canada and Australia [53].

7.2.3. The growth mechanism and contextual production

We also note another potential limitation that may spur new research in this area: the economic theories that we have selected for this study may not be sufficiently precise in their ability to pinpoint the exact engine for e-commerce growth. Although prior research permits us to make a case for the various included variables, our approach still begs a solution to identifying which country is the appropriate leading country, or whether it would be appropriate to model the exogenous effects in a less or more aggregated way. In addition, some readers will question the extent to which national level e-commerce expenditures and revenues are the result of "true" production. In this article, we have argued that the kind of production that we are studying is essentially "contextual production," since the growth we observe occurs in the presence of the various national endogenous and cross-national exogenous drivers. The key words here are "in the presence of" and we caution the reader to recognize that no "true" consumption is occurring. Instead, our emphasis has been on contextual variables for production. These issues also require additional research.

7.2.4. Single vs. multiple country exogenous effects

We further note that the exogenous effects are broad-based and not emanating from a single country. Instead, they may come from a variety of international sources. We have done some preliminary analysis with a variable to represent an aggregate exogenous driver of a country's e-commerce growth that can be measured by *international openness,* the ratio of exports plus imports to GDP [9]. Other researchers have documented a positive relationship between a country's economic growth rate and its openness to the international economy, including Balassa [4], Dollar [33] and Edwards [37]. International openness can be used to reflect a variety of business interactions, technology transfers and knowledge spillovers. By opening up to the global economy, countries ought to be able to benefit from scientific advances and improvements elsewhere. International openness also may be associated with higher levels of capital accumulation, according to Proudman et al. [93]. Although international openness may bear some exogenous driver-type relationship to the growth of e-commerce shopping activities in a country, we were not able to develop any useful information with respect to this variable in the econometric estimation that we did. We speculate that finding exogenous effects may be easier in the context of countries in the Asian, African and Latin and Central American regions, where there is a larger degree of externally-driven, international trade-related growth, and the countries are less likely to be recognized as world leaders in e-commerce.

7.2.5. On the United States as a leading country for e-commerce growth

Reflecting on our results, we note that it may be reasonable to question the extent to which European countries have influenced other European countries' e-commerce growth. In addition, building an exogenous model based on drivers that are not identical to the set of endogenous will serve to refine the results. Another possible alternative

explanation is that the main exogenous influences for e-commerce growth in Europe emanated from the United States, which was an earlier adopter of Internet-based selling business models. To investigate this conjecture, we attempted to run a model with the United States as the leading country. However, we were unsuccessful due to a common problem that occurs in econometric analysis when a dependent variable with many different values is regressed against an independent variable (or variables) with the same value(s) for each observation in the data set. There is insufficient variation in the independent variables to permit effective estimation. This led us to conclude that we could not include the United States as a potential leading country for European e-commerce growth using our current modeling approach.

7.2.6. Data availability

This kind of exploratory research is a challenge to conduct for several reasons. Developing effective research designs is hampered by the limited availability of cross-sectional data. Often it is necessary to utilize variables and measures that are imperfect proxies for the primary construct of interest. For example, the availability of e-security provisions, and tax and other government policies are interesting variables to explore in the cross-country e-commerce growth context. But does the European context offer sufficient variation to make extending the model like this worthwhile? In addition to cross-national similarity in e-security levels, our intuition is that this variable will covary with some of our other macro-level infrastructure variables, resulting (as was the case with the use of the United States as the leading country). Moreover, sometimes the country-level data may not all be built with the same level of care and rigor. So it is usually a challenge to match the data variable-by-variable and year-by-year for all of the countries that are included in a cross-national research design. With our choice of 17 Western European countries, we have minimized these issues. But the relative availability of the European data masks a more challenging problem: to create theoretical interpretations and explanations that will support a more complete understanding of the patterns of global e-commerce growth.

7.2.7. Adjusted e-commerce growth

A final consideration for this research is whether it is appropriate to distinguish between new e-commerce growth in terms of additional sales within the economy, and the cannibalization of conventional sales where B2C consumer expenditures replace sales that would have occurred through traditional channels. In future research, we will explore the efficacy of collecting cross-national data from the traditional and Internet-based retailing channels in parallel with one another. In closing, we caution the reader to recognize that in the absence of a "cannibalization adjustment" for cross-channel consumer expenditure, it is necessary to understand that our findings should be viewed as "upper bounds" on the actual level of economic growth that is associated with e-commerce. It is surely the case that some cannibalization of traditional channel sales is occurring in every economic setting that our data cover.

As a coda to our growth theory interpretation of the growth of consumer expenditures in e-commerce activities, we need to clearly and carefully state that our results reflect a more optimistic picture for e-commerce-led economic growth than probably actually obtains in the real world. We have additional research underway that attempts to overcome some of the limitations mentioned here, including the limited number of countries considered and the length of the time-series data. Clearly, there are many interesting directions to pursue, now that we have obtained a reading on the initial efficacy of the basic theoretical perspective and the study variables.

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Appendix. Online shopping expenditure indicators among the European countries, 2000–2004

See Figs. A1–A4 (*Note*: All online shopping expenditures are stated in terms of *purchasing power parity-adjusted international dollars* ($)).

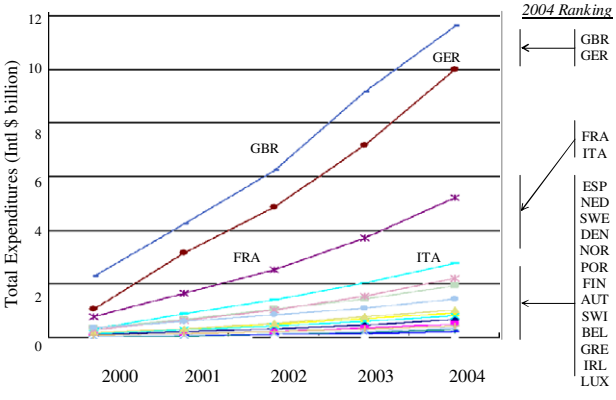

Fig. A1. Total online shopping expenditures by country.

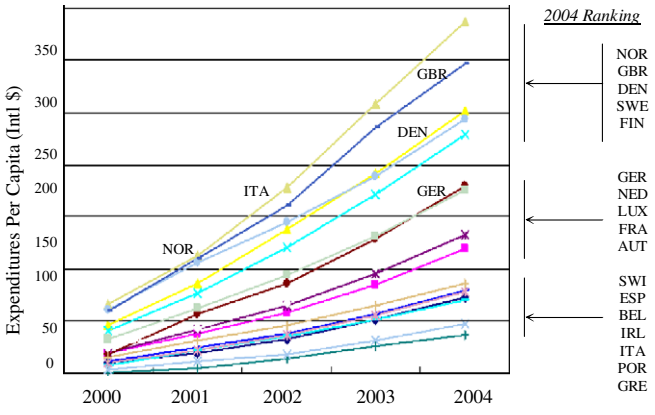

Fig. A2. Online shopping expenditures per capita by country.

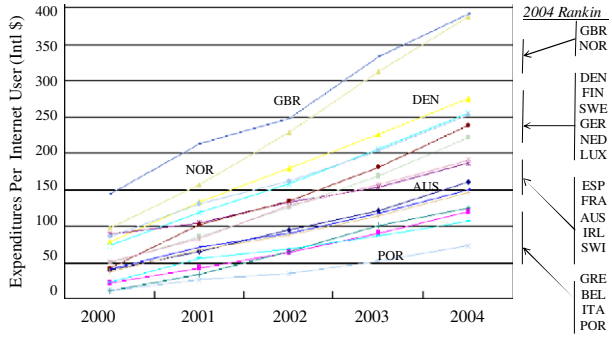

Fig. A3. Shopping expenditures per Internet user by country.

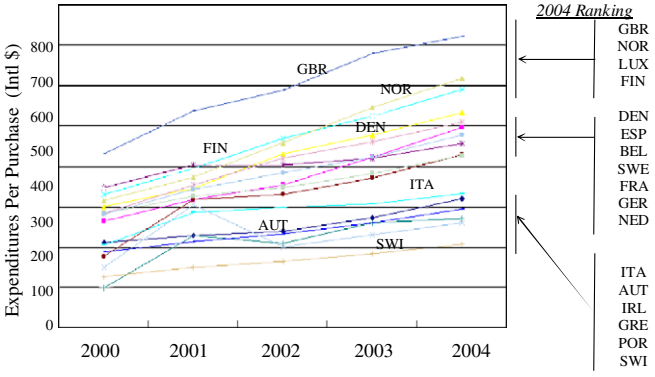

Fig. A4. Shopping expenditures per purchase by country.

References

[1] A. Aizcorbe, K. Flamm, A. Khurshid, The role of semiconductor inputs in IT hardware price decline, Working paper, McCombs School of Business, University of Texas, Austin, TX, 2001.

[2] P. Aghion, P.A. Howitt, Model of growth through creative destruction, Econometrica 60 (2) (1992) 323–351.

[3] P. Aghion, P. Howitt, Endogenous Growth Theory, MIT Press, Cambridge, MA, 1999.

[4] B. Balassa, Exports, policy choices and economic growth in developing countries after the 1973 oil shock, Journal of Development Economics 18 (2) (1985) 23–35.

[5] R.D. Banker, R.C. Morey, Efficiency analysis for exogenously fixed inputs and outputs, Operations Research 34 (4) (1986) 513–521.

[6] R.D. Banker, R. Natarajan, Evaluating contextual variables affecting productivity using data envelopment analysis, Working paper, School of Management, University of Texas, Dallas, TX, 2001.

[7] R.J. Barro, X. Sala-i-Martin, Convergence, Journal of Political Economy 100 (2) (1992) 223–251.

[8] R.J. Barro, X. Sala-i-Martin, Technological diffusion, convergence and growth, Journal of Economic Growth 2 (1) (1997) 1–26.

[9] R.J. Barro, X. Sala-i-Martin, Economic Growth, second ed., MIT Press, Cambridge, MA, 2003.

[10] W.J. Baumol, Productivity growth, convergence, and welfare: what the long-run data show? American Economic 76 (5) (1986) 1072–1085.

[11] D. Belsley, E. Kuh, R. Welsch, Regression Diagnostics: Identifying Influential Data and Sources of Collinearity, John Wiley and Sons, New York, NY, 1980.

[12] T. Breusch, A. Pagan, A simple test for heteroscedasticity and random coefficient variation, Econometrica 47 (1979) 1287–1294.

[13] E. Brousseau, B. Chaves, Diffusion and impact of e-commerce: the French, Working paper, Center for Research on Information Technology and Organizations (CRITO), University of California, Irvine, CA, 2004.

[14] E. Brynjolfsson, L.M. Hitt, Computing productivity: firm-level evidence, The Review of Economics and Statistics 85 (4) (2003) 793–808.

[15] P.S. Calem, G.A. Carlino, Urban agglomeration economics in the presence of technical change, Journal of Urban Economics 29 (1) (1991) 82–95.

[16] F. Caselli, W.J. Coleman, Cross-country technology diffusion: the case of computers, Technology Adoption and Economic Growth 91 (2) (2001) 328–335.

[17] M. Castells, The Rise of the Network Society, second ed., Blackwell Publishers, London, UK, 2000.

[18] R.B. Chase, Where does the customer fit in a service operation? Harvard Business Review 56 (6) (1978) 668–697.

[19] M.D. Chinn, R.W. Fairlie, The determinants of the global digital divide: a cross-country analysis of computer and Internet penetration, Discussion paper no. 881, Economic Growth Center, Yale University, New Haven, CT, 2004.

[20] A.M. Chircu, R.J. Kauffman, Maximizing the value of Internet-based corporate travel systems, Communications of the ACM 44 (11) (2001) 57–63.

[21] N. Corrocher, A. Ordanini, Measuring the digital divide: a framework for analysis of cross-country differences, Journal of Information Technology 17 (1) (2002) 9–19.

[22] E.M. Crenshaw, K.K. Robison, Jump-starting the Internet revolution: how structural conduciveness and global connections help diffuse the Internet? Journal of the Association for Information Systems 7 (1) (2006) 4–18.

[23] S. Dasgupta, S. Lall, Wheeler, Policy reform, economic growth, and the digital divide: an econometric analysis. Working paper, Development Research Group, World Bank, Washington, DC, 2001.

[24] S. Datta, A. Jain, The Networked Readiness Index 2003–2004: Overview and Analysis Framework, Center for International Development, Harvard University, Cambridge, MA, 2004.

[25] M.G. Dekimpe, P.M. Parker, M. Sarvary, Staged estimation of international diffusion models, Technology Forecasting and Social Change 37 (1–2) (1998) 105–132.

[26] J.B. De Long, L.H. Summers, Equipment investments and economic growth, Quarterly Journal Economics 106 (2) (1991) 445–502.

[27] J.B. De Long, L.H. Summers, How strongly do developing countries benefit from equipment investment? Journal of Monetary Economics 32 (3) (1993) 395–415.

[28] D. Depotis, Measuring human development via data envelopment analysis: the case of Asia and the Pacific, OMEGA: International Journal of Management Science 33 (5) (2005) 385–390.

[29] S. Dewan, D. Ganley, K.L. Kraemer, Across the digital divide: a cross-country multi-technology analysis of the determinants of IT penetration, Journal of the Association for Information Systems 6 (12) (2005) 409–432.
[30] S. Dewan, K.L. Kraemer, International dimensions of the productivity paradox, Communications of the ACM 41 (8) (1998) 56–62.
[31] S. Dewan, K.L. Kraemer, Information technology and productivity: evidence from country-level data, Management Science 46 (4) (2000) 548–562.
[32] S. Dewan, C. Min, The substitution of information technology for other factors of production: a firm-level analysis, Management Science 43 (12) (1997) 1660–1675.
[33] D. Dollar, Outward-orientated developing countries really do grow more rapidly: evidence from 95 LDC's, 1976–1985, Economic Development and Cultural Change 40 (1992) 523–544.
[34] Economics.About.com. Huber–White Standard Errors, Glossary Entry. Available from: <economics.about.com/library/glossary/bldef-huber-white-standard-errors.htm>. Accessed on March 1, 2006.
[35] Economist Intelligence Unit, The 2003 E-readiness Rankings, White Paper, The Economist Group, London, United Kingdom, 2003.
[36] Economist Intelligence Unit, The 2004 E-learning Readiness Rankings, White Paper, The Economist Group, London, United Kingdom, 2004.
[37] S. Edwards, Trade orientation, distortions and growth in developing countries, Journal of Development Economics 39 (1992) 31–57.
[38] P. Evans, Using panel data to evaluate growth theories, International Economic Review 39 (2) (1998) 295–306.
[39] C. Forman, A. Goldfarb, S. Greenstein, How do industry features influence the role of location in Internet adoption? Journal of the Association for Information Systems 16 (12) (2005) 383–408.
[40] J. Gibbs, K.L. Kraemer, J. Dedrick, Environment and policy factors shaping global e-commerce diffusion: a cross-country comparison, The Information Society 19 (1) (2003) 5–18. Also appeared in L. Applegate, R. Galliers, J.I. Degross (Eds.), in: Proceedings of the 23rd International Conference on IS, Barcelona, Spain, December 2002.
[41] K.H. Goh, R.J. Kauffman, Towards a theory of value latency for IT investments, in: R. Sprague (Ed.), Proceedings of the 38th Annual Hawaii International Conference on System Sciences, Kona, HI, IEEE Computing Society Press, Los Alamitos, CA, 2005, pp. 231–240.
[42] W. Greene, Econometric Analysis, Fifth ed., Prentice Hall, Saddle River, NJ, 2002.
[43] S. Greenstein, From superminis to supercomputers: estimating surplus in the computing market, Working paper, National Bureau of Economic Research, Cambridge, MA, 1994.
[44] Z. Grilliches, R&D and Productivity, Harvard University Press, Cambridge, MA, 1998.
[45] G.M. Grossman, E. Helpman, Endogenous innovation in the theory of growth, Journal of Economic Perspectives 8 (1) (1994) 23–44.
[46] G.M. Grossman, E. Helpman, Innovation and Growth in the Global Economy, MIT Press, Cambridge, MA, 1991.
[47] H. Gruber, F. Verbove, The diffusion of mobile telecommunications services in the European Union, European Economic Review 45 (3) (2001) 577–589.
[48] J. Hahn, R.J. Kauffman, Measuring the effectiveness of e-commerce Web sites, Working paper, MIS Research Center, Carlson School of Management, University of Minnesota, Minneapolis, MN, 2005.
[49] R.E. Hall, C.I. Jones, Levels of economic activity across countries, American Economic Review 87 (2) (1997) 173–177.
[50] A. Hartman, J. Sifonis, J. Kador, Net Ready: Strategies for Success in the E-economy, McGraw-Hill, NY, 2000.
[51] K. Helsen, K. Jedidi, W.S. DeSarbo, A new approach to country segmentation utilizing multinational diffusion patterns, Journal of Marketing 57 (3) (1993) 60–71.
[52] P.J. Huber, The behavior of maximum likelihood estimation under nonstandard conditions, in: L.M. LeCam, J. Neyman (Eds.), Proceedings of the Fifth Berkeley Symposium on Mathematical Statistics and Probability, vol. 1, University of California Press, Berkeley, CA, 1967.
[53] J. Jalava, M. Pohjola, Economic growth in the new economy: evidence from advanced economies, Information Economics and Policy 14 (2) (2002) 189–210.
[54] J. Jin, X. Chengyu, The digital divide in terms of national informatization quotient: the perspective of mainland China, in: Proceedings of the International Conference on Digital Divides: Technology and Politics in the Information Age, Hong Kong Baptist University, Hong Kong, SAR, China, 2002.
[55] D.W. Jorgenson, The embodiment hypothesis, Journal of Political Economy 74 (1) (1966) 1–17.
[56] D.W. Jorgenson, Information technology and the U.S. economy, American Economic Review 91 (1) (2001) 1–32.
[57] D.W. Jorgenson, K.J. Stiroh, US Economic growth at the industry level, American Economic Review 90 (2) (2000) 161–167.
[58] D.W. Jorgenson, K.J. Stiroh, Raising the speed limit: U.S. economic growth in an information age, Brookings Papers on Economic Activity 1 (2001) 125–211.
[59] G. Judge, R.C. Hill, W.E. Griffiths, H. Lutkepol, T. Lee, Introduction to the Theory and Practice of Econometrics, second ed., John Wiley and Sons, New York, NY, 1988.
[60] R. Kalakota, E-Business: A Roadmap for Success, Addison–Wesley, Reading, MA, 1999.
[61] R. Kalakota, A.B. Whinston, Electronic Commerce: A Manager's Guide, Addison–Wesley, Reading, MA, 1996.
[62] R.J. Kauffman, A. Kumar, The role of MAR and Jacob externalities in the growth of IT industry clusters, Working paper, MIS Research Center, Carlson School of Management, University of Minnesota, Minneapolis, MN, 2005.
[63] R.J. Kauffman, A.A. Techatassanasoontorn, Does one standard promote faster growth? An econometric analysis of the international diffusion of wireless technology, in: R. Sprague (Ed.), Proceedings of the 37th Hawaii International Conference on Systems Science, Kona, HI, January 2004, IEEE Computing Society Press, Los Alamitos, CA, 2004.
[64] R.J. Kauffman, A.A. Techatassanasoontorn, Is there a global digital divide for digital wireless technologies? Journal of the Association for Information Systems 6 (12) (2005) 338–382.
[65] R.J. Kauffman, A.A. Techatassanasoontorn, International diffusion of digital mobile technology: a coupled-hazard state-based approach, Information Technology and Management 6 (2) (2005) 253–292.
[66] R.J. Kauffman, A.A. Techatassanasoontorn, The global diffusion patterns of successive technology generations: modeling analog and digital wireless phone growth, in: R. Reddy, A. Saxenian (Eds.), Proceedings of the International Conference on Information and Communication Technologies and Development, School of Information Management and Systems, University of California, Berkeley, CA, May 2006.
[67] J. Kauffman, E.A. Walden, Economics and electronic commerce: survey and directions for research, International Journal of Electronic Commerce 5 (4) (2001) 5–116.
[68] R.J. Kauffman, Y.M. Wang, State and national linkages in network growth, Working paper, Center for Research on IS, Stern School of Business, NYU, New York, NY, 1995.
[69] P. Kennedy, A Guide to Econometrics, fifth ed., MIT Press, Cambridge, MA, 2003.
[70] S. Kiiski, M. Pohjola, Cross-country diffusion of the Internet, Information Economics and Policy 14 (2) (2002) 297–310.
[71] G.S. Kirkman, C.A. Osorio, J.D. Sachs, The Networked Readiness Index: Measuring the preparedness of nations for the networked world. Information Technologies Group (Eds.), Readiness for a Networked World: A Guide for Developing Countries, Center for International Development, Harvard University, Cambridge, MA, 2002 (Chapter 2).

[72] R. Kohli, S. Devaraj, Measuring information technology payoff: a meta-analysis of structural variables in firm-level empirical research, Information Systems Research 14 (2) (2003) 127–145.
[73] N. Kshetri, N. Dholakia, E-commerce patterns in South Asia: a look beyond economics, Journal of Asia-Pacific Business 6 (3) (2005) 63–79.
[74] T.P. Liang, S.C. Ho, J.H. Hu, Y.T. Wu, Effects of national factors and product characteristics on online shopping: a cross-national study, in: Proceedings of the Third Workshop on E-Business, Washington, DC, 2004, pp. 509–519.
[75] C.H. Lovelock, R.F. Young, Look to consumers to increase productivity, Harvard Business Review 57 (3) (1979) 168–178.
[76] R. Lucas, On the mechanics of economic development, Journal of Monetary Economics 22 (1) (1988) 3–42.
[77] B. Mahlberg, M. Obersteiner, Remeasuring the HDI by data envelopment analysis, Interim report IS-01-069, International Institute for Applied Systems Analysis, 2001, Laxenburg, Austria.
[78] M.A. Mahmood, K. Bagchi, T.C. Ford, Online shopping behavior: cross-country empirical research, International Journal of Electronic Commerce 9 (1) (2004) 9–30.
[79] N.G. Mankiw, D. Romer, D.N. Weil, A contribution to the empirics of economic growth, Quarterly Journal of Economics 107 (2) (1992) 407–437.
[80] P.K. Mills, J.H. Morris, Clients as partial employees of service organizations: role development in client participation, Academy of Management Review 11 (4) (1986) 726–735.
[81] S. Minton, D. Emberly, Information society index, 2003: Preliminary rankings and data. Document 29731, International Data Corporation (IDC), Framingham, MA, July 2003. Abstract available; full report available for purchase only.
[82] S. Minton, B. Ludovica, Information society index, 2004: Preliminary rankings and data. Document 32161, International Data Corporation (IDC), Framingham, MA, November, 2004.
[83] R.M. Moulton, GDP and the digital economy: keeping up with the changes, in: E. Brynjolfsson, B. Kahin (Eds.), Understanding the Digital Economy, MIT Press, Cambridge, MA, 2000.
[84] O. Ngwenyama, F.K. Andoh-Baidou, F. Bollou, O. Morawczynski, Is there a relationship between ICT, health, education and development? An empirical analysis of five West African countries from 1997 to 2003, Electronic Journal of Information Systems in Developing Countries 23 (5) (2006) 1–11.
[85] O. Ngwenyama, F. Bollou, O. Morawczynski, A DEA investigation of the contribution of ICT to development in five African countriesOperations Research in Africa, United Nations University Press, Tokyo, Japan, 2006.
[86] W.D. Nordhaus, The progress of computing, Working paper no. 1324, Cowles Foundation and Department of Economics, Yale University, New Haven, CT. Also working paper, National Bureau of Economic Research, Cambridge, MA, 2002.
[87] Organization for Economic Cooperation and Development (OECD). The economic and social impact of electronic commerce: preliminary findings and research agenda, Discussion paper no. 50441, OECD Publications Office, Paris, France, 1999.
[88] Organization for Economic Cooperation and Development (OECD), OECD productivity manual: a guide to the measurement of industry-level and aggregate productivity growth (Annex 1: Glossary), Paris, France, March 2001.
[89] M. Pohjola, Information technology and economic growth: a cross-country analysis, in: M. Pohjola (Ed.), Information Technology, Productivity, and Economic Growth, Oxford University Press, Oxford, United Kingdom, 2001.
[90] M. Pohjola, The new economy in growth and development, Oxford Review of Economic Policy 18 (3) (2002) 380–396.
[91] M. Pohjola, The adoption and diffusion of ICT across countries: patterns and determinants, in: D.C. Jones (Ed.), The New Economy Handbook, Elsevier Science and Technology Books, Amsterdam, Netherlands, 2003, Chapter 4.
[92] L. Press, The state of the Internet: Growth and gaps, in: The Internet Global Summit: Global Distributed Intelligence for Everyone, 10th Annual Internet Society Conference, Yokohama, Japan, July 18–21, 2000. Available from: <www.isoc.org/inet2000/cdproceedings/8e/8e_4.htm>. Accessed on March 1, 2006.
[93] J. Proudman, S. Redding, M. Bianchi, Is international openness associated with faster economic growth? Working paper no. 63, Bank of England, London, United Kingdom, 1997.
[94] F.J. Riggins, H.S. Rhee, Toward a unified view of electronic commerce, Communications of the ACM 41 (10) (1998) 88–95.
[95] L.A. Rivera-Batiz, P.M. Romer, Economic integration and endogenous growth, Quarterly Journal of Economics 106 (2) (1991) 531–555.
[96] E.M. Rogers (Ed.), Diffusion of Innovations, Free Press, New York, NY, 1983.
[97] P.M. Romer, Increasing returns and long run growth, Journal of Political Economics 94 (5) (1986) 1002–1037.
[98] P.M. Romer, The origins of endogenous growth, Journal of Economic Perspectives 8 (1) (1994) 3–22.
[99] J.D. Sachs, A.M. Warner, Fundamental sources of long-run growth, American Economics Review 87 (2) (1997) 184–188.
[100] X. Sala-i-Martin, Regional cohesion: evidence and theories of regional growth and convergence, European Economic Review 40 (6) (1996) 1325–1352.
[101] X. Sala-i-Martin, I just ran two million regressions, American Economic Review 87 (2) (1997) 178–183.
[102] H. Selhofer, T. Hüsing, The digital divide index: a measure of social inequalities in the adoption of ICT, Working paper, Statistical Indicators Benchmarking the Information Society (SIBIS), Information Society Programme, European Commission, Bonn, Germany, 2002. Also presented at the 2002 Information Systems and Technologies Conference IST 2002 Conference, Copenhagen, Denmark, November 4–6, 2002.
[103] D. Siegel, Futurize Your Enterprise: Business Strategy in the Age of the E-Customer, McGraw-Hill, New York, NY, 1999.
[104] R.M. Solow, A contribution to the theory of economic growth, Quarterly Journal of Economics 70 (1) (1956) 65–94.
[105] R.M. Solow, Growth Theory: An Exposition, second ed., Oxford University Press, New York, NY, 2000.
[106] J.H. Stock, M.W. Watson, Introduction to Econometrics, Addison–Wesley, Boston, MA, 2002.
[107] T.W. Swan, Economic growth and capital accumulation, Economic Record 32 (11) (1956) 334–361.
[108] D. Straub, D. Hoffman, B. Weber, C. Steinfield, Toward new metrics for Net-enhanced organizations, Information Systems Research 13 (3) (2002) 227–238.
[109] D. Talukdar, K. Sudhir, A. Ainslie, A Investigating new product diffusion across products and countries, Marketing Science 21 (1) (2002) 97–114.
[110] Taylor Nelson Sofres Interactive. Global E-Commerce Report, London, UK, 2002.
[111] A.A. Techatassanasoontorn, The state-based and contagion theories of technology diffusion, Ph.D. Thesis, Carlson School of Management, University of Minnesota, Minneapolis, MN, October 2005.
[112] G.W. Treese, L.C. Stewart, Designing Systems for Internet Commerce, Addison-Wesley, Reading, MA, 1998.
[113] United Nations Conference on Trade and Development (UNCTAD), E-Commerce and Development Report, 2001, White paper, New York, NY, January 2001.
[114] United Nations Conference on Trade and Development (UNCTAD), E-Commerce and Development Report, 2003, White paper, New York, NY, January 2003.
[115] United Nations Conference on Trade and Development (UNCTAD), E-Commerce and Development Report, 2004, White paper, New York, NY, January, 2004.
[116] H. Varian, Microeconomic Analysis, third ed., W.W. Norton and Company, New York, NY, 1992.

[117] S. Wallsten, Regulation and Internet use in developing countries, World Bank Policy Research, Working paper no. 2979, World Bank, Washington, DC, 2003.
[118] H. White, A heteroscedasticity-consistent covariance matrix estimator and a direct test for heteroscedasticity, Econometrica 48 (1980) 817–838.
[119] P. Wolcott, L. Press, W. McHenry, S. Goodman, W. Foster, A framework for assessing the global diffusion of the Internet, Journal of the Association for Information Systems 2 (6) (2001) 1–50.
[120] P. Wong, ICT production and diffusion in Asia, Discussion paper no. 2001/8, World Institute for Development Economics Research, United Nations University, Tokyo, Japan, 2001.
[121] S. Xu, K. Zhu, J. Gibbs, Global technology, local adoption: a cross-country investigation of Internet adoption by companies in the United States and China, Electronic Markets 14 (1) (2004) 13–24.
[122] M. Xue, G.R. Heim, P.T. Harker, Consumer and co-producer roles in e-service: Analyzing efficiency and effectiveness of e-service designs, International Journal of Electronic Business 3 (2) (2005) 174–197.
[123] J. Zeira, Workers, machines, and economic growth, Quarterly Journal of Economics 13 (4) (1998) 1091–1117.
[124] V.A. Zeithaml, A. Parasuraman, L.L. Berry, Delivering Quality Service: Balancing Customer Perceptions and Expectations, Free Press, New York, NY, 1990.
[125] K. Zhu, K.L. Kraemer, Post-adoption variations in usage and value of e-business by organizations: cross-country evidence from the retail industry, Information Systems Research 16 (1) (2005) 61–84.
[126] K. Zhu, K. Kraemer, S. Xu, Electronic business adoption by European firms: a cross-country assessment of the facilitators and inhibitors, European Journal of IS 12 (4) (2003) 251–268.
[127] V. Zwass, Electronic commerce: structures and issues, International Journal of Electronic Commerce 1 (1) (1996) 3–23.
[128] V. Zwass, Electronic commerce and organizational innovation: aspects and opportunities, International Journal of Electronic Commerce 7 (3) (2003) 7–37.