Modeling the Economic Impacts of Korean Unification*

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This paper explores the economic impacts of Korean unification on North and South Korea. It presents a new consistent database on macroeconomic, sectoral and trade data, and an input–output table for the North Korean economy, and then incorporates it in a global intertemporal multi-sector general equilibrium model. Assuming hypothetical scenarios such as North Korea's reform and gradual convergence, its sudden collapse and immediate unification, and chaos and crises in both Koreas, we quantify the consequences of Korean unification on economic activity, trade and capital flows in the two Koreas. The results highlight the importance of the unification processes and of alternative policy responses in both Koreas to the economic impacts of unification.

I. Introduction

There is significant uncertainty and concern about the current situation and prospects in the Korean Peninsula. Amid its economic hardship, North Korea launched its nuclear weapons program and is highly unlikely to denuclearize, at least in the immediate future, despite harsh sanctions by the USA and the United Nations. Looking into the economic and political future of North Korea is highly speculative at this moment. In the immediate future, no one would expect

any significant change in North Korea. The North Korean leaders will likely continue current policies, obstinately avoiding domestic reforms and developing nuclear weapons and long-range missiles. Although it is a slim possibility, North Korea could adopt serious market reforms and open up its economy, which could lead to gradual and peaceful unification. On the other hand, the North Korean regime may collapse, but it is hard to predict when and how this collapse would happen. No one expected the fall of the Berlin Wall and the German reunification or the end of the Vietnam War and the sudden unification of North and South Vietnam until they happened.

This study quantitatively assesses the impacts of Korean unification on North and South Korea and the rest of the world under three hypothetical scenarios, including (i) North Korea's reform and gradual convergence, (ii) North Korea's sudden collapse and immediate unification; and (iii) chaos and crises in North and South Korea. Regardless of the scenarios, Korean unification would have far-reaching political, economic and strategic consequences not only in the two Koreas but in neighboring economies in Asia and the Pacific.

There are many studies suggesting various views on the future of North Korea and consequences of Korean unification. One major branch of the literature constructs general equilibrium models for North Korea to simulate unification scenarios.[1] Noland et al. (2000) use a computable general equilibrium model to analyze economic integration between North and South Korea. They show that product market integration generates large welfare gains for North Korea, in contrast to only a trivial gain for South Korea. Bradford and Phillips (2005) and Bradford et al. (2011) construct a dynamic general equilibrium model to examine the impacts of economic reform and unification of North and South Korea. Their results suggest that the gains for North Korea in all scenarios are dramatic in the short run as well as in the long run. Funke and Strulik (2005) construct a two-region endogenous growth model in which the productivity is determined by productive public capital. They argue that with fiscal transfer from South to North Korea, the productivity level of North Korea can increase quickly, reducing its gap with that of South Korea. St. Brown et al. (2012) also build a growth model of productivity catchup, and show that the economic consequences of unification hinge critically on speed of productivity convergence, labor migration from North to South Korea, and capital flows from South to North Korea to South Korea.

The present study contributes to this line of literature with a particular focus on the linkages between the North Korean and South Korea economies and the world economy and the dynamics of adjustment to economic reform and unification, with various unification scenarios. We construct a new consistent database of macroeconomic, sectoral and trade data (including an input–output table) for

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1   Lee and McKibbin (2018) provide a complete review of the literature on estimating the economic impacts of Korean unification from an economic perspective.

the North Korean economy. It is then combined with South Korea and other economies in the world using the G-Cubed model of the world economy, which is a global dynamic stochastic general equilibrium model. The G-Cubed model considers an inter-industry input–output structure, factor movements, and dynamics of consumption and investment (McKibbin and Wilcoxen, 2013). The model also incorporates spillovers across the border through trade and financial linkages. Using this model, we explore what would happen in the two Koreas if Korean unification occurs. Assuming three different scenarios, this paper quantifies the consequences of Korean unification on economic activity, trade and capital flows in the two Koreas.

Use of a dynamic multi-sector global economy model in this paper where a new database for the North Korean economy is incorporated contributes to the literature in several aspects. First, it helps to analyze more thoroughly the process and impact of Korean economic integration and unification. Whether the unification is gradual or sudden would have different economic impacts on South and North Korean economies. When the unification process is gradual along an anticipated path, for example, South Korea will have more time to construct better policies and more financial resources to reduce the unification costs and to mitigate the adverse effects of unification. In contrast, a military conflict or political risk in North Korea is likely to augment the fiscal burden of South Korea and the uncertainty and risk in the Korean peninsula and Northeast Asia. Our approach allows assessing the impacts of these different scenarios on trade and investment relations among North Korea, South Korea and neighbors such as China and Japan.

Second, by building a new macroeconomic and sectoral database including a 6-sector input–output table for North Korea, the paper allows analysis of the impacts of sectoral productivity changes and inter-industry resource allocation in North Korea under different unification scenarios. The productivity levels and growth rates vary across sectors in North Korea. If North Korea adopts serious market reforms and opens up, it would have more trade and financial transactions with South Korea and the rest of the world. The patterns of structural change and economic growth of the North Korean economy will depend on its natural comparative advantage but also the sectoral adjustment to international integration. In addition, an industrial policy that aims to promote mining or manufacturing industries with comparative advantage could be an option for North Korea during the process of reform and unification. The multi-sector analysis using the input–output table enables exploration of the impact of industrial policy.

There are many other issues that the research in this paper can be used to explore, including the role of different policies and institutions on short-run adjustment, and the role of different exchange rate regimes, fiscal institutions, monetary and wage policies of North and South Korea during the unification process. While this paper focuses on analyzing the effects of the different unification scenarios on both Koreas, the unification process will have significant spillovers to the neighboring economies in Asia and the Pacific. These will be the focus of a series of future papers.

The organization of this paper is as follows. Section II describes the North Korean economy and constructs a new input–output table for North Korea. Section III shows our simulation of the effects of the unification, including the model, scenarios and simulation results. We conclude in Section IV.

## II. Growth and Structural Change of North Korean Economy

In this section, we describe the North Korean economy from the perspectives of economic growth, trade openness, economic policy and industrial structure, in comparison with South Korea. We then illustrate how we construct a new input–output (IO) table for North Korea in 2014.

II.1   Economic growth, trade openness and industrial structure

Since the political division of the Korean Peninsula in 1948, North Korea adopted a centrally planned economic system, while South Korea followed a market-based system. Half a century later, the two different roads have led to an enormous disparity between the two economies. In the 1950s North Korea had a similar level of GDP per capita to South Korea, but their gap has been remarkably widened over time. The Bank of Korea estimates that North Korea's per-capita income, at US$1200, was less than 5 percent of South Korea's in 2015.[2]

This wide divergence was attributed not only to the rapid growth of the South Korean economy but also to the stagnation and crisis in the North Korean economy. It is estimated that the North Korean economy nearly halved in the 1990s due to both domestic and external changes (see Figure 1). The external economic assistance from the former Soviet Union and China was important for the North Korean economy. The collapse of the Soviet Union and China's demand for trade settlement in hard currency significantly undermined the North Korean economy. On the domestic side, North Korea suffered a series of natural disasters in the mid-1990s but maintained its defense spending as high as approximately 25 percent of its GDP (Wolf and Akramov 2005). All these adverse factors contributed to a severe contraction in the economy given its rigid economic system. The Bank of Korea estimates that the aggregate economy of North Korea shrank at an annual rate of −0.5 percent over the period of 1990–2014. The economy performed very badly in the 1990s, with an average GDP growth rate of −4.6 percent in 1990–1995 and −1.0 percent in

2   There are other sources that report the North Korean statistics. For example, the United Nations Statistical Division (https://unstats.un.org/) reports estimates of North Korean national accounts data. However, most of the recent estimates by the UN are constructed using the Bank of Korea's estimates as raw data. The UN estimates the North Korean per-capita gross national income at US$652US in 2015, which is far smaller than the Bank of Korea's estimate. The Central Intelligence Agency (2018) also provides estimates for the North Korean economic data. It estimates North Korea's per-capita GDP in 2015 at US$1700, a higher value than the Bank of Korea's estimate.

Figure 1   Real GDP of North Korea (trillion South Korean won)
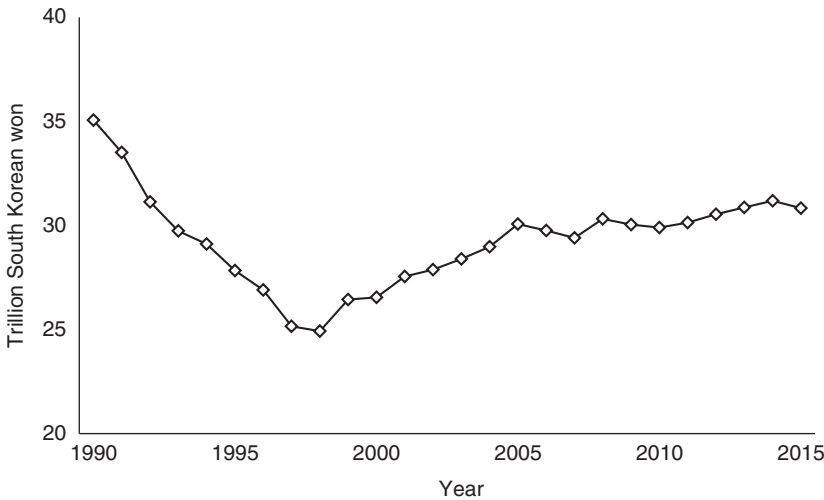
Source: Bank of Korea, Economic Statistics System

1995–2000. The North Korean economy performed better after 2000. It grew at an annual rate of 1.3 percent over the 2000s and 1.1 percent over 2010–2014.

At the sectoral level, the agriculture and government sectors are the two largest sectors of North Korea. Since the 2000s, agriculture has accounted for 20–30 percent of GDP, and government services for 20–25 percent of GDP (see Figure 2). In 2014, services amounted to 31.3 percent of the whole economy. Government services (22.7 percent) comprised a much larger share than other market services (8.6 percent). Agriculture, forestry and fishing and manufacturing had similar shares in aggregate nominal GDP: 21.8 and 21.3 percent, respectively.

In the initial stages after the Korean War, North Korea followed the Soviet Union model with the ideology of self-reliance, and its economic development was dominated by industrialization, especially in heavy industry. The share of heavy manufacturing was above 25 percent in 1990 and thereafter declined sharply following the economic trouble starting in the early 1990s. While the agriculture and service sectors grew slightly, all other sectors contracted over the period of 1990–2014 according to the Bank of Korea's estimates. In particular, the heavy manufacturing industries contracted, with an average growth rate of −8.5 percent per year over the 1990s.

Table 1 presents the number of workers by industry and the employment share of each industry of North Korea in 2008.[3] Agriculture had the biggest

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3   The number of workers over age 16 by economic activities in North Korea comes from the North Korea Statistics of Korea National Statistical Office in South Korea. The data was originally constructed by the United Nations Population Funds (UNFPA). North Korea conducted a population census with the assistance of UNFPA in 1993 and 2008.

Figure 2   Industrial structure of North Korea (%)
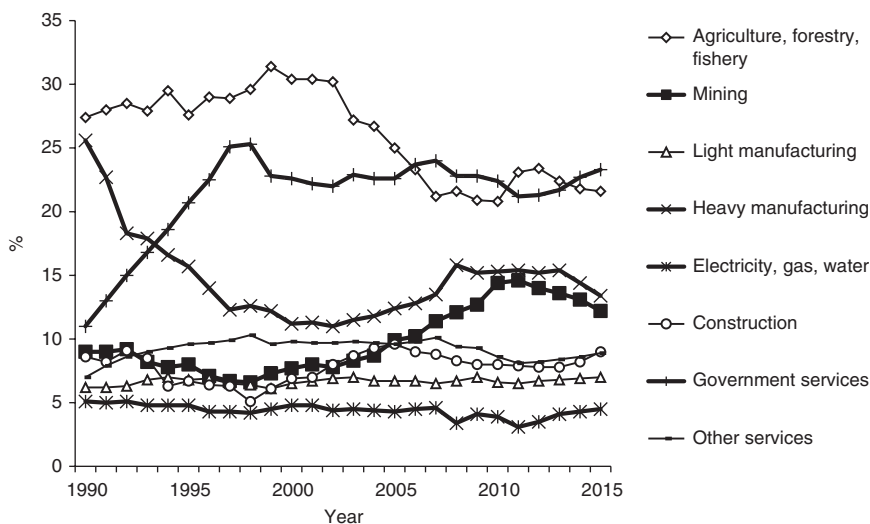
share of employment, with 36 percent of total workers. The share of the service sector (29.7 percent) in employment was larger than that of manufacturing (23.7 percent). With respect to the sectoral shares in employment, the economic structure of North Korea in 2008 was similar to that of South Korea in the late 1970s. In 1978, the employment shares of agriculture, manufacturing and services of South Korean were 38.4, 22.3 and 38.5 percent, respectively.

In 2008, the aggregate labor productivity of North Korea was 2.49 million won per worker. The labor productivity of agriculture was quite low at 1.46 million won in 2008, even though the share of agriculture in employment was the highest. Another sector that had a high employment share but low labor productivity was manufacturing. Its employment share was 23.7 percent but its labor productivity was 2.35 million won. However, in manufacturing, the labor productivity of heavy industry was 3.04 million won, which was higher than the aggregate labor productivity. The service sector had similar labor productivity to the aggregate economy, but it was mainly driven government services. In the North Korean economy, mining, electricity, gas and water supply, and construction had higher labor productivities than other sectors.

For comparison, Table 2 presents the sectoral labor productivity of South Korea in 2008, and the ratio of sectoral labor productivity between South and North Korea. In 2008, the aggregate labor productivity of South Korea was 45.2 million won which was approximately 18 times larger than that of North Korea. The labor productivities of all sectors of South Korea were much larger than those of North Korea, ranging from 5.1 times in construction to 33.4 times in manufacturing.

Table 1   North Korea's industrial employment and labor productivity in 2008

Industry	Number of workers	Industrial shares in employment (%)	Real GDP (billion won)	Labor productivity (million won)
Agriculture, forestry and fishing	4 386 895	36.0	6425.8	1.46
Mining and industry	3 601 177	29.6	11 133.4	3.09
Mining and quarrying	718 195	5.9	4346.2	6.05
Manufacturing	2 882 982	23.7	6776.2	2.35
Light industry	1 323 366	10.9	2030.1	1.53
Heavy industry	1 559 616	12.8	4744.8	3.04
Electricity, gas and water supply	216 282	1.8	1170.6	5.41
Construction	367 650	3.0	2368.3	6.44
Services	3 612 716	29.6	9217.7	2.55
Government	2 405 770	19.7	6636.1	2.76
Others	1 206 946	9.9	2580.2	2.14
Aggregate economy	12 184 720	100	30 297.0	2.49

North Korea's GDP is estimated in terms of South Korean won. Light Industry includes food products, salt, beverages, tobacco, textiles, wearing apparel, leather and related products, wood and of products of wood and cork, except furniture, paper and paper products, printing and reproduction of recorded media, furniture, living necessities products, other manufacturing, and repair and installation of machinery and equipment
Source: Bank of Korea, Economic Statistics System (http://ecos.bok.or.kr) for real GDP and Korea Statistical Office, North Korea Statistics (http://kosis.kr/bukhan/index.jsp) for number of workers

The North Korean economy is one of the most internationally isolated economies in the world, with very limited trade with a small number of trading partners. South Korean trade was approximately 30 times more than that of North Korea in 1990 and this ratio exploded to more than 150 times in 2015. North Korea experienced a notable decline in international trade in the 1990s due to the collapse of the Soviet Union and the reduction of Chinese exports to North Korea, but this recovered in the 2000s, especially in the late 2000s (see Figure 3), with much of the export growth being with China. China and South Korea dominate the small group of North Korea's trading partners, accounting for more than 90 percent of its international trade in 2015. Mining, and fabrics and wood in the non-durable manufacturing sector are the major exporting sectors, while metal, electronics and plastics in the manufacturing sector are the major importing sectors. Trade between North Korea and South Korea increased markedly in the late 1990s when South Korea's Sunshine Policy warmed up their relationship (see Figure 4).

North Korea has kept the centrally planned socialist command system while other socialist countries have followed a process of marketization to reduce the inefficiency in their economies. In North Korea, there has been some expansion of the private market since the centrally planned command system failed to

Table 2   South Korea's sectoral labor productivity in 2008

Industry	*South Korea in 2008*				
	Number of workers (thousands)	*Industrial Shares in employment (%)*	*Real GDP (billion won)*	*Labor productivity (million won)*	*Ratio of North Korean labor productivity to South Korea (%)*
Agriculture, forestry and fishing	1686	8.6	28 646.6	17.0	8.6
Mining and industry	3986	3.9	313 517.8	78.7	3.9
Mining and quarrying	23	5.7	2462.1	107.0	5.7
Manufacturing	3963	3.0	311 055.7	78.5	3.0
Electricity, gas and water supply	156	3.7	23 063.9	147.8	3.7
Construction	1812	19.6	59 503.8	32.8	19.6
Services	15 938	6.3	640 431.3	40.2	6.3
Government services	7078	7.0	278 132.5	39.3	7.0
Other services	8860	5.2	362 348.8	40.9	5.2
Aggregate economy	23 577	5.5	1 065 183.3	45.2	5.5

Industry classification is fitted to North Korean case by the authors. The North Korean labor productivity level of each sector comes from Table 1

Source: Bank of Korea, Economic Statistics System (http://ecos.bok.or.kr)

overcome the food crisis in the 1990s. Thus, there exists a dual economic system in North Korea, which has centrally planned official as well as a marketized private component. According to Choi (2016), the informal (marketized) economy is estimated to constitute approximately 28.5 percent of the final demand of North Korea.

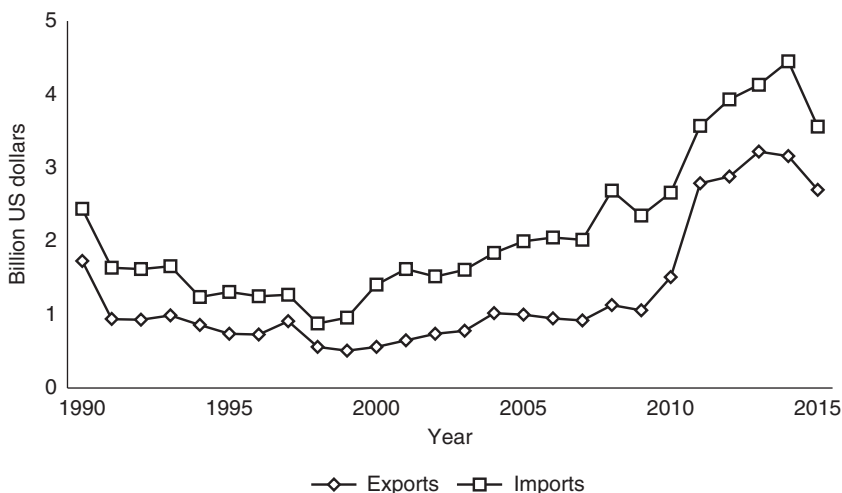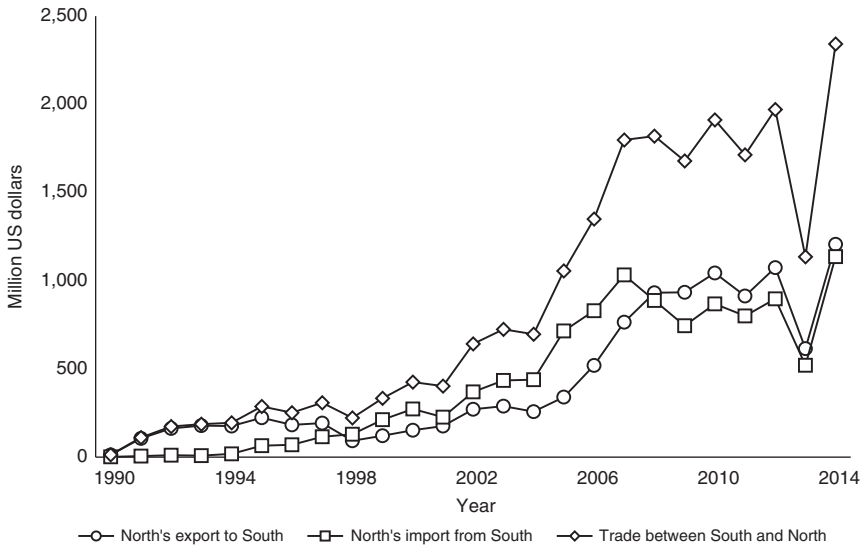**Figure 3   Exports and imports of North Korea (Billion US dollars)**

Figure 4   Trade between South Korea and North Korea (Million US dollars)

Source: Korea Statistical Office, North Korea Statistics

To maintain the centrally planned economy, the North Korean Government budget was large until the 1980s. During the economic crisis in the 1990s, North Korea suffered from severe budget deficits, and it tried to reduce fiscal expenditure. According to the estimates by the U.S. Department of State (2015), the military expenditures of North Korea amounted to 22 percent of GDP in 2012, contrasting with only 2.7 percent of GDP in South Korea.

Because North Korea is a centrally planned economy, all economic decisions, such as those relating to prices, interest rates, production, investment and financing, are made by the government, so monetary policy that aims at economic growth or price stabilization is not required at all.[4] However, the government uses 'the currency control work', which eliminates the discordance of money in the economy through the central bank adjusting money supply, to facilitate currency circulation and to stabilize the currency value.

The exchange rate of North Korea is also controlled by the government. There are three types of exchange rates: the official exchange rate; the trade exchange rate; and the non-trade exchange rate. The official exchange rate is used when the aggregate economic indicators are converted into foreign currencies. The non-trade exchange rate is applied to money exchange and financial transactions of tourists. The trade exchange rate is used in international trade settlement. It is frequently adjusted by the government and represents the exchange rate of

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4   For details of the monetary policy, the central bank and the exchange rate policy in North Korea, refer to Lee (2012) and Cho (2015).

North Korea. In addition, there is an exchange rate in the black market. Since the economic reforms in July 2002, the government devaluated the official exchange rate with the market exchange rate as the benchmark, from 2.2 to 152.5 won per US dollar. After this devaluation, the official exchange rate was relatively stable, while the market exchange rate continued to devaluate, with the market exchange rate approximately 20 times the official exchange rate over the past decade (Lee, 2012).

II.2   Input–output table

An IO table is an economic tool that systemically and completely presents the sales and purchase relationships between sectors in a country for a specific time period following specific rules and formats. In this section we introduce IO tables that have been constructed by previous studies and then construct a new IO table for North Korea for the year 2014.

Choi (2014) establishes North Korea's IO table for 2011. The IO table divides the North Korean economy into 7 industries matched to the industry classification of the Economic Statistics System of the Bank of Korea. Shin (2009) constructs an IO table for North Korea for 2009 with 11 industries. Both Choi (2014) and Shin (2009) apply the cross-entropy minimization method to estimate North Korean IO tables. To use the cross-entropy minimization (Robinson et al., 1998), the benchmark IO coefficient matrix is required. Choi (2014) uses Vietnam's 2000 input coefficient matrix assuming that the North Korean economy in 2011 was similar to the Vietnamese economy in 2000. In contrast, Shin (2009) uses East Germany's input coefficient matrix, assuming that the North Korean economy in 2007 was similar to East Germany's around unification time.

Estimation of a new input–output table

We use the cross-entropy minimization method to construct a new North Korean input coefficient matrix that is not only close to the benchmark input coefficient matrix by minimizing a cross-entropy of the difference between the new and the benchmark matrix but also satisfies all constraints imposed by the IO table.

Because of the scarcity of North Korean data, all previous studies assume that the IO structures under the centrally planned systems are similar, and then use the IO tables of other former socialist countries for North Korea. Shin (2009) estimates a North Korean 2007 IO table using an East German IO table around the time of unification as a benchmark coefficient matrix. However, the current North Korean economy is clearly different from the East German economy around the time of unification. Around the time of unification East Germany was much more developed than North Korea nowadays. Compared to North Korea in 2014, East Germany in 1991 had a much smaller agriculture sector and a much bigger service sector.

Choi (2014) uses Vietnam's 2000 I/O table as a benchmark input coefficient matrix to estimate North Korea's 2011 IO table, and also uses other information, including North Korea's sectoral outputs, exports and imports in 2011. We also use a Vietnamese IO table as the benchmark information but assume that the current North Korean economy is more similar to the Vietnamese economy in 2011 than in 2000. The per capita income of North Korea in 2014 was more similar to that of Vietnam in 2011 than in 2000. Table 3 shows that the industrial structure of Vietnam in 2011 was similar to that of North Korea in 2014. Therefore, it is more reasonable to use the Vietnam 2011 IO table as the benchmark rather than the Vietnam 2000 IO table. We use the IO table for Vietnam in 2011 collected from the OECD STAN database as prior information for the North Korean IO table.

Choi (2016) uses the South Korean IO table in 1975 as prior information to estimate the North Korean IO table, assuming that the main features of the input–output structure of the North Korean economy are close to those of the South Korean economy in the 1970s. However, this assumption is not well justified because South Korea had grown rapidly since the 1960s under the market economy. According to World Bank data, the shares of agriculture, manufacturing and services in South Korean GDP were, on average, 24, 19 and 47 percent, respectively, in the 1970s. Thus, the industrial structure of North Korea in 2014 is more similar to that of Vietnam's in 2011 than South Korea's in 1970. In addition, between Vietnam and North Korea we observe similarity in the industrial share in total trade as well (Table 4). In North Korea in 2014, agriculture comprised almost 10 percent and manufacturing approximately 65 percent of total trade. The shares of agriculture and manufacturing in Vietnamese 2011 trade were 5 and 68 percent. In contrast, those shares in South Korean trade in 1970 were 22 and 65 percent. In 1970, South Korea had a much bigger trade share in agriculture than the current North Korea. We judge that it is a reasonable assumption to use Vietnamese economy as a benchmark for North Korea.

ECOS of the Bank of Korea reports North Korea's sectoral GDP up to 2015. We obtained North Korea's sectoral export and import data up to 2014 from the Korea Trade-Investment Promotion Agency (KOTRA) and North Korea's

Table 3   Industrial structure of North Korea and Vietnam in 2000, 2011 and 2014

Industry	North Korea (% of GDP)			Vietnam (% of gross value added)		
	2000	2011	2014	2000	2011	2014
Agriculture, hunting, forestry, fishing	30.4	23.1	21.8	24.1	18.0	16.7
Mining, manufacturing, utilities	30.2	39.6	38.7	32.6	35.2	35.9
Manufacturing	17.7	21.9	21.3	16.3	24.5	25.7
Construction	6.9	7.9	8.2	5.3	6.6	6.6
Services	32.5	29.4	31.3	37.4	40.5	41.3

Source: Bank of Korea for North Korea and United Nations Statistics Division for Vietnam

Industry	North Korea	Vietnam	South Korea	
	2014	2011	1970	1975
Agriculture	9.9	4.7	21.9	17.8
Manufacturing	65.4	68.6	64.5	63.2
Services	0.0	20.8	7.4	8.1

Source: KOTRA (North Korea), OECD STAN database (Vietnam) and Bank of Korea (South Korea)

Government budget size up to 2014 from the Korean Statistical Information Service (KOSIS). ECOS of the Bank of Korea reports North Korean nominal and real GDP by sector in South Korean won. We calculate the total sectoral output for North Korea by dividing the North Korean sectoral GDP by the Vietnamese sectoral value-added coefficients.

Because data for consumption, investment and government expenditure for North Korea is not available, we need to make some assumptions about them. We use data for the government budget size of North Korea as a proxy for the government expenditure. We use the shares of consumption and investment in GDP of the Vietnamese economy in 2011 for North Korea. We also use the sectoral shares of consumption, investment and government expenditures of Vietnam in 2011 for North Korea but adjust those shares to satisfy the constraint that the aggregate value added is equal to the total expenditure of national income.

Results of North Korean new input–output table

As mentioned above, to apply the cross-entropy minimization method, we use the Vietnamese input coefficient matrix for 2011 as prior information. In this matrix, the sectoral shares of the intermediate demand, exports and imports come from the OECD STAN database and the data for the remaining exogenous part comes from GTAP 9 because the IO table in the OECD STAN database does not report government expenditure. The cross-entropy minimization method produces a new input coefficient matrix for North Korea (Table 5). Table 6 shows the new IO table of North Korea in 2014 that we construct by using the new input coefficient matrix and all sectoral output and aggregate data for the exogenous part.[5]

5   When the new input coefficient matrix of North Korea 2014 in Table 4 is compared with the Vietnamese 2011 input matrix, the input structure of North Korea is similar to that of the Vietnamese economy, but North Korea uses less energy input and services input than Vietnam in producing the durable manufacturing goods. In the exogenous part, the shares of the energy, mining and agriculture sectors in private consumption (C), investment (I) and total exports (X) of North Korea have larger shares than those of Vietnam in 2011.

Table 5 Input coefficient matrix of North Korea in 2014

	Energy	Mining	Agriculture	Durable manufacturing	Non-durable manufacturing	Services	C	I	G	X	M
Energy	0.0477	0.0046	0.0039	0.0036	0.0094	0.0144	0.0350	0.0443	0.0002	0.2701	0.1348
Mining	0.1443	0.1713	0.0043	0.0577	0.0771	0.0103	0.0697	0.0624	0.0066	0.0939	0.0203
Agri.	0.0002	0.0001	0.2930	0.0078	0.2149	0.0660	0.3465	0.0862	0.0271	0.0679	0.1229
Durable manufacturing	0.0393	0.0724	0.0131	0.6238	0.0356	0.0852	0.1233	0.6971	0.0394	0.2100	0.3551
Non-durable manufacturing	0.0240	0.0080	0.1034	0.0930	0.3659	0.1106	0.1286	0.0104	0.0109	0.3580	0.3668
Services	0.0546	0.0501	0.0551	0.0543	0.1114	0.1440	0.2970	0.0997	0.9158	0	0
Labor	0.3276	0.3296	0.1583	0.0867	0.0844	0.2900					
Capital	0.3623	0.3639	0.3690	0.0731	0.1013	0.2794					
Sum	1	1	1	1	1	1	1	1	1	1	1

Source: Author's calculation

Table 6 New input–output table of North Korea in 2014 (millions, USD)

	Energy	Mining	Agriculture	Durable manufacturing	Non-durable manufacturing	Services	Total intermediate demand	C	I	G	X	Total final demand	M	Total output
Energy	103.1	30.4	57.3	114.1	122.7	278.3	705.8	519.9	507.4	1.7	1180.7	2209.7	−752.8	2162.7
Mining	312.0	1137.7	62.3	1826.4	1010.8	198.2	4547.4	1036.1	714.6	46.7	410.4	2207.7	−113.5	6641.6
Agriculture	0.4	0.7	4260.9	247.9	2816.6	1273.3	8599.8	5152.4	987.0	192.9	296.7	6629.1	−686.3	14 542.6
Durable manufacturing	85.0	480.8	190.6	19 728.7	466.7	1642.6	22 594.5	1833.5	7984.3	280.8	918.1	11 016.7	−1982.3	31 629.0
Non-durable manufacturing	51.9	53.2	1503.2	2941.1	4795.7	2133.8	11 478.8	1913.0	119.3	77.3	1564.9	3674.5	−2047.9	13 105.4
Services	118.2	332.5	800.6	1718.4	1459.5	2776.3	7205.5	4416.6	1141.6	6520.6	0.0	12 078.8	0.0	19 284.2
Total intermediate input	670.5	2035.3	6875.0	26 576.4	10 672.0	8302.6	55 131.8	14 871.4	11 454.2	7120.0	4370.9	37 816.5	−5582.7	87 365.6
Labor	708.6	2189.3	2301.7	2741.5	1105.5	5593.1	14 639.7							
Capital	783.6	2417.1	5365.8	2311.0	1327.9	5388.6	17 594.1							
Value added	1492.2	4606.4	7667.6	5052.5	2433.4	10 981.7	32 233.8							
Total input	2162.7	6641.6	14 542.6	31 629.0	13 105.4	19 284.3	87 365.6							

Source: Author's calculation

Table 7 Economies and regions in the G-Cubed model

USA	*North Korea (PRK)*
Japan	China
Australia	India
Europe	Eastern Europe the former Soviet Union
Republic of Korea (KOR)	Oil exporting developing countries
Rest of OECD	Rest of the world

Table 5 shows that approximately 92 percent of the government expenditure is used for the final demand for the service sector. Because the service sector contains government services, it implies that the government expenditure for government services takes most of the final demand for government services. When we divide services into government services and other services, government expenditure for government services is approximately 90 percent of the total government expenditure. This implies that the government purchases almost all the final services produced by the government using other sectors' inputs, labor and capital, so we reallocate the final demand for government services across the other sectors, labor compensation and capital compensation. After the reallocation of government services, the shares of durable manufacturing, nondurable manufacturing and services in final demand of the government expenditure (G) are 14, 12 and 14 percent, respectively. The shares of each of the three sectors are less than 5 percent. In the final demand of the government expenditure, the labor share is 31 percent and the capital share is 23 percent.[6]

III.   Simulation of the Consequences of Unification

We incorporate North Korea into the G-Cubed model, which is an intertemporal general equilibrium model of the world economy. The main features of the G-Cubed model are outlined in McKibbin and Wilcoxen (2013). A number of studies have used the G-Cubed model (or its precursor, the McKibbin-Sachs Global Model) to assess a range of issues including German unification in the early 1990s (McKibbin 1990; Gagnon, et al., 1996).

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6   Considering that most government services such as defense, education and public administration are produced and supplied by labor, we assume that expenditure on labor takes the biggest share in government expenditure. However, it may not be easy to estimate the reasonable shares because of the lack of the reliable data. Some articles report wages in the government sector are lower than that in mining and manufacturing sectors. Because the North Korean Government has underestimated military expenditure, wage costs for military might be underestimated too. There is a possibility that the labor share, 31 percent, is underestimated.

III.1 The model

The model is based on a combination of explicit intertemporal optimization by the agents (consumers and firms) in each economy and rule of thumb behavior. In contrast to static computable general equilibrium (CGE) models, time and dynamics are of fundamental importance in the G-Cubed model. The G-Cubed model is known as a dynamic stochastic general equilibrium (DSGE) model in the macroeconomics literature and as an intertemporal general equilibrium (IGE) model in the CGE literature. The main difference from the small-scale DSGE models now popular at central banks is the large amount of sectoral disaggregation and the considerable degree of economy disaggregation.

To replicate the macro time series, the behavior of agents is modified to allow for short-run deviations from optimal behavior either due to myopia or to restrictions on the ability of households and firms to borrow at the risk-free bond rate on government debt. Thus, aggregate consumption is a weighted average of consumption based on wealth (current asset valuation and expected future after-tax labor income) and consumption based on current disposable income. Once the level of overall consumption has been determined, spending is allocated among goods and services according to a two-tier constant elasticity of substitution (CES) utility function. Similarly, aggregate investment is a weighted average of investment based on Tobin's Q (a market valuation of the expected future change in the marginal product of capital relative to the cost) and investment based on a backward-looking version of Q. The model allows for short-run nominal wage rigidity (by different degrees in different economies) and, therefore, allows for significant periods of unemployment depending on the labor market institutions in each economy. Equilibrium between aggregate demand and aggregate output is maintained with flexible prices, which causes demand to adjust together with short-term supply. There is explicit treatment of the holding of financial assets, including money.

Global accounting identities are imposed on the model so, for example, for every borrower there is a lender. Likewise, the model gives a careful modeling of stock-flow relations, such as the accumulation of current account deficits into foreign claims on domestic output, which have to be serviced by future trade surpluses. On the fiscal side, the accumulation of fiscal deficits into government debt has to be serviced from future revenues, although it does not have to be completely paid off.

The model distinguishes between the stickiness of physical capital within sectors and within economies, and the flexibility of financial capital, which immediately flows to where expected returns are highest. This important distinction leads to a critical difference between the quantity of physical capital that is available at any time to produce goods and services, and the valuation of that capital as a result of decisions about the allocation of financial capital.

The G-Cubed model embodies a wide range of assumptions about individual behavior and empirical regularities in a general equilibrium framework.

The interdependencies are solved out using a computer algorithm that solves for the rational expectations equilibrium of the global economy. In the version of the model used here there are 12 economies and regions as set out in Table 12. Each economy has six sectors (energy, mining, agriculture, manufacturing durables, manufacturing non-durables and services) as well as a generic capital-producing sector in each economy that draws largely on the durable manufacturing sector for inputs.

Applying this modeling framework to a country like North Korea under various scenarios requires a number of choices to be made. An economic model is made up of several key parts. The first is data. The section above describes the database that has been constructed for this project. The second is the identities of the model, both static and intertemporal. It is assumed that these hold in each country, including in North Korea. The third is how to model the decisions of households, firms and governments and how each agent interacts within markets for inputs and outputs. This latter choice is obviously problematic for a country like North Korea. The choice we make is to model North Korea as if there are shadow markets determining shadow prices and agents make decisions based on these shadow prices. The results of this study clearly depend on the data, which is extremely unreliable, and the modeling assumptions, which are highly speculative. We acknowledge this problem but point to the valuable insights from the early modeling papers on German unification summarized in Gagnon et al. (1996), which made similar assumptions about East Germany. The argument is that the specific details of a scenario will be affected by the model assumptions, but the big picture results largely driven by the identities and assumptions of the scenario design will be useful for understanding some of the major issues in Korean unification.

III.2   Unification scenarios

There are clearly a very large number of alternative scenarios that the model developed in this paper could be used to analyze. We choose to present some illustrative scenarios to understand a number of major issues.

Status quo

The first scenario is our 'status quo' scenario. In this case there is no collapse of North Korea. Existing barriers to the flows of people and capital into and out of North Korea are maintained. There is slow technological change of 0.5 percent per year in North Korea and the main driver of growth is the supply of labor generated from the UN mid-term fertility population projections and capital investment by the public and private sector.

The average GDP growth rate maintains approximately 1.0 percent for the initial period but declines over time as the population growth rate declines. There is a central bank in North Korea managing inflation and unemployment and a

fiscal authority setting spending targets and raising revenue from taxing companies and households.

Reform and gradual convergence

This is the case where North Korea follows a similar path to China in gradually opening to the world economy through market-oriented economic reform. This process can be accompanied by gradual unification between the two Koreas. Although this may seem highly unlikely, it does provide a benchmark for what might be possible in North Korea given initial conditions in 2017 and given the empirical evidence from other countries entering the global economy after a period of isolation. We call this scenario 'reform and gradual convergence'. The convergence (or conditional convergence) theory indicates that when other conditions are controlled, a country with a low level of initial per-capita output will have a higher growth rate than a country that has a higher level of per-capita output. A country with a significant gap with its potential per-capita output would be able to begin a rapid 'catching-up' process through high rates of physical and human capital accumulation, owing to higher rates of return to investment and technology diffusion and imitation of more technologically advanced economies.

The assumption is that given the initial gaps between the labor productivity of each sector in North Korea and the equivalent sector in the USA, reform increases the rate of catchup from 0 in 2017, rising by 0.1 percent per year in 2018 and 2019 and then 0.05 percent per year until the catchup rate reaches 2.0 percent by 2055. That is, the labor productivity gap between North Korea and the USA closes by 2 percent per year after 2055.[7] The gap in the level of productivity will still be very large but the rate of growth of productivity will be high enough to close the gap by 2 percent per year. This is the empirical 'Barro Catchup Rate'. The 2-percent catchup rate in 2055 indicates that North Korea can adopt policies and reforms over many years that can gradually improve its steady-state potential level of productivity to that of the USA.

We assume that this gradual reform scenario can be combined with the integration and cooperation between North and South Korea, which may accompany peaceful unification. Specifically, South Korea can provide North Korea with substantial financial aid. We assume there are fiscal transfers from South Korea to North Korea of 1.5 percent of South Korea's GDP or 60 percent of North Korea's initial level of GDP every year. These transfers are gradually phased in at 25 percent (i.e. 15 percent of North Korea's GDP) in 2017, 50 percent in 2018, 75 percent in 2019 and then fully implemented from 2020. This amounts to almost double that for the case of German unification, where the transfers

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7   Previous studies, such as Funke and Strulik (2005) and St. Brown et al. (2012), assume faster speed of convergence of North Korea's productivity to South Korea's when the two Koreas integrate. They assume significantly larger capital transfers from North Korea to South Korea or technology transfers.

were 40 percent of East German GDP, although it was only half of 4 percent of West German GDP. The transfers are ended in 2043 (25 years later). We assume that of this transfer the proportion used to support private consumption is 0.5 in 2017 and rising by 0.1 per year to be the entire transfer by 2022. The remainder of the transfer goes to government spending in North Korea.

Managed chaos in North Korea

In the third scenario, we assume that North Korea collapses and there is immediate unification between North and South Korea. The details matter for this scenario and there are many different assumptions that could be made and explored. In particular, we assume:

1. As the economy collapses, 20 percent of physical capital stock in all North Korean sectors becomes obsolete immediately in 2017. Labor productivity also falls by 20 percent in 2017. Although arbitrary in size, this generates an approximately equivalent collapse in the value of capital in East Germany once the Berlin wall had fallen.
2. There are larger fiscal transfers from South Korea to North Korea compared to the convergence scenario. These are 0.5 percent of South Korea's GDP in 2017, 1 percent in 2018, 1.5 percent in 2019 and 2 percent in 2020. These are 20 percent of North Korea's initial GDP in 2017, 40 percent in 2018, 60 percent in 2019 and 80 percent from 2020.
3. There are migrants moving from North to South Korea every year equal to 0.5 percent of the North Korean population or 0.25 percent of South Korea's population. This is scaled to the East German case. The migration occurs for 15 years and then stops.
4. Economic reforms begin to be implemented and the convergence process starts slowly in the first few years but thereafter accelerates at a faster pace than in the gradual convergence. We assume that the catchup rate rises from 0.2 percent in 2017 to 0.4 percent in 2018 and by 0.2 percent per year until the Barro rate of 2 percent per year is reached in 2026.

It is important to note that although unification occurs, we keep the monetary and fiscal authorities separate in the two economies and manage the flow of capital and labor between North and South Korea. Thus, it is not a full unification scenario across all institutions.

Chaos in North Korea and crisis of confidence in South Korea

The final scenario is a modification of the Chaos scenario. The reform process in North Korea is delayed by 5 years (i.e. reforms begin in 2022, 5 years after the collapse). In addition, there is a loss of confidence in the ability of the South Korea government to manage the unification. This is modeled as a sharp jump in the country risk premium of South Korea of 1000 basis points (10 percentage

points) in 2017 followed by a gradual decline by 100 basis points per year to zero by 2027. The initial jump is of a similar magnitude to that during the Asian financial crisis in 1997/1998. The fiscal transfers from South Korea to North Korea and the migrants moving from North to South Korea are assumed to be the same as in the managed chaos case.

III.3   Simulation results

Status quo

We first generate a baseline of the model following the approach in McKibbin et al. (2007). We make assumptions about the level of productivity in each sector in each country relative to the USA and the rate at which sectors catch up to the technical frontier of the USA. This generates a projection of productivity growth by sector by country out to 2100. We combine this with the UN population projections (mid-term fertility) to generate the two exogenous drivers of economic growth in the model. We also make assumptions about tax rates, fiscal rules and monetary rules to generate a baseline projection of the global economy from 2015 to 2100. We adjust the model so that the dynamic equations generate 2015 as the equilibrium of the model consistent with dynamic adjustment towards a steady state in the long distant future and consistent with firms and households having a degree of rational expectations. Capital accumulation and human capital are endogenously determined by the model; thus the rate of economic growth is driven by population, productivity growth and sector-specific capital accumulation, which varies across sectors, across countries and across time.

In this status quo scenario, there are exogenous technological changes, demographic changes and endogenous capital response to these changes. There are a large number of results for the global economy and the two Koreas. To provide an idea of the growth implications in the status quo scenario, Figure 5 shows the average productivity plus population assumptions built into the scenario for four of the countries in the model: the USA, China, South Korea and North Korea. As can be seen from Figure 5, there is strong exogenous growth in China (mostly productivity), South Korea (productivity and demographics), and North Korea (mostly demographics). These are not the growth rates generated by the model but summarize the exogenous drivers of growth. Overall growth is determined by these assumptions plus the endogenous response of capital accumulation.

Gradual convergence and reform

In reading the results, it is important to note that all variables are expressed relative to the status quo. Thus, a zero means the variable is equal to the status quo value of that variable. Variables are either: percentage deviation from the status quo (i.e. the level of GDP, investment); change in the growth rate relative to status quo; percentage point deviation from status quo (i.e. for interest rates a 1

Figure 5   Population plus labor productivity growth in status quo
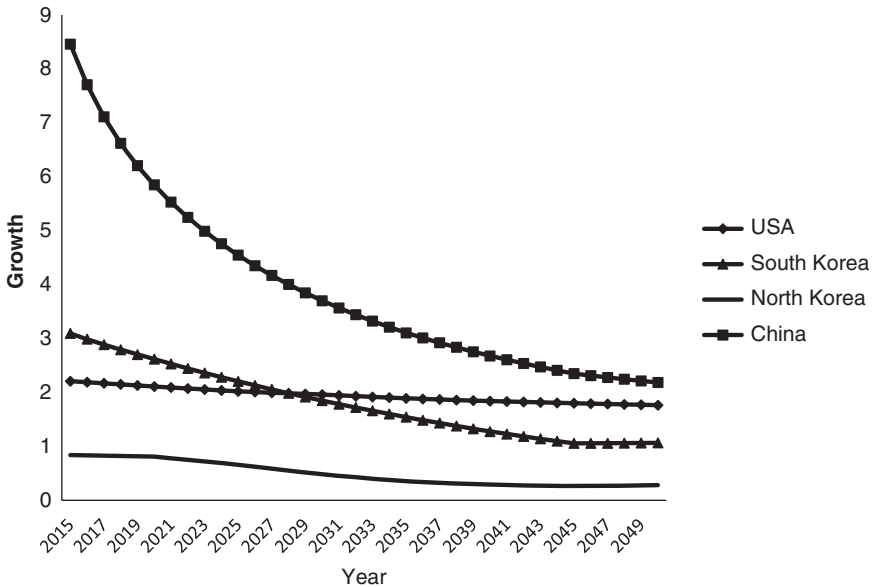
percentage point rise would be an interest rate rising by 1% or 100 basis points); or percent of GDP deviation (e.g. trade balance and current account).

Figure 6 shows results for North Korea. It is clear that gradual reform that allows faster catchup of productivity plus transfers from South Korea raises the rate of economic growth (top right). Persistently higher economic growth of between 10 and 15 percent gradually increases the level of GDP (top left). The North Korean economy becomes 400 percent bigger by 2040. This is illustrative and very sensitive to the assumption of how quickly North Korea will catch up. A key part of the catchup is a rise in private investment which is shown in the middle left-hand chart. Note that because we have maintained a high degree of capital controls, a significant part of financing of the internal reforms and growth is funded by a fall in private consumption for a decade as resources are moved into more private investment. The transfers from South Korea are used to offset this consumption decline but there is still much weaker consumption than GDP growth for a decade from 2020 as resources are channeled into private investment. If it is assumed that capital markets will open or the government will borrow on global markets, then this internal financing can be avoided. The bottom two charts show the change in trade balance as a share of GDP and the change in real interest rates. The deterioration in the trade balance is the extent to which we allow capital to flow into North Korea. Thus, there are significant capital controls that delay the desired accumulation of private capital.

Figure 6   Convergence plus transfer scenarios: Results for North Korea
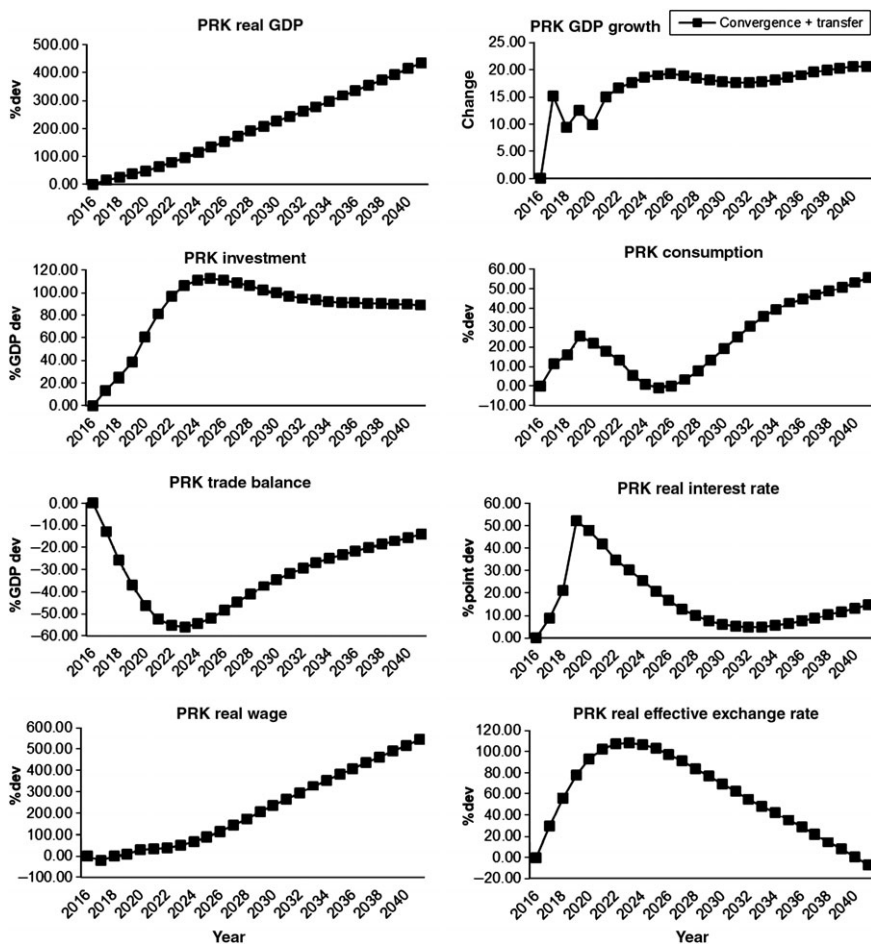

With more capital and higher productivity, the average real wage rises in North Korea. With an imbalance between the demand for capital and available supply of capital, the shadow real interest rate in the economy rises but eventually falls as investment drives back down the marginal product of capital over a long period. The inflow of capital from overseas causes the North Korean won to appreciate in real terms as well relative to the nominal US dollar. Once production rises in North Korea and trade expands, the relative price of North Korean goods begins to fall in the global economy.

A fiscal transfer from South to North (as a gift) is accounted for as a rise in the current account of North Korea. It enables some financing of the growth in North Korea: just enough to offset the fall in private consumption. The transfer we assume is exogenous and based on the German experience.

The results for South Korea are shown in Figure 7. It is clear that under the assumptions used, the spillovers to South Korea are small relative to the South Korean economy. The transfer from South to North dominates the scenario. It implies a reduction in South Korean GDP that flows on to a reduction in investment and consumption because someone has to pay for the transfers to North Korea. Given current trade relations, very little of the transfer finds its way back into demand for South Korean goods. This might be very different if the aid is targeted at buying capital goods from South Korea. This and many other policy issues can be explored in this model and is analyzed in Lee and McKibbin (2018).

Although the focus of this paper is on the macroeconomic implications of different scenarios, the sectoral disaggregation provides some interesting, although

**Figure 7 Convergence scenarios: Results for South Korea**
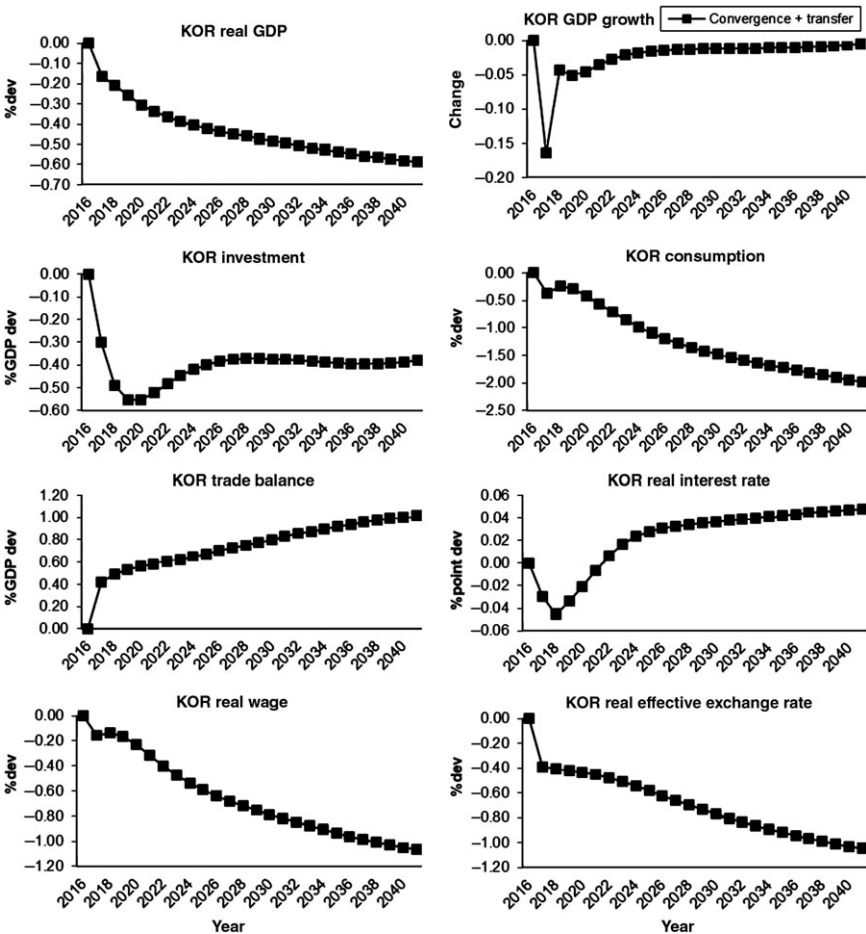
preliminary, insights. The major output expansions in the North Korean economy occur in the durable manufacturing sector (up 2500 percent by 2030) in response to the investment boom in the mining sector (up 550 percent by 2030). Agriculture also steadily expands, with output 200 percent higher than otherwise by 2030. In contrast, energy output and services output initially fall before rising after a decade.

Managed chaos in North Korea

This scenario consists of a number of shocks as outlined above. The results for North Korea are contained in Figure 8.

Figure 8   Managed chaos in North Korea: Results for North Korea
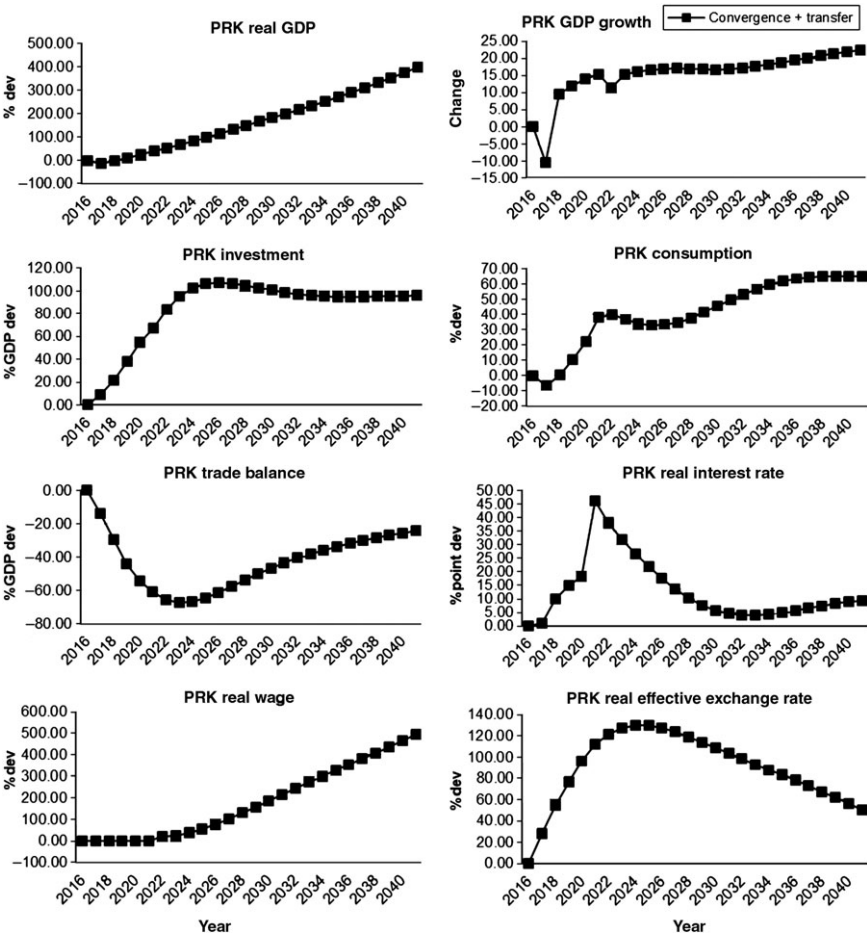
The collapse in productivity shows up as an immediate fall in the North Korea GDP growth rate directly from the fall in productivity and destruction of the capital stock. It is important to note that the behavior in the first period is also affected by the knowledge in this scenario that eventually reform will be undertaken in future years. If the future reform was not expected, the collapse in North Korea would be more severe than in these charts. As reform begins 2 years after the collapse, real GDP growth rises in North Korea. The initial fiscal transfers also help buffer the decline in real GDP. Note that the migration from North to South Korea does limit the rise in real GDP because it reduces potential growth in North Korea. Also note that private consumption falls in the first year but rises more quickly than under the convergence scenario and there is a smaller rise in private investment due to the initial crisis.

At the sectoral level, the results for North Korea are very different to those for the convergence scenario. In the managed chaos scenario, all sectors contract. The durable manufacturing sector recovers more quickly in anticipation of the future reforms.

Figure 9 presents the results for South Korea from managed chaos in North Korea. It is assumed that the only spillovers are through trade, some capital flows and a flow of migrants from North South. In practice, a number of other spillovers could be incorporated, including those assumed in the final scenario below. The biggest effect in South Korea is the inflow of migrants from North Korea, which raises potential output in South Korea. This is not surprising given that the size of the North Korean economy is small relative to that of South Korea but the number of people flowing from North to South is large relative to South Korea.

Real GDP, consumption and investment in South Korea gradually decline after the collapse of North Korea. This reflects the fiscal transfers from South to North which need to be paid out of either consumption or investment unless the South Korean government borrows on world markets to pay for the transfers (not considered in this paper but a plausible scenario). Note that the South Korean trade balance improves, reflecting the flow of some capital out of South Korea into North Korea and also reflecting greater exports to North Korea. The South Korean current account worsens, reflecting the payment of fiscal transfers to North Korea. Despite the negative effects on South Korea from the fiscal transfers in the short run, the inflow of migrants from North Korea gradually increases the labor supply in South Korea. This reduces real wages in South Korea but increases potential output. The size of the gain in potential output should decrease if North Korean migrants have less human capital than that of the average South Korean worker and they need new education and training to adjust to South Korea's free-market capitalism.

With private capital and government transfers flowing to North Korea and greater private investment to absorb the additional migrants in South Korea, private consumption needs to fall slightly to fund the fiscal transfers and investment increase. Without migration, the positive effects on GDP from North

**Figure 9   Managed chaos in North Korea: Results for South Korea**
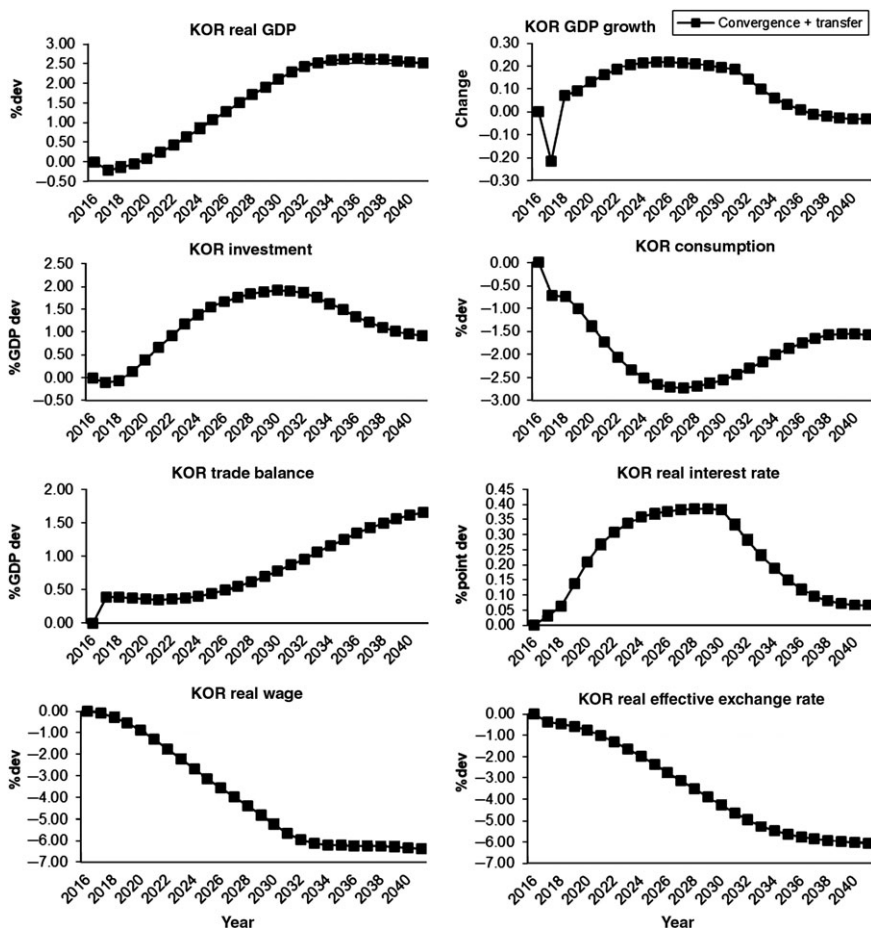
Korea are eliminated. Note that consumption falls by less in the short run without migration but falls by more in the long run without migration. This is because absorbing the workers in the short run is not necessary but losing the gain in potential output is more costly in the long run.

In addition, the financial effects on South Korea are dominated by the inflow of workers raising the marginal product of capital and pushing up interest rates. The real exchange rate depreciates due to the capital relocation within the two Koreas, although the flow of migrants is the main cause of the depreciation.

Chaos in North Korea and crisis of confidence in South Korea

Figure 10 presents the results for North Korea when there is instability in both Koreas due to the crisis in North Korea spreading more widely to the

Figure 10 Chaos and crisis in North and South Korea: Results for North Korea
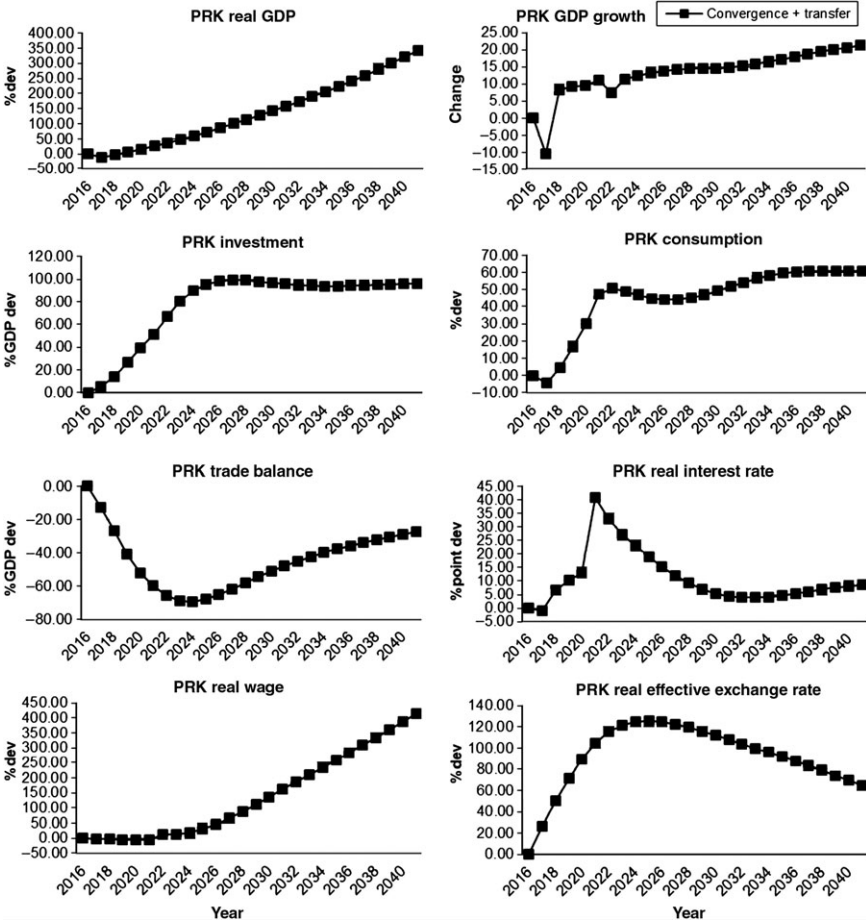
South. The more severe problems in the Korean Peninsula a reflected by a large fall in GDP growth and a persistently slow recovery with weaker investment in North Korea. However, as reforms are implemented, North Korea shows strong investment and GDP growth over the middle term and long term.

The results of this scenario are very different for South Korea (see Figure 11). The loss of confidence in the South Korean policy-makers leads to a capital outflow from South Korea, an increase in real interest rates and a collapse in private investment. South Korea enters recession and the South Korean won depreciates by 14 percent in real effective terms. The falls in real GDP and real wages in South Korea are significant.

Figure 11   Chaos and crisis in North and South Korea: Results for South Korea
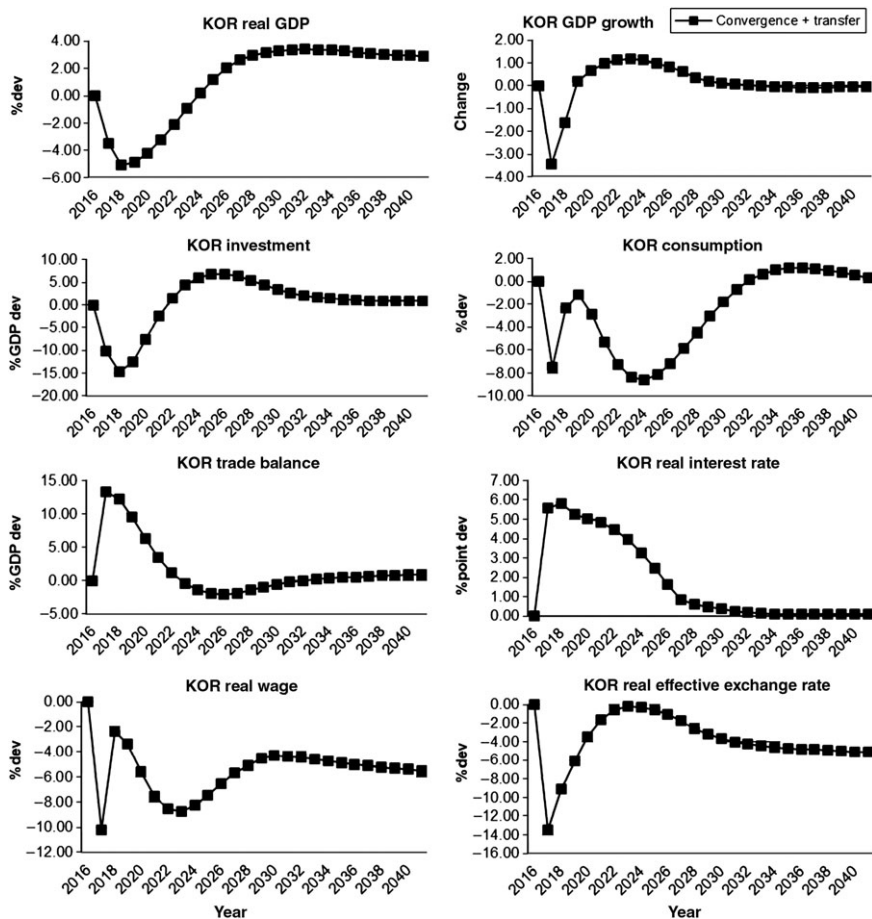
IV.   Concluding Remarks

This paper has developed a new macroeconomic and sectoral database for North Korea for 2014. This data has then been used to develop a new model of the North and South Korean economies embedded in a widely used global economic model called the G-Cubed model.

The goal of the project is to develop a rigorous framework for analyzing scenarios for Korean unification. It is also to analyze a wide range of alternative policy responses in the two Koreas and the Asian region, focusing on institutional design issues such as monetary and fiscal frameworks, and spillovers to other countries in Asia and the Pacific. Given constraints on the amount of material that can be covered in a single paper we have focused here on

developing the model and presenting a limited number of illustrative scenarios. This paper focuses on analyzing the effects of the unification process on North and South Korea. The spillovers to the neighboring economies will be the focus of a subsequent paper. Other papers will also cover the wide range of economic issues that emerge in attempting to model such a complex set of issues as the economics of Korean unification.

Despite the illustrative nature of this paper, a number of important insights emerge. First, the relative scale of the two Koreas is very different from East and West Germany before unification, with population sizes much closer in the case of the two Koreas but the differentials in economic activity of greater magnitude than for the two Germanys. The importance of relative population sizes is clear since the potential migration flows from North to South are much larger than between East and West Germany. We simulate a relative modest flow of migrants but even this has a large impact relative to the economic spillovers through trade and capital from North to South which are quite small. Despite the direct spillovers being small, there are important effects of the reform process on confidence in South Korea and the Korean Peninsula more generally, which suggest potentially large costs if the process of unification is not handled well.

Another result is that resources need to be found to fund any unification process. This can be through North Korea giving up consumption in the short run to fund reform over time (considered in this paper), through fiscal transfers from South Korea (considered in this paper) or from opening the capital account to allow greater capital inflow (to be considered in a future paper). Each has a different implication for both Koreas. If South Korea is to fund fiscal transfers, then either these resources must come from reducing consumption and investment in South Korea (considered in this paper), higher taxes in South Korea (not considered) or borrowing from international markets (partially considered through capital inflows). In addition, migration flows from North to South have medium-term and long-term implications for potential growth in both Koreas.

There are many more scenarios that the framework developed in this paper can be used to explore. These will be the focus of future papers.

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