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Abstract

This study reveals the economic impact of seaports on regions in Korea. Econometrics analysis employing an augmented Solow model is conducted based on the panel data covering all the regions of Korea over the period 2000-2013. The econometrics analysis shows that cargo ports without sufficient throughput obstruct regional economic growth, whilst cargo ports contribute to regional economic growth only when they have sufficient throughput. Furthermore, the result indicates that container port activities positively affect regional economic growth, whilst port investment indirectly leads to economic growth. This study contributes to the better understanding of the role of ports in Korean economies.

Keywords: impact of seaport; regional economies; South Korea; augmented Solow model; port.

1. Introduction

Many academics have argued that transport infrastructure provides regions with an opportunity for growth and prosperity (Pradhan and Bagchi, 2013; Cohen and Monaco, 2008; Aschauer, 1989). As one important transport infrastructure, seaports (hereafter ports) are traditionally viewed as an economic springboard for regional development, since the services and manufacturing activities create economic benefits and socio-economic wealth via labour income, business earnings and taxes in the region (Song and van Geenhuizen, 2014; Deng et al., 2013; Talley, 2009; Grobar, 2008; DeSalvo, 1994). They have economic and social impacts (direct, indirect, induced and catalytic) on their corresponding hinterlands (Danielis and Gregori, 2013, Ferrari et al., 2010). In the case of the UK, the economic contribution of the ports sector in 2011 was approximately £ 21.2 billion, which included 391,800 employed and £ 6.2 billion in tax revenue (Oxford Economics, 2013). Indeed, the port activities can help the regional economies in various ways: (1) decreasing production cost (Cohen and Monaco, 2008; Gripaiosa and Gripaiosa, 1995); (2) lowering transportation cost (Fujita et al., 1999; Yochum and Agarwal, 1987); (3) enticing port-related activities (Ferrari et al., 2010; Yochum and Agarwal, 1987); (4) promoting employment (Acciaro, 2008); (5) providing domestic manufacturers access to profitable foreign markets (Cohen and Manoco, 2008; Bryan et al., 2006); (6) offering inter-modal transport networks (Bryan et al., 2006); (7) helping the location of distribution centres by retailers and manufacturers within the regions of the ports (Talley, 2009; Yochum and Agarwal, 1987). Port foreign trade cargoes directly indicate the status of national foreign trade, and the export volume contributes to GDP growth (Tyler, 1981). On the other hand, landlocked countries, which do not have their own ports, may be likely to face vast cost disadvantages owing to the higher inland transport costs from the neighbouring ports, extra costs for inter-modal transport, and political costs of crossing at least one additional international border when involving in international trade

(Radelet and Sachs, 1998). On this point, landlocked regions would encounter a GDP shortage compared to port regions that could be as large as approximately 40% in the case of developing countries (Chowdhury and Erdenebileg, 2006).

A port city functions as both a port and a city, implying that the port and its host port city rely on one another (Shan et al., 2014). A large body of literature has examined the role of the port on regions, whilst some authors have investigated the relationship in the opposite direction (e.g. the impact of economic and demographic city factors on port production growth) (see Cheung and Yip, 2011). Others have explored the simultaneous development of a port-city as a spatial location, where the port and city are complementary and interact with each other in a complex way (Ducruet et al., 2013). In other words, the port fosters its city's growth and economy, whereas the city's growth drives its port's development and evolution (Cheung and Yip, 2011). In fact, the city function and port function maintain a balanced combination of centrality and intermediacy (Ducruet and Lee, 2006). Although ports perform particular activities not always in accordance with their adjacent cities, in a wider unban context, they may be viewed as one function (Lee and Ducruet, 2009; Wang and Ducruet, 2012). The port cities sometimes bear the external costs of port development such as congestion, noise, air pollution, and the loss of large coastal spaces to the public (Musso et al., 2000; Cohen and Monaco, 2008; Grobar, 2008). Nonetheless, the port development not only allows the city to facilitate efficient movement of cargo between cities, but also foster the nation's supply chain and international trade due to availability of relatively cheap transportation costs of shipping. A large number of warehouses, manufacturers and distributors are likely to locate in the vicinity of ports in order to exploit its full advantage of close distance. Many governments try to induce free-trade zones and distriparks near port areas so as to foster foreign investments. Additionally, the port itself contributes to job creation for local citizens, because the port requires numerous auxiliary businesses such as shipbuilding, repair, mooring, dredging, bunkering, ship broking, ship management, classification society, customs service, legal service, maritime salvage and survey, pilotage, tug service, port security service, ship survey, maritime insurance, ship registry, ship finance, port authorities, freight forwarders, shipping firms, inland transport company, and third-party logistics providers. The port management and operation thus create numerous demands for local goods and services in such a way that the port leads to additional outputs in the regional value chain (Bryan et al., 2006). For example, to seamlessly connect ports and their hinterlands, the development of the port inevitably includes the construction of further infrastructure such as roads, bridges and highways. These investments for improving the accessibility would stimulate the related city's economy.

The port-city relationship and value-adding services (e.g. via re-assembling and packing of interim products or cargoes) derived from today's port/hinterland activities are salient, since they significantly contribute to the port-city's economies. In particular, added value produced by ports may create a wider economic rent (Musso et al., 2001). Considering South Korea (hereafter Korea) as an example, major cities are mostly port-cities which are in the vicinity of the busy ports, and are economically advanced regions. These regions tend to have a number of port-centric logistics companies whose main role is to increase added value on the products in the proximity of the ports. Korea may be regarded as suitable for examining the economic impacts of ports on regions, because Korea plays a critical role in the international trade and maritime industry in the world (Seo et al., 2015). Busan port ranked the fourth largest container port in terms of container throughput of approximately 23 million TEU in 2013. Two other container ports, Yeosu-Gwangyang port (63th) and Incheon port (65th) were ranked in the top hundred global business container ports (Lloyd's list, 2014). Also, Korea ranked fifth for dead weight tonnage with leading container shipping lines such as Hanjin shipping, Hyundai Merchant Marine, Korea Marine Transport Company, and Heung-A Shipping Company within the world top 50 leading liner shipping companies, whilst its shipbuilding industry, which dominates the markets for container vessels (69%), oil tanker (60%) and gas carrier (81%), was the second largest in the world in 2013 (UNCTAD, 2014). Notably, in terms of Liner Shipping Connectivity Index, Korea was ranked fourth (UNCTAD, 2014). Korea remains one of the largest importers of iron ore, coal, copper, oil, LNG and LPG as well as exporter of steel products, vessels, cars, machinery and electronics (UNCTAD, 2014). Korea relies heavily upon its maritime sector for imports/exports. It owns approximately 440,000 km^2 of water territory under its jurisdiction, which is about 4.5 times its land size, whilst more than 90% of international cargoes are transported by sea. Korea is likely to emphasise export-oriented growth strategies in its national strategies, resulting in extensive port investment, development and rationalisation. The Korean government has made considerable investment in port capacities in order to build effective logistics chains over the last decade. Notwithstanding, the important role of Korea in the maritime industry in the world and the huge investment in ports by the Korean government, it is somewhat strange that little research has examined the economic impact of ports on regions in the Korean context. In addition, to what extent these port investments have a positive impact on the regional economy is overlooked. Answering this question may provide the policy makers with invaluable insights into port investment required for fostering the corresponding regions' economy, since in general investments in the port can improve the port capacity and efficiency, resulting in reduced shipping costs and higher volume of international trade. This answer also may be utilised as a rationale behind new port investment and further expansion of current ports. The existing studies were based on either small samples or one city. As such, their implications may be difficult to generalise. Moreover, most conclusions lack statistical evidence. Given the significant roles in the maritime industry played by Korea and the aforementioned research gap, Korea is selected as a case to study the impact of ports on the regional economies.

Accordingly, this study may contribute to revealing the ports' economic impacts on all the regions in Korea by using data from 11 major port cities and their local ports and 5 regions without ports over the period 2000-2013. Econometrics analysis employing the augmented Solow model is conducted to answer the following questions: do port activities, investments, cargo handling have any positive or negative impact on the regional economy?

The structure of this study is as follows. The next section revisits existing literature pertaining to the impacts of the transport infrastructure and port on the region's economies. Section 3 delineates the main methodology, incorporating chosen variables and provinces. Then, the main results are displayed in Section 4. We end the study with concluding remarks in Section 5.

2. Literature review

A considerable body of literature has contended that the transport infrastructure investment has an impact on the regional economies. Economic theory argues that the provision of the transport infrastructure service positively exerts regional developments in many ways: (1) increasing productivity; (2) lowering production costs; (3) better specialisation; (4) trade growth; (5) enlargement of related markets; (6) exploitation of scale economies; (7) bringing about territorial cohesion; (8) reducing economic disparities; and (9) improvement in the division of labour (Cohen, 2010; Crescenzi and Rodríguez-Pose, 2012; van de Vooren, 2004; Aschauer, 1989). The transport system can stimulate multiplier effects on economic growth by changing aggregate demand for intermediate inputs from other industries (Pradhan and Bagchi, 2013). Some authors have estimated the economic impact of road infrastructure on production, productivity, or employment (Bottasso and Conti, 2010), whilst others analysed the role of railways (Bronzini and Piselli, 2009) and airports (Cohen and Paul, 2003). Most studies have supported the existence of a positive effect of transport infrastructure on regional growth, whereas some academics empirically find that those relationships do not fit always (Globar, 2008; Hall, 2004; Helling and Poister, 2000, Fujita and Mori, 1996). For example, Crescenzi and Rodríguez-Pose (2012) found little evidence of an impact of the transport infrastructure endowment on the region's economic growth in the case of the EU. This result might be attributed to different econometric approaches, different proxies for infrastructure and the different levels of data aggregation (Crescenzi and Rodríguez-Pose, 2012). In a similar vein, the port impact studies showed the differences in methodologies employed pertaining to defining and measuring several types of port impacts, resulting in misconceptions and ambiguous comparisons across the ports-regions (Dooms et al., 2015). It would be reasonable that the impacts of ports vary noticeably from region to region and rely on port size and the typology of traffic (Acciaro, 2008).

On the stance of the ports, the estimation of their economic impact has common denominators with other transport infrastructure research (Bottasso et al., 2013). Due to the rapid development of global supply chains and international trade, the role of ports has become vital in the regional transport system. The role of ports is getting broader from a sea-shore interface towards a wide-ranging logistics centre. Indeed, as for the geographical parameters of the port, the proliferation of logistics integration and network orientation in the port and maritime industry has reshaped the ports' functional role in value chains, which introduce a port regionalisation phase beyond the traditional port boundaries (e.g. three steps in the port development process identified in the Anyport model (which demonstrates an evolving port-city relationship): setting, expansion and specialisation (Notteboom and Rodrigue, 2005; Rodrigue and Notteboom, 2009). The ports can provide better accessibility with low transport costs, which facilitate trade and reduced price of goods. This aspect may enable various regions to achieve comparative advantage (Crescenzi and Rodríguez-Pose, 2012; Fujita and Mori, 1996). The existence of the port not only helps transport but also various activities ranged from importing raw materials by sea in order to avoid high land transport costs to those manufacturing products to be exported by sea (Grobar, 2008; Musso et al., 2000). The rent created by ports can disseminate across an economic system larger than the one in which the port is embedded (Gripaios and Gripaios, 1995). In port studies, a large number of extant studies have made an effort to investigate the role of ports on economic developments during port construction, expansion and operation by creating strong externalities in the hinterland regions (Gripaiosa and Gripaiosa, 1995; Bryan et al., 2006; Acciaro, 2008; Cohen and Monaco, 2008; Danielis and Gregori, 2013; Bottasso et al., 2014; Deng et al., 2013; Song and van Geenhuizen, 2014; Artal-Tur et al., 2015). The results of these studies may stimulate and justify the budget allocation to undertake port investments from Central or municipal government, so sometimes such investigation is commissioned by government or the port authority (Danielis and Gregori, 2013). In other words, positive impacts of the port in terms of job creation and value added may be utilised to persuade relevant stakeholders to invest (Doom et al., 2015; Yochum and Agarwal, 1987).

Most of the existing research has solved the above issues by employing non-sponsored research based on empirical and data-focused methods like Input-Output (IO) analysis that can further classify the direct, indirect, induced and catalytic effects of ports on local economies (Danielis and Gregori, 2013; Bryan et al. 2006; Castro-Villaverde and Coto-Millán, 1998; Warf and Cox, 1989; Yochum and Agarwal, 1987; Davis, 1983). Some authors explored the role of the port on economies by dividing it into port-required, port-attracted and port-related activities (Yochum and Agarwal, 1988). Technically, the system of the relevant actors is categorised into sectors, defined in terms of the resources they need for inputs and what they create as outputs so as to create an input-output matrix for a given period (Musso et al., 2010). Danielis and Gregori (2013) conducted IO analysis with a disaggregation of the various port-related sectors in Italy, building a bi-regional IO table with a top-down and bottom-up approach via *ad hoc* survey. They estimated both direct (employment, output, value added) and indirect impacts with 480 firms such as port-related, inland transport, maritime transport and non-transport-related firms. Their finding verified a relevant macroeconomic role of the port in its corresponding regions. Bryan et al. (2006) assessed the direct and indirect consequences of the port activity of Associated British Ports (ABP) in South Wales by employing an IO framework. They noted that many firms, which rely on the port infrastructure, are major regional organisations, contributing to the economic and social needs of the local economy. Despite numerous prior studies using IO methods, IO has limitations (e.g. the assumptions of no technological development, no economies of scale and no input-substitution in production) (Danielis and Gregori, 2013). Also, it is time-consuming and labour-intensive, which causes a difficulty in updating the analysis (Musso et al., 2000; Davis, 1983). Mostly importantly, the IO model does not typically embrace port industry as a single element of the inter-industry mix (Yochum and Agarwal, 1987). In order to avoid these limitations of using the IO model on port impact studies, some scholars have developed or utilised alternative methodologies such as a price elasticity of demand model (DeSalvo and Fuller, 1995), supply-demand model (DeSalvo, 1994), control group model (Isserman and Merrifield, 1982), survey approach (Yochum and Agarwal, 1988; Gripaios and Gripaios, 1995), location coefficient model (Musso et al., 2000), and spatial computable general equilibrium model (Haddad et al. 2010).

Recently, some studies are dedicating to adopting more sophisticated and quantitative methods in order to overcome the aforementioned methodologies' limitations. Song and van Geenhuizen (2014) explored the output elasticity of port infrastructure via production function with panel data, which include the ordinary least squares regression analysis, unit root test and co-integration test. Their finding designated the positive impacts of port infrastructure investment in four port regions in China. They also found that differences in these impacts may be attributed to the port characteristics, international network connectivity, the stage of economic development of the region and the spill-over effects from neighbouring regions. Shan et al. (2014) examined the effect of the port on the host city's economic development with 41 major port cities data over the period 2003-2010 by utilising panel data linear regression; they found that cargo throughput has a positive impact on the port cities' economic growth. By employing spatial panel data econometrics, Bottasso et al. (2014) analysed the economic effects of ports' total production on 621 regions of 13 Western EU countries over the period 1998-2009. Additionally, Bottasso (2013) estimated the impact of port throughput on local employment of 560 regions in 10 West EU counties over the period 2000-2006 with 116 samples of ports via the estimation of a set of employment equations with GMM techniques which are robust to regional unobserved heterogeneity and to endogeneity of port activity. Interestingly, by using structural equation modelling with the institutional data, Deng et al. (2013) investigated the association between port demand, port supply, value added activity in port and regional economy of five costal port clusters in China. Ferrari et al. (2010) employed two-stage econometric processes that individually appraised traffic and an employment equation in order to examine the role of ports on local development in Italy. Some authors evaluated the role of transport infrastructure including both ports and highways at the same time on production and employment in the manufacturing industry by using state-level total cost function from the 48 contiguous states in the U.S. (Cohen and Monaco, 2008). Kawakami and Doi (2004) applied a lag-augmented vector auto regression approach, which is a multivariate time-series framework instead of the production function approach, to analyse causal relationships amongst port capital, private capital, transport user cost and GDP in Japan with the data over 1966-1997. They uncovered that port capital affects GDP and user transport costs, whilst port capital positively and indirectly exerts a private capital.

However, there has been little consideration of the economic theories of growth, production or unemployment in the above literature. For example, the literature of the port impact on economic growth rarely examines relevant economic theories, e.g. the Solow growth model (Solow, 1956) or the endogenous growth model (Romer 1993; 1986), when developing empirical models. Likewise, their choices of exogenous or control variables are not fully supported by economic theories. One of the few exceptions is Shan et al. (2014) who briefly mention their control variables are based on Mankiw et al. (1992).

This study implements the augmented Solow model. The neo-classical original Solow model explains economic growth by capital accumulation, population growth and technological advances using a production function, but the growth only depends on exogenous factors. On the other hand, the endogenous growth model incorporates growth factors such as human capital or knowledge endogenously within the model; however, too many assumptions are required to model the relationship among too many unmeasurable factors (Krugman, 2013) and thus it has difficulty fitting with the data such as economic convergence among countries (Parente, 2001). The augmented Solow model developed by Mankiw et al. (1992) successfully incorporates human capital from the endogenous growth model into the original Solow model to overcome these issues. With these advantages of the augmented Solow model that may outperforms the original Solow model or endogenous growth model, this study employs the augmented Solow model for the main analysis.

3. Methodology

3.1. Model specification

In neo-classical economics, economic growth is commonly defined as growth in production (Y) in the economy, which is a function of capital (K) and labour (L).

$$Y_t = F(K_t, L_t)$$

where t is time index.

By dividing both sides by the amount of labour, a per-capita or per-worker production function is acquired.

$$y_t = f(k_t)$$

where y is the level of production or output per worker (Y/L) and k is the amount of capital per worker (K/L). In other words, how much an individual worker produces (y) depends on the amount of capital available to each worker (k). It can be seen that k is the only determinant of y.

On the other hand, capital stock per worker (k) could change over time by external factors. For example, according to the Solow model of economic growth (Solow, 1956), k increases as part of output is saved and invested but decreases by depreciation. Also it can be diluted with increasing population and advancing technology since they effectively increase the amount of labour.

Suppose saving rate is s, capital depreciates at a rate δ, population grows at a rate n and the technology advances at a rate g, the change in capital stock per worker is:

$$k_{t+1} - k_t = sf(k_t) - (\delta + n + g)k_t$$

If capital stock per worker converges to a certain level i.e., reaches steady-state capital stock (k^*) where k_{t+1}- k_t =0, the level of output will be determined only by the remaining factors. In other words, at a steady-state, the above equation becomes:

$$0 = sf(k^*) - (\delta + n + g)k^*$$

Rearrange this to define a function of output per worker, Φ:

$$\Phi(k^*) = \frac{f(k^*)}{k^*} = \frac{\delta + n + g}{s}$$

Then, k* is obtained as the solution for the above equation:

$$k^* = \Phi^{-1}\left(\frac{\delta + n + g}{s}\right)$$

It can now be seen that s, δ, n and g decide k*. Subsequently, it also determines y*, steady-state output per worker, since $y^*=f(k^*)$.

Mankiw et al. (1992) presented the augmented Solow model by adding human capital (H) to overcome shortcomings of the textbook Solow models. Their Cobb-Douglas production function explicitly includes the level of technology (A), which was only implicitly included in F above.

$$Y_t = F(K_t, L_t, A_t, H_t) = K_t^{\alpha} H_t^{\beta} (A_t L_t)^{1-\alpha-\beta}$$

where K is now defined as physical capital. Note that α>0, β>0 and α+β<1 are typically assumed. Then, it can be shown that each type of capital per effective labour evolves in a similar way to the above.

$$k'_{t+1} - k'_t = s_k f(k'_t) - (\delta + n + g)k'_t$$

$$h'_{t+1} - h'_t = s_h f(h'_t) - (\delta + n + g)h'_t$$

where $k' = K/AL$ and $h' = H/AL$ are quantities of each type of capital per effective unit of labour. s_k and s_h are the fraction of income invested in physical and human capital, respectively.

Since the production function is fully specified, the functional forms of Φ and Φ^{-1} can be found. Subsequently, a steady-state k* and h* can be obtained.

$$k^* = \left(\frac{s_k^{1-\beta} s_h^{\beta}}{\delta + n + g}\right)^{\frac{1}{1-\alpha-\beta}}$$

$$h^* = \left(\frac{s_k^{\alpha} s_h^{1-\alpha}}{\delta + n + g}\right)^{\frac{1}{1-\alpha-\beta}}$$

Finally, substituting these into the production function yields an equation for output per capita.

$$ln\, y_t = lnA_0 + gt + \frac{-(\alpha+\beta)}{1-\alpha-\beta} ln(\delta + n + g) + \frac{\alpha}{1-\alpha-\beta} ln(s_k) + \frac{\beta}{1-\alpha-\beta} ln(s_h)$$

Economic growth depends on the initial level of technology and its advancement. Also, it is affected by the share of income invested in human capital (s_h) and in physical capital (s_k) and how fast both capital depreciate (δ+n+g). Suppose this relationship is fixed at any given time and let time be 0 for simplicity, a testable empirical model can be derived.

$$lny = \beta_0 + \beta_1\, ln(\delta + n + g) + \beta_2\, ln(s_k) + \beta_3\, ln(s_h) + u$$

where β_0, β_1, β_2 and β_3 are coefficients and u is the country-specific error term. This is the empirical benchmark model based on the augmented Solow model. Since α and β are positive numbers and their sum is less than 1, it is expected that $\beta_1<0$, $\beta_2>0$ and $\beta_3>0$. That is, economic growth is expected to increase as more human or physical capital is available in the economy, but to decrease if capital depreciates faster.

To test how significantly port industry affects economic growth, it is necessary to add factors (x's) that represent port activities to the above benchmark model.

$$lny = \beta_0 + \beta_1 \, ln(\delta + n + g) + \beta_2 \, ln(s_k) + \beta_3 \, ln(s_h) + \boldsymbol{\beta}'\mathbf{x} + u$$

where **β** is a vector of coefficients associated with each variable of port activity (**x**). The model can now be estimated on the data using appropriate proxy variables.

In this model, the variables from the benchmark model, i.e. the first three independent variables, basically work as control variables. If the port industry contributes to economic growth, the coefficients (**β)** associated with port activity variables (**x**) should be positive and significantly different from zero even after controlling for the impacts from capital depreciation, physical and human capital. For example, if cargo throughput is used as the only port activity variable (x) and it indeed contributes to economic growth, the associated coefficient β should be positive and significant.

3.2. Data collection and preparation

The sample considered in this study is the province-level yearly panel dataset which covers the period 2000-2013. It contains all 11 scale ports and provinces and 5 regions that do not have ports in Korea as shown in Figure 1 and Table 1. The total number of observations is 224. The province-level macroeconomic data such as economic growth rate, rate of capital depreciation, share of income invested in physical capital and human capital are acquired from Korea Statistical Information Services (KOSIS) that is managed by Korea National Statistical Office. The port related data such as cargo throughput and container throughput except for the port investment are collected from the Shipping and Port Integrated Data Centre (SP-IDC) database of the Ministry of Oceans and Fisheries of Korea. The amount of port investment is publicly unavailable, so we directly obtained the internal data from a public officer of Ministry of Ocean & Fisheries (MOF) in Korea. Table 2 reports descriptive statistics of the main variables in this study.

Figure 1

Map and Provinces of South Korea

Table 1

General information of each province

Average (2000-2013)	Variable	Area	Population	GDP per capita	Cargo port	Container port
	Unit	km^2	capita	USD		
ID	Province					
1	Seoul	605	10,205,597	26,897.00	N	N
2	Busan	770	3,620,312	17,026.97	Y	Y
3	Daegu	884	2,508,803	14,782.16	N	N
4	Incheon	1,041	2,687,736	20,254.70	Y	Y
5	Gwangju	501	1,424,367	16,252.67	N	N
6	Daejeon	540	1,470,274	17,010.66	N	N
7	Ulsan	1,061	1,103,634	50,987.62	Y	Y
8	Gyeonggi	10,173	11,015,547	21,351.66	Y (2012-)	Y (2012-)
9	Gangwon	16,830	1,528,640	19,331.29	Y	Y
10	Chungbuk	7,407	1,522,139	23,303.75	N	N
11	Chungnam	8,670	2,020,619	33,674.02	Y	Y (2007-)
12	Jeonbuk	8,066	1,900,523	18,542.70	Y	Y
13	Jeonnam	12,304	1,967,694	28,476.67	Y	Y
14	Gyeongbuk	19,029	2,709,688	27,258.30	Y	Y
15	Gyeongnam	10,537	3,214,435	25,093.97	Y	Y
16	Jeju	1,849	565,242	18,519.39	Y	Y
National Average		6,267	3,091,578	23,672.72		

Table 2

Descriptive statistics

Avg. (2000-2013)	Description	Economic growth rate		Rate of capital depreciation		Share of income invested in physical capital		Share of income invested in human capital		Cargo throughput		Container throughput[a]		Port investment including new construction	
	Variable	y'		n'		s_k		s_h		x_1		x_2		x_3	
	Unit	%		%		%		%		ton		ton		million Korean Won	
ID	Province	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
1	Seoul	1.046%	1.325%	5.218%	0.189%	44.235%	1.457%	32.432%	4.941%	-	-	-	-	-	-
2	Busan	1.195%	1.144%	5.010%	0.239%	29.989%	3.418%	22.870%	4.721%	26,119,663	1,010,868	209,434,591	65,492,021	455,047	169,226
3	Daegu	1.064%	1.064%	5.229%	0.189%	21.506%	2.859%	22.953%	4.366%	-	-	-	-	-	-
4	Incheon	1.071%	2.405%	5.864%	0.173%	44.078%	2.582%	17.822%	3.401%	148,393,028	25,902,611	26,218,864	11,589,317	131,223	39,760
5	Gwangju	1.079%	1.447%	5.688%	0.283%	27.571%	2.398%	29.741%	3.937%	-	-	-	-	-	-
6	Daejeon	1.074%	1.197%	5.712%	0.189%	29.573%	1.622%	31.228%	4.722%	-	-	-	-	-	-
7	Ulsan	0.969%	3.059%	5.777%	0.313%	75.736%	1.086%	18.228%	3.446%	164,496,163	16,742,503	4,625,863	822,214	101,342	34,273
8	Gyeonggi	0.958%	1.335%	6.447%	0.677%	42.760%	1.382%	26.288%	4.422%	20,161,252	41,843,169	1,637,141	3,391,183	67,897	30,614
9	Gangwon	1.039%	1.326%	5.266%	0.397%	43.489%	2.607%	18.006%	3.546%	38,644,360	4,867,207	69,547	36,421	16,422	10,832
10	Chungbuk	1.393%	2.105%	5.468%	0.320%	54.125%	2.945%	17.569%	3.286%	-	-	-	-	-	-
11	Chungnam	2.076%	1.720%	5.864%	0.814%	66.104%	4.773%	15.575%	3.817%	79,536,020	14,601,867	356,751	431,358	29,480	8,321
12	Jeonbuk	1.335%	1.106%	5.059%	0.620%	42.397%	4.279%	19.296%	3.826%	15,965,617	2,246,847	755,098	504,199	85,348	26,804
13	Jeonnam	1.593%	2.645%	4.789%	0.665%	63.199%	4.112%	12.451%	2.543%	186,177,531	33,376,733	24,901,925	9,486,848	273,505	127,821
14	Gyeongbuk	1.382%	1.825%	5.147%	0.294%	60.199%	3.672%	13.037%	2.785%	58,396,943	5,211,225	481,272	748,374	77,123	29,697
15	Gyeongnam	1.358%	1.021%	5.604%	0.133%	55.459%	2.081%	18.377%	3.316%	43,952,309	10,817,489	446,502	365,341	41,409	23,196
16	Jeju	1.424%	1.591%	5.662%	0.399%	37.911%	3.088%	17.926%	2.808%	2,401,188	430,474	415,986	204,661	53,006	17,780
National Average		1.253%	1.708%	5.488%	0.575%	46.146%	15.116%	20.863%	7.029%	49,015,255	63,246,678	16,833,971	53,076,911	121,073	141,646

[a]Container throughput is expressed in ton in this study. For a conversion in container equivalent, 1 million ton is equivalent to approximately 90,000 TEU.

The benchmark regression model follows the specification of Mankiw et al (1992) but it is modified to adopt a two-way error component (Baltagi, 2013) that accounts for a varying intercept over both time and region. Since the dataset covers the recent financial crisis, it is more reasonable to allow for variation over time. This two-way model will be tested for a possible reduction to a one-way model later, which Mankiw et al (1992) theoretically support. Fixed effects models are used as the sample contains the entire population (Brooks, 2014). On the other hand, the benchmark model uses economic growth rates (y') as in Shan et al. (2014), not the level of output (y), to avoid spurious regression.

$$y'_{it} = \beta_0 + \beta_1 \, ln(n'_{it}) + \beta_2 \, ln(s_{k,it}) + \beta_3 \, ln(s_{h,it}) + \beta_4 \, ln(y_{it-1}) + \epsilon_{1,i} + \epsilon_{2,t} + u_{it}$$

where i is a region or province index.

Control variables are measured as follows. Growth rates are measured by regional real GDP per capita based on geometric rate rather than log approximation. The effective rate of capital depreciation (n') is approximately calculated by adding population growth rate to 0.05 as recommended by Mankiw et al (1992). The share of income invested in physical capital (s_k) is measured as the amount of regional real investment and real government expenditure divided by regional real GDP. The share of income invested in human capital (s_h) is represented by a fraction of university graduates over the number of economically active people who are either employed or actively seeking jobs. The previous year's value of real GDP per capita (y_{t-1}) is also added to control for convergence in economic growth (e.g. larger economies tend to have slower economic growth than smaller economies over time).

Five variables are employed to represent port activities and investment. First, regional cargo throughput in ton (x_1) is a measure of non-container port activities as Shan et al. (2014) suggested. It includes various wet and dry bulk cargoes excluding container cargoes and passengers. Some prior evidence noted that the economic effect of passengers is not related, since a considerable share of the traffic is relevant to transit passengers (Bottasso et al., 2014; 2013). Second, container throughput in ton (x_2) that represents capital-incentive modern container port activities was employed as Bottasso et al. (2014) recommended. Third, the amount of regional port investment including new construction (x_3) is also used as some academics recommended (Song and van Greenhuizen, 2014; Cohen and Monaco, 2008). They are all measured in natural logs to find the relative impact on economic growth and to remove the scale effect. They will be tested in different combinations alongside control variables in the benchmark model.

$$y'_{it} = \beta_0 + \beta_1 \, ln(n'_{it}) + \beta_2 \, ln(s_{k,it}) + \beta_3 \, ln(s_{h,it}) + \beta_4 \, ln(y_{it-1}) + \boldsymbol{\beta}'\mathbf{x} + \epsilon_{1,i} + \epsilon_{2,t} + u_{it}$$

Additionally, two dummy variables are added. The first dummy (D_1) is for a cargo port in the region (or the existence of cargo handling activity), which has a value of 1 if $x_1>0$; the second dummy (D_2) is for a container port or that of container handling activity, which is assigned a value of 1 if $x_2>0$. These two dummies can reveal whether the existence of ports in the region positively or negatively affect regional economic growth.

$$y'_{it} = \beta_0 + \beta_1 \, ln(n'_{it}) + \beta_2 \, ln(s_{k,it}) + \beta_3 \, ln(s_{h,it}) + \beta_4 \, ln(y_{it-1}) + \boldsymbol{\beta}'\mathbf{x} + \boldsymbol{\gamma}'\boldsymbol{D} + \epsilon_{1,i} + \epsilon_{2,t} + u_{it}$$

4. Results

The previous section showed that if the port industry indeed improves economic growth, more port activity, e.g. larger cargo throughput, will enhance economic growth. Subsequently, it can be expected that the coefficients (**β**) associated with port activities (x_1, x_2 and x_3) in the empirical model will be positive and significant. On the other hand, according to the augmented Solow model, faster capital depreciation negatively affects economic growth. Also, it is known that economic growth converges. Thus, it can be anticipated that the effective capital depreciation rate and the previous year's value of real GDP per capita are negatively related to economic growth, i.e. β_1 and β_4 <0. Also, the augmented Solow model expects that the larger amount of physical or human capital encourages economic growth. Thus, both of the shares of income invested in physical and human capital are expected to affect economic growth positively i.e. β_2 and β_3 >0.

Table ~~Table~~ 3 shows the regression results of the benchmark model (Model 1) and the other 4 models without dummies for cargo and container ports (Model 2 to 6). Table ~~Table~~ 4 summarises the regression results of the models with the dummies (Model 6 to 11). Overall, the significance and sign of the impact of physical capital (s_k) and previous output per capita ($y_{(-1)}$) in all results are as expected and revealed in Mankiw et al. (1992) and Shan et al. (2014). However, human capital (s_h) is insignificant despite it having an expected positive sign. Capital depreciation (n') does not have any significance.

Table 3

Regression results: models without dummies[b,c]

Model	1		2		3		4		5		6	
c	2.1461	***	2.3073	***	2.2818	***	2.1835	***	2.2821	***	2.1819	***
	0.3312		*0.3409*		*0.3373*		*0.3329*		*0.3363*		*0.3355*	
n'	-0.0018		0.0048		0.0035		0.0056		0.0029		-0.0006	
	0.0147		*0.0164*		*0.0162*		*0.0162*		*0.0148*		*0.0148*	
s_k	0.1162	***	0.1157	***	0.1154	***	0.1161	***	0.1154	***	0.1165	***
	0.0191		*0.0191*		*0.0190*		*0.0191*		*0.0190*		*0.0191*	
s_h	0.0134		0.0137		0.0118		0.0118		0.0119		0.0158	
	0.0184		*0.0187*		*0.0184*		*0.0184*		*0.0183*		*0.0187*	
$y_{(-1)}$	-0.2021	***	-0.2178	***	-0.2150	***	-0.2046	***	-0.2151	***	-0.2061	***
	0.0296		*0.0307*		*0.0303*		*0.0297*		*0.0301*		*0.0302*	
x_1			0.0001		0.0001		0.0006					
			0.0007		*0.0007*		*0.0006*					
x_2			0.0006		0.0006	^			0.0006	*		
			0.0004		*0.0004*				*0.0003*			
x_3			0.0013								0.0015	
			0.0022								*0.0022*	
Obs	208		208		208		208		208		208	
adj R^2	0.5182		0.5209		0.5227		0.5187		0.5254		0.5169	

Note: *** indicates the significance of a coefficient at 1% level. **, * and ^ are for 5%, 10% and 15% significance level, respectively; [b]Numbers in non-italics are the values of the coefficients (β) associated with the variables in the leftmost column. Numbers in italics are standard deviation; [c]None of the data series have a unit root according to the results from the Levin-Lin-Chu panel unit root tests (Levin et al., 2002). The test results for redundant fixed effects using likelihood ratios and Hausman test results, not reported, support two-way fixed effects models against random effects and one-way fixed effects alternatives in all estimated models. Obs is observation number and adjR^2 is adjusted R^2.

Among the models reported in Table ~~Table~~ 3, the best model is Model 5 in terms of adjusted R^2 and individual significance. The findings in Model 5 are as follows. Container throughput is positively related to regional economic growth at the 10% significance level. Its magnitude does not seem strong e.g. 1% increase in container throughput raises economic growth by 0.06%. However, container throughput increased rapidly over the sample period, e.g. around 2-6 times in major container ports located in Busan, Incheon and Jeonnam, so the contribution of the container ports is quite substantial with 1.25% average real regional growth. For example, 3 times increase (i.e. 300%) in container throughput in 12 years is equal to the increase in economic growth by 0.57% point per annum (=(300%^(1/12)-1)×0.06). On the other hand, cargo throughput and port investment are not significant in economic growth. This contradicts what is expected and revealed in the literature and may indicate mis-specification errors of non-dummy models (Model 1 to 6) in general.

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Table 4

Regression results: models with dummies[b,c]

Model	7		8		9		10		11	
c	2.6117	***	2.4717	***	2.2838	***	2.6128	***	2.2838	***
	0.3462		0.3404		0.3379		0.3453		0.3389	
n'	-0.0020		0.0014		0.0029		-0.0015		0.0036	
	0.0160		0.0159		0.0148		0.0159		0.0163	
s_k	0.1181	***	0.1192	***	0.1155	***	0.1185	***	0.1155	***
	0.0187		0.0187		0.0191		0.0186		0.0191	
s_h	0.0103		0.0112		0.0121		0.0111		0.0120	
	0.0181		0.0181		0.0185		0.0179		0.0185	
$y_{(-1)}$	-0.2479	***	-0.2330	***	-0.2153	***	-0.2478	***	-0.2151	***
	0.0314		0.0306		0.0303		0.0313		0.0304	
x_1	0.0283	***	0.0266	***			0.0278	***	0.0001	
	0.0089		0.0089				0.0088		0.0007	
x_2	0.0011				0.0005		0.0007	**	0.0005	
	0.0010				0.0010		0.0004		0.0010	
D_1	-0.5264	***	-0.4804	***			-0.5159	***		
	0.1661		0.1639				0.1636			
D_2	-0.0052				0.0011				0.0014	
	0.0131				0.0130				0.0133	
Obs	208		208		208		208		208	
adj R^2	0.5438		0.5387		0.5227		0.5460		0.5200	

The results from the models with dummies (Model 7 to 11) are stronger than the model without dummies in terms of adjusted R^2. The best model is Model 10 which contains cargo and container throughput and the cargo port dummy. Also, the likelihood ratio test indicates that those three variables are not redundant with the likelihood ratio of 15.9426 and p-value of 0.001.

In addition, it should be noted that economic growth may lead to larger port throughput, so the causation can be reversed or be bi-directional unlike the prediction by the economic theories. Therefore, the causation is also tested between economic growth (y') and cargo or container throughput in growth form using the vector autoregressive (VAR) Granger causality test by additionally specifying n', s_h and s_k as exogenous variables. Although the main focus of this paper is on the economic impacts of the ports on the regions, we test this reverse causation as an ex post fashion with an assumption that economically and demographically richer regions that have a myriad of manufacturing and service companies are likely to be involved with larger transport volumes. The results (Table 5) generally support the use of uni-directional model with economic growth as a dependent variable and cargo throughput as an independent variable since its significance is only marginally insignificant at the 10% level while the causality from economic growth to both cargo and container throughput is strongly rejected.

Table 5
Granger causality tests: economic growth and cargo or container throughput growth

Null Hypothesis (H_0):	p-value
Cargo throughput growth does not Granger cause economic growth	0.1152
Economic growth does not Granger cause cargo throughput growth	0.2865
Container throughput growth does not Granger cause economic growth	0.5917
Economic growth does not Granger cause container throughput growth	0.9908

Finally, the results of Model 10 can be represented in equation form:

$$\widehat{y'_{it}} = 2.2618 - 0.0015\, ln(n'_{it}) + 0.1185\, ln(s_{k,it}) + 0.0111\, ln(s_{h,it}) - 0.2478\, ln(y_{it-1}) + 0.0278x_2 + 0.0007x_3 - 0.5159D_1$$

The findings in Model 10 are:

(1) The increase in cargo throughput (x_1) is now significantly and positively related to regional economic growth. That is, more cargo throughput means higher economic growth. When the log of cargo throughput increases by 1, economic growth goes up by 2.78% points.

(2) The existence of cargo ports in the region has a negative effect on regional economic growth on average. Cargo ports undermine economic growth by 51.59% points given zero cargo throughput. The sign and magnitude of this coefficient is confusing. Since active cargo ports process 76,886,674 tons (or 18.1578 log tons) on average, the actual negative impact is only around -1.41% points (= 51.59% - (18.1578 x 2.78%)) per annum on average.

(3) If the regional cargo ports handle more than 114,662,088 tons (or 18.5575 log tons), it actually positively affects regional economic growth. This works as a threshold value and it corresponds to three regions with large cargo throughput (Incheon, Ulsan and Jeonnam).

(4) Container throughput is also significantly and positively related to regional economic growth. A 1% increase in container throughput leads to a 0.07% point increase in economic

growth. Again, regarding the magnitude of increase in container throughput over the sample period and the average real regional growth (1.25%), this is a significant contribution. For example, 3 times increase in container throughput in 12 years indicates that the annual contribution of container ports is a 0.67% point (=(300%^(1/12)-1)×0.07) increase in economic growth per annum.

On the other hand, the estimation results with port investment (x_3) are not reported in Table 4 due to overall weaker significance of the models including it. However, the 1-lag Granger causality tests among port investment, cargo and container throughputs (x_1 and x_2) in Table 6 indicate that port investment Granger-causes cargo and container throughput. This implies that port investment indirectly leads to economic growth, but its impact cannot be discerned in economic growth models with control variables such as Model 10.

Table 6
Granger causality tests: port investment, cargo and container throughput

Null Hypothesis (H_0):	p-value
Cargo throughput does not Granger Cause Container throughput	0.0007
Container throughput does not Granger Cause Cargo throughput	0.9973
Port investment does not Granger Cause Container throughput	0.0000
Container throughput does not Granger Cause Port investment	0.7087
Port investment does not Granger Cause Cargo throughput	0.0008
Cargo throughput does not Granger Cause Port investment	0.1928

In summary, the analysis of the impact of the port industry on regional economies of Korea shows:

(1) Cargo ports without sufficient throughput obstruct regional economic growth.

(2) Cargo ports contribute to regional economic growth only when they have sufficient throughput.

(3) Container port activities positively affect regional economic growth.

(4) Port investment indirectly leads to economic growth.

In conclusion, large scale investment in the port industry to increase cargo and container throughput of the regions is important to help regional economic growth.

5. Concluding remarks

It is broadly recognised that there are some academic contributions to uncovering the economic impact of ports on local regions. Although the previous literature mostly has analysed inter-industry effects, research approaching this topic from an augmented Solow model by directly linking the port and aggregated economic growth is still limited, especially in the context of Korea, where its port, shipping and shipbuilding activities are dynamically vibrant. This study contributes to filling this gap by estimating the effects of ports on their 16 corresponding provinces in Korea through a panel data econometric approach over the period 2000-2013. To the best of our knowledge, this research is the first exploration covering all Korean ports. This study may contribute to the better understanding of the role of ports in Korean economies, and provide port policy makers with valuable insights. The result of this study seems to support a neoclassical trade theory, in particular, the neoclassical port-city model (Fujita and Mori, 1996), arguing that the presence of a natural advantage such as deep seaport compared to the absence of that in land-locked countries facilitates the development of the regions via the use of the port, which results in better accessibility, reduced transport cost, inducing more trade and so on. The empirical finding discloses that ports are likely to improve their corresponding province's economy in Korea, which is consistent with prior port impact studies (Bottasso, 2014; 2013; Song and van Geenhuizen, 2014; Shan et al., 2014), but with obvious differences according to the port type and the amount of cargo throughput. These differences might be associated with differences in cargo activities, level of cargo throughput, phases of port development, and the level of dependence of the province on the port. In detail, our finding is the following: firstly, cargo ports without sufficient throughput obstruct regional economic growth; secondly, cargo ports contribute to regional economic growth only when they have sufficient throughput; thirdly, container port activities positively affect regional economic growth, and fourthly port investment indirectly leads to economic growth.

The first finding might be attributed to the different data settings with prior research. For example, much prior research excluded minor ports when their marginal contribution to the overall traffic was close to zero (Bottasso et al., 2014), or less than 3 million tons (Bottasso et al., 2013). This result is not surprising, because some studies suggested the presence of the port may not serve as an engine of local growth (Grabar 2008; Hall, 2004; Helling and Poister, 2000; Fujita and Mori, 1996). Deng et al. (2013) noted that the regional economy may be affected by environment, labour market, firm cost, transport network, and so on. Also some scholars pointed out that some small ports might have a negligible impact on the local economy (Bottasso et al., 2014; 2013). Additionally, this result is consistent with Ferrari et al.'s (2010) argument that the impact of the port on the local economy depends on the initial conditions, and it is not necessarily positive. This result may be associated with the port size as Acciaro (2008) noted. The ports with insufficient cargo throughput in this study are mostly small ports. Inevitably, it is difficult for them to achieve economies of scale due to the small size of port infrastructure and operations. Accordingly, their operation might be inefficient, which makes it difficult for the ports to achieve the cheap inputs or markets (Haddad et al., 2010). It may be noted from this result that the port policy makers are required to make an effort to create large ports instead of having multiple small ports, if they are keen to vitalise the corresponding regions' economies. This result raises an interesting question about the prominence of the ports with insufficient cargo throughput, and about opportunity costs. In regard to these provinces, port policy makers might re-consider the role of ports or not to depend heavily on port development as a device for economic reinforcement. In order to better understand the above result, we implemented an unornamented interview with a senior public officer at Ministry of Ocean and Fisheries in Korea. He commented that "Korean government have kept investing in port infrastructures in island regions and rural regions for better accessibility in sense of the public welfare, although those regions do not have sufficient cargo volume and large population. Sometimes, these regions' port investments are conducted in a public welfare-oriented way, aside from an economic way". This interview may provide us with a viable reason for the first result.

The second finding is statistically and economically significant: our estimation suggests that an increase of 1 log ton of cargo throughput in a non-container port tends to increase economic growth in the corresponding province by about 2.78%. Third, when it comes to the container ports, our result infers that an increase of 1% in container cargo results in an average of 0.07% increase in economic growth in the given provinces. Interestingly, the port policy makers may refer to this finding during port development (investment) decision-making that the non-container ports have a higher level of economic influence on the regions than the container ports in Korea when only considering the level of cargo throughput, even though the construction of the port needs a larger amount of capital than the non-container one. These findings are consistent with the prior studies arguing that the regional economy is largely influenced by the existence of the ports (Shan et al., 2014; Cohen and Monaco, 2008; Grobar, 2008; Musso et al., 2000). In addition, different levels of the role of ports according to different regions and port types are not surprising, as Ducruet and Lee (2006) noted that the impact would differ depending on the characteristics and contexts of ports and regions. In conclusion, in the context of Korea, it turns out that the container and cargo ports (with only sufficient cargo volume) are instructive for boosting the regional economies.

Finally, the result indicates that port investment has an indirect impact on the regional economies. It implies that the port investment positively exerts both cargo and container throughput. In turn, those throughputs may contribute to the regional economy. This result is in line with Deng et al.'s (2013) argument that port supply has an indirect impact on the regional economy possibly mediated by other variables. Our empirical analysis shows that port investment indirectly acts as a catalyst for the regional economy. Accordingly, port policy makers should note that when they determine the level of port investment in order to boost the regional economy, the port investment should be in conjunction with the current level or accurate forecast of cargo or container throughputs. If there is insufficient throughput, the port investment no longer boosts the local economy.

The above results may provide an awareness of the importance of ports, because this study firstly confirms the role of the port on its regional economy in Korea covering all ports. Port policy makers could use our results when they plan to implement port construction or expansion. Based on our results, it would be plausible that port policy makers in Korea could regard the port as a dominant development type of intervention so as to enable the port-cities to obtain greater economic growth, although how the ports generate external economics may not be readily visible to the general public (Chang, 1978). On the other hand, the use of the augmented Solow model provides the theoretical justification for the empirical models and confirms the above findings are robust even after considering the increasingly important role of human capital in economic development. This study can also help the future researchers who want to pursue the related research questions through empirical models supported by economic theories.

Notwithstanding this study's contributions, there is room for future research. First, it would be worthwhile if future study employs the socio-economic factors. For instance, how does the current port competition or the adoption of environmental-friendly logistics influence the port development? Second, this study was limited to investigating only Korea. Future study may assess the similar methodologies with the data of multiple countries such as Korea, Japan and China. Third, further research may take into consideration the characteristics of port governance or port localisation. Fourth, some islands or rural areas may attract many tourists through passenger ports, which may contribute to a region's economy. Accordingly, including the number of passengers or tourists would be interesting.

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