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Structural Breaks, Manufacturing Revolutions, and Economic Catch-up: Empirical Validation of Historical Evidence from South Korea

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Abstract

The main goal of this study is to look at how South Korea can catch up to the rest of the world through policy-driven structural change and manufacturing revolutions. To achieve the objective, this study used annual data on real exports and real GDP from the World Development Indicator WDI of South Korea for the period 1960 to 2019. The study's goal is to use econometrics to detect this policy-driven structural change trend. Multiple nonlinear Granger causality test was used to accomplish this. The findings revealed structural breaks and nonlinearities in the dynamic link between South Korea's real GDP and real exports. Furthermore, results also show evidence of multiple structural breaks in South Korean data. South Korea's economic catch-up was the result of a constant reevaluation of industrial policies, readjustment, and structural change to constantly explore and utilize comparative advantage, realizing economies of scale at the global level, and reallocating and redistribution of resources towards productive sectors with high value-added output, according to econometric analysis. If South Korea would have not done this structural change this miracle to escape the middle-income trap would not have been possible. These findings support the descriptive evidence of structural change in favor of manufacturing revolutions and value addition industry development in South Korea.

Keywords: Structural Change, Catch-Up, Exports, Economic Growth, Non-Linear Causality

JEL Classification Code: N65, O25, O31, L52, L60

1. Introduction

In the 1980s, Washington Consensus promoted trade liberalization, privatization, and capitalization as the main cure from economic backwardness. Many countries around the globe in a hurry to break free of the Middle Income Trap (MIT) joined in, however, apart from a few, none saw the materialization of unsaid promises. South Korea was one of those few countries which could break free from low and middle traps and became an ideal example of economic catch-up.

Naturally, South Korea became an interesting case study for the developing economies that wanted to follow the same path. The research found that South Korea could transit to high-income countries list based on industrial policies and structural transformation (Amsden, 1994; Yulek, 2018). Structural change and transformation can be traced via descriptive/historical evidence or empirical analysis. Descriptively and statistically it is evident from the change in the type of products being produced and exported by the country over time (Yulek, 2018). Furthermore, expenditure on human capital formation in the form of expenses on R&D (Mechitov et al., 2019; Yülek et al., 2020) and expenses on education (Mechitov et al., 2019) are two important indicators of structural change. Government intervention via fiscal policy and other management tools is necessary for structural change via industrial policy (Csaba, 1982). There is a plethora of research supporting descriptively the change

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in industrial policies and structure of South Korea to attain high-income country status. However, empirical exploration of structural breaks and matching of historical evidence to the empirical investigation has yet to be done.

The current paper aimed to fill this gap of literature by empirically investigating the existence of structural breaks in real GDP and real Exports of South Korea during the years pointed out by historical and descriptive evidence, using data from 1960 till 2019 from the World Development Indicator website. After necessary investigations non-linearity of both variable series and the presence of heteroskedasticity was established. This led to the usage of granger causality tests (Zhang et al., 2020). Test results established two-way Granger causality between real exports and the GDP of South Korea. Furthermore, for historically known years of structural breaks Chow test was applied. Empirical results validated three important structural breaks in South Korea during 1975, 1997, and 2008. These results are seminal as they strongly support industrial policy and transformation towards value-added advancement as a major determinant of Economic Catch-up.

2. Structural Transformation and Economic Catch-up of South Korea

2.1. The Historical Context

To understand the present-day transformation and economic catch-up of South Korea, we first need to understand her transformation from Kingdom to the colony and then to an independent country. Since the beginning, Koreans had this very beneficial trait of absorbing and learning from invaders. Despite multiple aggressions from powerful neighbors like China and Manchuria Korean Kingdom survived till 1910 (Cho & Kim, 1992).

Occupied by Japan in 1910, Korea remained hanging between international disputes until 1945 as a colony. Until, 1947 under implicit US policy assumption of reuniting the peninsula, there was no South Korea. In between Soviet-US conflicts, South Korea was born as a separate state backed by the US in 1948. Right after two years of her birth South Korea was invaded by North Korea in 1950 and this turmoil lasted till 1953. South Korea inherited 'state intervention' as a Japanese colonial legacy. Born and torn between wars of the giants, Korea was an extremely poor country with production way below pre-war era, crime and disease rampant with additional refugee burden. To add to this, out of the hatred of the Japanese as their oppressors, Koreans destroyed many good accomplishments and public properties built by the Japanese during 1910–1945 (Cho & Kim, 1992).

South Korea remained dependent on the US till the 1960s. Therefore, South Korea was predominantly an agricultural state with little or no industry and no electrical power production till the 1960s (Seth, 2017). In the late 1960s, the fall-out of the Vietnam War led to the "Nixon drive' to withdraw American troops from the Asian region. The withdrawal of American support made South Korea reconsider its development strategies. Both sudden shock of support withdrawal and the threat from the communist backing of North Korea led to a paradigm shift in the South Korean Growth Strategy. Realization of disparity in military power with their northern counterparts and industrial strength of North Korea greater than their own led to industrialization drive which was previously missing due to dependence on the USA.

South Korea after taking almost a decade of covert planning launched the Heavy Chemical and Industry (HCI) drive in 1973. This drive lasted for only 6 years and right after the assassination of President Park in 1979 HCI drive lost its ground. This drive though short in time period proved to be the catalyst of change and its effects were far-reaching. Contrary to what is commonly believed, HCI drive did not overprotect HCI industries, rather it promoted intermediate imports and capital formation, which helped the process of development even after 1979. Apart from the major industrial policy shift in 1973 South Korea also changed its industrial structure and kept updating it progressively.

Two other major policy shifts took place in 1997 and 2008. 1997 policy shift took place when due to financial liberalization and debts IMF bailout was required by South Korea to stabilize her economy (Mah, 2007). However, within a decade it was realized by South Korea that IMF policies were damaging their economic stability, and thus after the 2007–08 global financial crisis South Korea reverted to controlled high-tech industrial transformation policies (Yülek et al., 2020). Due to strong structural changes but a long-term commitment to the strategic goals, South Korea became an exemplary case of catching up by changing product sets and gaining price-setting power through technological development, design, and branding capabilities (Yulek, 2018).

2.2. Some Descriptive Evidence

The transition of South Korea from a very poor country to a high-income country within a short period of four decades is no less than a miracle. In the presence of remarkable performance evidence, there is no denial of this fact. Constant and rapid increase in real GDP, per capita income, Total factor productivity and capital accumulation per person employed human capital formation, inequality decline, and value-added exports are a few prominent indicators of this economic catch-up (Hahn & Shin, 2010; Yulek, 2018).

Yulek (2018) stated that even within Europe, relative to Germany productivity and productivity growth levels remained very stable from 1970 till 2015 except for South Korea (Table 1).

South Korea remarkably did this transition from low to high-income country within four decades and has been maintaining the status for another two decades.

2.3. Human Capital Formation and Economic Catch-Up

Literature highlights human capital accumulation as the main vehicle of endogenous growth (Arrow, 1962). Human capital accumulation is either achieved via learning-by-doing which in turn leads to increased productivity and growth rates (Dasgupta, 2012; Simon & Folen, 2001) or education (Romer, 1986). Both go hand in hand, where education leads to human capital formation, learning-by-doing and hands-on experience produces knowledge and expertise (Göcke, 2004; Widarni, 2021). Learning by doing is a very important phase of R&D which not only leads to better productivity but also enhanced production capacity in the future (Dasgupta, 2012). Education, on the other hand, is the initial phase of human capital formation without which learning by doing loses its effect (Romer, 1986). Yulek (2018) has discussed the impact of education and R&D on human capital formation via export-led growth. He has emphasized human capital formation as the key catalyst for manufacturing.

2.3.1. Education

South Korea is an exemplary state for following endogenous growth theory with respect to human capital formation both via Education and R&D. Right after the end of the Korean War first six-year human resource development plan was implemented in South Korea in 1954 which focused on universal primary education. Other important milestones in the educational policy of South Korea included the 1958 Education Act, expanding primary education target to secondary and later on higher education, specifying education targets, and relating them to skill attainment and technology education for all (Hariyono, 2021; Tcha, 2015). These educational policies led to a more equitable distribution of income, which led to the lowest Gini coefficient in all East Asia. Today more than 80% of high school graduates in South Korea enter universities under the national strategy and life-long learning policies. This educated and skilled labor force participated significantly in the economic development of South Korea (Tcha, 2015).

2.3.2. Research and Development

Expenditure on R&D is a major indicator of technology advancement and economic growth (Yulek, 2018). South Korea's expenditure history on R&D paints a beautiful picture of utmost importance to technology development via research. The 1980s saw a rapid increase in domestic R&D expenditure. Intense competition among companies

Table 1: The Course of Relative Productivity in Selected OECD Countries Relative to Germany (Average GDP Generated Per Hour Relative to Germany, Current Prices In PPP US Dollars)

	1970	1975	1980	1985	1990	1995	2000	2005	2010	2015
Germany / Turkey	1.9	1.9	2.1	1.9	1.7	1.9	2.4	2.2	1.8	1.7
Germany / Portugal	1.8	2.1	1.9	2.0	1.9	2.0	1.9	1.9	1.8	1.9
Germany / USA	0.7	0.8	0.9	0.9	0.9	1.0	0.9	0.9	0.9	1.0
Germany / Korea	7.0	6.5	5.9	4.6	3.5	3.0	2.4	2.2	1.9	2.1
Germany / Mexico	…	…	…	…	…	3.3	3.1	3.2	3.2	3.3
Germany / Holland	0.9	0.8	0.9	0.9	0.9	1.0	0.9	0.9	0.9	1.0
Germany / Japan	1.8	1.7	1.7	1.6	1.4	1.5	1.4	1.4	1.5	1..5
Germany / Switzerland	0.7	0.8	0.8	0.9	1.0	1.1	1.0	1.1	1.0	1.0
Germany / UK	1.2	1.3	1.3	1.2	1.3	1.3	1.2	1.2	1.2	1.3
Germany / Finland	1.4	1.4	1.4	1.3	1.3	1.2	1.1	1.2	1.1	1.2
Germany / Sweden	0.9	0.9	1.0	1.0	1.1	1.1	1.1	1.1	1.1	1.1
Germany / Spain	1.4	1.4	1.3	1.1	1.2	1.2	1.3	1.3	1.3	1.3
Germany / Russia	…	…	…	…	…	…	4.7	3.6	2.5	2.8

Source: (Yulek, 2018).

is revealed by increased private sector expenditure on R&D along with public expenditure. Capital goods imports increased to 57% in 2000 which significantly contributed towards technology growth (Tcha, 2015). Table 2 indicates this situation very clearly.

The nature of imports changed from raw materials to capital goods from the 1970s till 2009. Consumption goods imports as a share of total imports decreased from 24% to almost 10% during this period, whereas the share of capital goods imports increased from 23.1% to 32.2%, with a major increase in the share of equipment investment which from being nonexistent till 1990 reached rapidly up to 77.8%. This depicts a major shift in industrialization policy in the 2000s.

2.4. Total Factor Productivity, Capital Accumulation, and Economic Catch-up

The persistently high total factor productivity (TFP) of South Korea as compared to the rest of the world is one of the many contributors to economic catch-up. Also, the capital accumulation of South Korea is more than double of the rest of the countries in comparison, as shown in Figure 3. This Figure compared South Korea with other 82 countries from differing income and geographical areas of the world. Apart from 1971–1980 when the TFP of South Korea South Korea had more TFP as compared to other countries. To be precise, the TFP of South Korea was 38% which was only smaller than advanced countries at 52% (See Table 2).

2.5. Brief Detail of Development Phases

Literature has broadly classified South Korean economic development into 4 major phases; pre-take-off (1948-the 1960s), take-off (1970–1980s), age of maturity (1990s–2000), and technological drive (2000-now) (Seth, 2017; Tcha, 2015).

Pre takeoff stage has been roughly bordered from 1948 till the end of the 1960s or even the early 1970s. South Korea during this phase was an agricultural state with little or no industry. This is because any industrialization that was done in Korea was during Japanese colonization (1910–1945), which too existed mostly on the Northern side (Seth, 2017). This poor state of South Korea lasted till the realization of the fact that US dependency has lagged them way behind North Korea. At that time South Korean per capita income was almost as that of Haiti (Seth, 2017). This realization and the constant threat of their communist enemies led South Korea in the early 1960s to covertly plan High Chemical and Industry (HCI) drive.

Planning continued for the next ten early and in 1973 President Park announced the HCI drive. This drive was the beginning of the transformation and economic catch-up of South Korea. Despite their initial hatred for Japan, Park not only normalized relations with Japan nonetheless

Table 2: Decomposition of Economic Growth by Major Regions in Comparison to South Korea (1961–2004)

	GDP Growth	GDP Growth per Person Employed	Contribution to Economic Growth	
			Capital Accumulation per Person Employed	TFP Increase
Total (83)	4.0	2.4	1.2	1.3
Advance Countries (22)	3.3	2.1	1.1	1.1
South Korea	71.0	4.7	2.9	1.8
1961–1970	7.7	4.7	3.0	16.0
1971–1980	7.3	46.0	3.8	18.0
1981–1990	8.6	61.0	2.8	3.4
1991–2000	5.8	4.1	2.7	1.5
2001–2004	4.5	2.9	1.3	1.5
East Asia (5)	5.7	2.8	1.8	1.0
Central & South America (22)	3.7	1.0	0.6	0.4
South Asia (4)	4.9	3.0	1.1	1.8
Sub-Saharan Africa (19)	3.4	1.0	0.6	0.3
Middle East & North Africa (9)	4.4	2.0	1.2	0.9

Note: Number in Parenthesis represent the number of countries in each column.
Source: (Hahn & Shin, 2010).

South Korea imitated the economic development policy of Japan via long-term economic plans of appropriate structural shift where required and the formation of advanced firms (zaibatsus) in form of the *chaebols* (Yulek, 2018). Furthermore, both Japan and South Korea being 'developmental states' (Johnson, 1982) and 'regulatory states' (Johnson, 1982) kept economic development and rising standard of living as their top priority. Impacts of market failures and abusive market powers were minimized with centralized economic planning. Prominent features of this drive included sectorial choice instead of broad-based industrialization, centrally planned industrial drive based on 53 *chaebols,* investment incentives, and trade policy (Seth, 2017). Not only did these big private businesses fill the low finance gap, but these Korean conglomerates were also a surety against failure due to their mere size (Tcha, 2015). Heavy Chemical Industry including steel, non-ferrous metal, shipbuilding, machinery, electronic and petro-chemicals was initiated depending upon strategic goals and feasibility (Tcha, 2015; Seth, 2017).

Similarly, for exports instead of broad-based promotion, targeted industry-specific policies were introduced. These policies were broadly classified into investment incentives and trade policies. Long-term investments like machinery, factories, and construction, policy-oriented loans, differential lending, HCI-promoting tax policy, and industry-specific subsidies were some of the prominent investment incentives during this era. Trade policies on the other hand shifted from a virtual free trade regime for exporters (pre-1973) to general elimination of this regime except for the HCI industry (post-1973) (Tcha 2015). During this phase along with industrialization and structural change, the rapid expansion of education, land reforms, normalization of international relations with Japan and China, dissemination of technological knowledge, and learning from other fast catching up economies took place (Seth, 2017; Tcha, 2015; Yulek, 2018). Although the HCI drive only lasted for 6 years till the assassination of President Park in 1979 but critics say that its positive implications went a long way (Seth, 2017).

All these positive factors contributed towards the third phase which started in the 1980s and lasted till the end of the 90s. Contrary to the general belief that South Korea was not ready for heavy industrialization, the transformation of the industry from low value-added primary goods to value-added high-tech production (Tcha, 2015; Yulek, 2018). Tcha (2015) has very beautifully summarized South Korea's transformation in his title 'from potato chips to computer chips. Investment of South Korea in long-term productivity-enhancing sectors like education (Mechitov et al., 2019) and R&D (Dasgupta, 2012; Tcha, 2015) during the second phase started paying off in the third and fourth industrialization ages (Tcha, 2015). That is why South Korea could refute predictions of a slowdown in economic growth by many like Hahn and Shin (2010). However, South Korea did face fluctuations in the late 90s and early 2010. The global financial crisis in 1997 and 2007–08 were the two reasons for temporary economic shocks in South Korea. The 1997 financial crisis started in the mid-90s due to foreign debt increasing up to 24% of GNP. Even deadly was the short-term debt which had reached up to 350% of foreign reserves at that time (Laurence, 1999). Reasons for this financial crisis were financial liberalization and tight monetary policy which resulted in domestic interest rates being higher than foreign interest rates thus leading to heavy foreign borrowing by the banks (Demetriades & Fattouh, 1999). This also affected exchange rates adversely so much so that the government had to ask for an IMF bailout in 1997 (Mah, 2007). Nevertheless, certain characteristics of the South Korean economy which are shared with other East Asian tigers helped South Korea not only recover from the financial jolt of the late '90s and global financial crisis in 2007–08 but to progress further. Figure 3 shows how World Bank summarized the characteristics of East Asian economies including South Korea with long term and consistent economic progress making it possible for them to catch up with high-income countries.

Nevertheless, these shocks were isolated and today South Korean industrialization policies and structural change has led to high per capita income. South Korea was finally recognized as an official member of the Organization of Economic Cooperation and Development (OECD) in 1996 (Seth, 2017). South Korea enjoys the reputation of technological innovation, high GDP per capita and is one of the highest countries in educational attainment and health provision. Industrial policies with selected intervention used by South Korea to attain this catch-up now cannot be used as WTO prohibits and regulates certain government interventions.

2.6. Some Descriptive Indicators

Economic Catch-up of South Korea was a multidimensional effort including high human capital formation via R&D and Education, sectorial specific industrial growth, structural change towards value addition, and high-tech manufacturing under target-oriented selective state intervention (Seth, 2017; Tcha, 2015; Yulek 2018). Following Endogenous growth theory (ENGT) which believes that a lot of effort, money, and the time investment is required in formal R&D activities by multiple shake holders to achieve technological progress (Arrow, 1962; Romer, 1986), South Korea successfully graduated from low to middle-income trap and then finally to high-income country status.

South Korea's Policies leading to R&D, innovation, entrepreneurship, and human capital formation impacted growth and productivity, which resulted in overall structural

change, narrowing of income and output gaps with the rich countries. These structural changes are evident via structural breaks in GDP growth, exports, and other economic indicators (Cho & Kim, 1991).

Far-reaching effects of the HCI drive were due to the sectorial choice which continued to develop even after the drive. Depending upon both the feasibility and strategic goals initially six industries including steel, non-ferrous metals, shipbuilding, machinery, electronics, and petrochemicals were focused. South Korea dynamically changed its product range between 1960 and 2000 (Tcha, 2015; Yulek 2018) as shown in Table 3. A clear trend of shifting from lower value-added goods like fish and raw silk etc. to more design, technology, and branding intensive high value-added industrial goods like electronics, petrochemicals, etc., is evident (Yulek, 2018). This move from low value-added to high value-added processed goods led to structural change, improved exports, and diversification of the South Korean economy with the eventual shift from low income to high-income country list. What marvels developed and developing nations alike is the pace at which South Korea could attain this transformation. The industrial structure of South Korea in the 1960s was as of UK in 1700, the USA in 1880, and Japan in the 1900s but by the 1990s South Korean industrial structure progressed and became similar to that of the UK in 1890s, the USA in 1950s and Japan in 1970s (Tcha, 2015). The transition of the top 10 export products of South Korea depicts this rapid structural change within six decades (See Table 3).

South Korea did not achieve this shift in income status by following a particular policy, rather a combination of various industrial policies including sectorial choice (picking selected industries with high expected returns such as electronics, transportation equipment), and development-based public procurement policies focused at export promotion and import substitution (Amsden, 1994) along with improved state-capacity (Yülek et al., 2020).

2.7. Empirical Investigation

With the theoretical background built-in preceding sections current paper empirically tested for structural breaks in Real GDP and Real exports of South Korea. It was expected based on historical evidence that both real exports and the real GDP of South Korea will show structural breaks. Furthermore, it is expected that the structural breaks would affect the strength of the causal relationship between exports and GDP. Previous studies discussed earlier have descriptively analyzed the structural change in the industrial sector. Increased output and developed industrial sector lead to increased exports which in turn increase the real GDP of a country. This is known as the export-led growth (ELG) argument (Balassa, 1978).

In the literature, there are two basic hypotheses on the causal relationship between export and GDP: export-led growth (ELG) and growth-led export (GLE). The former is based on the concept that, as a component of GDP, increasing exports will grow GDP both directly

Table 3: Change in South Korea's Production Pattern: Top 10 Exports Over Time

1960	1970	1980	1990	2000	2010
Iron Ore	Textiles	Textiles	Electronics	Semiconductors	Marine Structure and Components
Tungsten	Plywood	Electronics	Textiles	Computers	Semiconductors
Raw Silk	Wings	Iron and Steel Products	Footwear	Automobiles	Warless Communication
Anthracite	Iron Ore	Footwear	Iron and Steel Products	Petrochemical	Apparatus
Cuttlefish	Electronics	Ships	Ships	Ships	Flat display and Sensor
Live Fish	Fruits and Vegetables	Synthetic Fibers	Automobiles	Wireless Telecommunication	Automobiles / Automobiles components
Natural Graphite	Footwear	Metal Products	Chemicals	Iron and Steel Products	Petroleum Products
Plywood	Tobacco	Plywood	General	Textile products	Synthetic Resins
Rice	Iron and Steel Products	Fish	Plastics Products	Textile fabrics	Steel Plate
Bristles	Metal	Electrical Goods	Containers	electronics home appliances	Computers

Source: Yulek (2018); Tcha (2015).

(Balassa, 1978; Krueger, 1978) and indirectly (Balassa, 1978; Balcilar & Ozdemir, 2013). The growth-led exports (GLE) theory, on the other hand, claims that an increase in output leads to an increase in exports of a country. GLE is attributed to two primary factors: technological advancement and growing human capital. Then there are others who have explored and supported the bi-directional causal relationship between exports and GDP such as (Amoateng & Amoako-Adu, 1996; Awokuse, 2007; Awokuse & Christopoulos, 2009; Kwan & Cotsomitis, 1991). Most of the studies have applied the linear Granger causality test for exploring causality between exports and GDP. As in real life, these series face structural breaks because of policy shifts and natural calamities, etc. non-linear Granger causality testing would be more suitable for exploring bidirectional causality between exports and the GDP of South Korea.

The current study aims to validate the importance of industrial policy and resulting structural change as a central ingredient of economic catch-up. Empirically this can be done in two ways; one by establishing that real exports and real GDP show Granger causality and two, by validating the existence of structural breaks as the indicators of structural change and changing industrial policy matching with the historical evidence. The export-led growth (ELG) thesis will be established if there is a Granger causality between real exports and real GDP in South Korea. The presence of structural breaks in the same years that have historically shown major changes in industrial policy and structure, on the other hand, will highlight the importance of industrial policy and planning in bringing about the necessary structural change that leads to graduation from the middle-income trap.

3. Data and Methodology

3.1. Data

This study used annual data for South Korea from 1960 to 2019 from the World Development Indicator WDI on real exports (constant 2010 LCU) and real GDP (constant 2010 LCU). Ajmi et al. (2015) examined causation between real exports and real GDP using a century of data for South Africa. Other studies, such as (Amoateng & Amoako-Adu, 1996; Awokuse, 2007; Balcilar & Ozdemir, 2013), have used data from the last three to five decades for various countries. To investigate the connection between real exports and real GDP, many of these articles used exports and GDP in constant local currencies.

The current study examined data on South Korea from the World Development Indicators website for the previous six decades, from 1960 to 2019. This study examines GDP and export growth pathways to evaluate if and when structural breaks occurred, as well as what lessons may be learned from this comparison.

3.2. Methodology

Keeping in mind the dual aim of the paper following steps of analysis were followed. We started with a descriptive analysis of the data for both countries to see if major kinks and bends of the line graphs for real exports and real GDP match the historical evidence of structural change in South Korea. Secondly, same line graphs of exports and GDP for each country gave a rough idea about the similarity in trends of exports and GDP respectively. After matching these trends and kinks with historical evidence years for testing structural breaks were determined via chow test. Also, the similarity of trends between exports and GDP gave an idea of a causal relationship between exports and GDP for each country.

The empirical analysis started with testing the stationarity of the series and the Cointegration test. Augmented Dickey-Fuller (ADF) test, Z_{α} unit root test by Phillips (1987), and Phillips & Perron (1988) were applied to check if unit root existed in both series. After establishing stationarity of exports (constant 2010 LCU) and GDP (constant 2010 LCU) at first differences we investigated the causal relationship between the two. Analysis of Granger Causality started with the application of linear Granger causality tests LGCT. LGCT indicated the nonexistence of ELG. This led to the exploration of VAR estimation, parameter stability, and the existence of Heteroskedasticity. Sup-MZ parameter stability test gave the best results under Heteroskedasticity. At this stage, stability was checked for estimated VAR by applying Sup-F, Avg-F, Exp-F, and MZ tests.

For checking stability, the MZ test developed by Maasoumi et al. (2010) and tested by Ahmed et al. (2014) was applied. This test is an improvement to Sup-F, Avg-F, and Exp-F tests developed by Andrews (1993). Tests developed by Andrews (1993) and others assume homoscedasticity and additionally, there is no test available to detect unknown breaks whereas the MZ test does not assume homoscedasticity in structural change. The MZ test was developed by Maasoumi et al. (2010) for simultaneous changes in regression coefficients and error variances at a defined breakpoint. According to Ahmed et al. (2014), MZ tests account for unknown breakpoints, have a low cost in the event of homoscedasticity, and outperform other tests in the case of heteroskedasticity. For South Korea, a high value of the Sup MZ parameter stability test revealed the presence of structural breakdowns. All of this research revealed that non-linear Granger causality tests, or NLGCTs, were appropriate in this case because both countries' VARs were unstable. The Granger causality test was used on pairs

of people. Exports do not Granger cause GDP, and GDP does not Granger cause Exports, were our null hypotheses. At first, the Linear Granger Causality Test was used. For variables in their log-level, the optimal lag length for sequential LR tests was set at three. Finally, the Chow structural stability test was used.

4. Results

South Korean exports and GDP both show a pretty stable increasing trend in the past six decades. However, the late 1970s early 2000s, and early 2019 show clear breaks. Data of South Korea show the impact of 1997 and 2007–08 financial crisis impact with a downward bend in both exports and GDP. In South Korean data there seems to be a significant relationship between exports and GDP with stable upward trends.

4.1. Cointegration Test and Linear Granger Causality Test

Another concern was to see if Cointegration existed because it did then that means our model specification was wrong. Therefore, we tested the Granger Cointegration equation between real exports and real GDP. Equation 2 shows that a 1 unit change in exports leads to a 0.43 units change in GDP.

$$\text{EXPORT}_t = \alpha + \beta \text{GDP}_t + \varepsilon_t \quad (1)$$

$$\text{EXPORTS} = 13 + 0.426914709064 \times \text{GDP} - 7.40828263579\text{e} \quad (2)$$

Table 4 clearly shows that there was no cointegration and that the model specification was correct. As a result, the hypothesis that variables are cointegrated was rejected. It's also worth noting that the aforementioned parameter instability undermines the linear Granger causality test, which examines the relationship between exports and GDP.

The relationship between export (constant 2010 LCU) and GDP (constant 2010 LCU) was examined for linear causation. Exports do not Granger cause GDP, and GDP does not Granger cause Exports, were our null hypotheses. For variables in their log-level, the optimal lag length for sequential LR tests was set at ten. Both null hypotheses were not rejected, implying that there is no causal relationship between Turkey's real exports and its real GDP in both directions, according to the Linear Granger causality test. Table 4 shows the results.

4.2. Parameter Stability Tests

The VAR model was estimated before parameter stability tests. The MZ tests (Maasoumi et al., 2010) were used to check the stability of the computed VAR Sup-F, Ave-F, and Exp-F. The MZ test (Maasoumi et al., 2010), which was evaluated by Ahmed et al. (2014), is an improvement on Andrews' Sup-F, Ave-F, and Exp-F tests (1993). According to Ahmed et al. (2014), this test accounts for unknown breakpoints, has a low cost in the event of homoscedasticity, but outperforms other tests in the case of heteroskedasticity. The Sup-F, Exp-F, and Ave-F tests for the Export equation show that the SR and LR parameters are stable. In both SR and LR, the Sup-F test reveals parameter instability, but the Exp-F and Ave-F tests fail to reject the null hypothesis. All three tests show parameter instability in the GDP equation, however, the Exp-F and Ave-F tests provide some indication of both SR and LR stability in the Exports equation. Sup-F or Max-F tests, on the other hand, are considered superior to Exp-F and Ave-F tests (Andrews, 1993), and because both superior tests find structural instability in exports, both GDP and exports series were deemed structurally unstable.

The structural stability of regression coefficients is assumed in all applications of linear regression models.

Table 4: Cointegration Test and Linear Granger Causality Test

Unrestricted Cointegration Rank Test (Trace)					Linear Granger Causality Test Results		
Hypothesized		**Trace**	**0.05**		**Sample: 1960–2019**		
No. of CE(s)	**Eigenvalue**	**Statistic**	**Critical Value**	**Prob.****	**Lags: 3**		
None*	0.434	33.20	15.49	0.0000	Null Hypothesis:	*F*-statistic	Prob.
At most 1	0.001	0.093	3.841	0.7593	GDP does not Granger Cause EXPORTS	5.12993	0.0009
					EXPORTS does not Granger Cause GDP	5.25435	0.0007

Note: Trace test indicates 1 cointegrating eqn(s) at the 0.05 level. *Denotes rejection of the hypothesis at the 0.05 level.
**MacKinnon-Haug-Michelis (1999) *p*-values.

What is surprising is the total reliance on the assumption of homoskedasticity when testing structural change; that is, the regression coefficients are believed to change but the variances remain constant. This is a perplexing literature gap because structural change is frequently accompanied by changes in variances. Ahmed et al. (2017) developed the Sup-MZ test, which was first established by Maasoumi et al. (2010) and looks for breaks in both regression coefficients and variance.

The absence of homoskedasticity was demonstrated by the results of the Glejser Test for Heteroskedasticity in Table 5, thus Sup MZ tests were used to determine where structural breaks existed in both the Exports and GDP series for South Korea. Furthermore, the structural breaks discovered in both regression equations Sup MZ value > critical value with 100 bootstrap show structural instability in both series in the lower portion of Table 5. South Korea's Sup MZ values

Table 5: Parameter Stability Tests and Glejser Test for Heteroskedasticity

Parameter Stability Tests				
Null Hypothesis: No breakpoints within 15% trimmed data				
Varying regressors: All equation variables				
Equation Sample: 1960 2019				
Test Sample: 1969 2011				
Number of breaks compared: 43				
Statistic			**Value**	**Prob.**
Maximum LR *F*-statistic (1999)			304.7424	0.0000
Maximum Wald *F*-statistic (1999)			609.4849	0.0000
Exp LR *F*-statistic			148.6319	0.0000
Exp Wald *F*-statistic			300.9815	0.0000
Ave LR *F*-statistic			118.0576	0.0000
Ave Wald *F*-statistic			236.1152	0.0000
Note: probabilities calculated using Hansen's (1997) method				
Glejser Test for Heteroskedasticity				
F-statistic	10.62183	Prob. F(1,58)		0.0019
Obs * *R*-squared	9.287276	Prob. Chi-Square(1)		0.0023
Scaled explained SS	6.212803	Prob. Chi-Square(1)		0.0127
Variables	**Coefficient**	**Std. Error**	***t*-statistic**	**Prob.**
C	4.26E+13	5.90E+12	7.223462	0.0000
GDP	0.022107	0.006783	3.259115	0.0019
R-squared	0.154788	Mean dependent var		5.68E+13
Adjusted R-squared	0.140215	S.D. dependent var		3.32E+13
S.E. of regression	3.08E+13	Akaike info criterion		64.98812
Sum squared resid	5.50E+28	Schwarz criterion		65.05793
Log-likelihood	–1947.644	Hannan-Quinn criter.		65.01543
F-statistic	10.62183	Durbin-Watson stat		0.201795
Prob(*F*-statistic)	0.001872			
Sup-MZ (2015) Parameter Stability Test				
	Breakdown Location	**SupMZ Value**	**SupMZ Critical Value at 95%**	***n* Boot**
Export to GDP	35	328.6747	143.4896	100
GDP to Export	35	379.9374	137.9962	100

range from 328.6747 to 379.9374. When compared to critical values, these values are much higher. As a result, they point to clear structural splits in South Korea's exports and GDP. Furthermore, South Korea seems to have a more valid GLE as compared to the ELG hypothesis.

Finally, the Chow test was applied to validate the existing structural breaks. Results in Table 6 show that there are structural breaks during 1975, 1997, and 2008.

4.3. Comparison of Historical and Empirical Evidences of Structural Breaks

Although South Korea has had several periods of economic growth in the past, important policy shifts and structural adjustments have been implemented three times: the HCI push in 1973, the IMF bailout in 1997, and the return to regulated industrial policy in 2008. Table 7 compares descriptive and econometrically investigated structural cracks in South Korean real exports and GDP data.

Economic analysis of structural fractures using the Chow test (Chow, 1960) revealed South Korean industrial policy moves in almost the same three years, namely 1975, 1997, and 2008. President Park initiated the HCI drive in 1973, and it took two years for real exports and real GDP in South Korea to transform. As a result, data from 1975 shows a structural break. The Asian financial crisis began in the mid-1990s, and South Korea was bailed out by the IMF in 1997, resulting in a structural break in 1997. Finally, legislative changes in reaction to the global financial crisis of 2007–08 coincided with the structural split in 2008. This implied that South Korea was able to catch up using industrial policies supporting manufacturing investment which had positive productivity, economic development, and catch-up consequences.

Table 6: Detection of Structural Breaks via Chow Test

	1975	1997	2008
Null Hypothesis: No breaks at specified breakpoints			
Varying repressors: All equation variables			
Equation Sample: 1960–2019			
F-statistic	12.60	294.64	78.86
Log-likelihood ratio	22.29	146.66	80.36
Wald Statistic	25.20	589.28	157.70
Prob. *F*(2,56)	0.0000	0.0000	0.0000
Prob. Chi-Square(2)	0.0000	0.0000	0.0000
Prob. Chi-Square(2)	0.0000	0.0000	0.0000

5. Conclusion

Countries that could escape the middle-income trap and graduate to high-income countries list are very few. South Korea is an inspiring example in this regard. In the past six decades, South Korea rapidly achieved economic development and caught up with rich countries. From low to middle and then high-income country transition was achieved by structural change in the industrial sector. Value-added for the industrial sector (construction, capital, electricity, manufacturing, and gas business) and also services sector almost doubled over time, and value-added in primary sectors (fishery, agriculture, and forestry) declined sharply. Along with rapid industrialization, South Korea worked on integration into the world market therefore a sharp increase in value-added exports. Nature of imports changed from raw material and consumption goods to capital, machinery, and equipment, etc. Despite contrary expectations, South Korea did rapid and consistent economic progress.

South Korea drew a plethora of studies due to economic catch-up and preserving her high-income status, as well as a high per capita income. All of these studies indicated that industrial policy and structural change have helped South Korea achieve high-income status. Previous research, on the other hand, has mostly been descriptive. They explain South Korea's industrial policy and structural transformation in terms of its nature, phases, strategic aims, and efficacy. The goal of industrial policy is to establish a long-term structural change in the industrial production pattern that can be tracked

Table 7: South Korean Industrial Policy Shifts and Empirical Evidence of Structural Breaks

Phase Periods	Descriptive Structural Breaks	Econometric Structural Breaks
1948–60	Pre-take off	–
1960–73	Planning to take-off stage	1975 HCI drive impact
1973–79	Take-off stage	–
1980–1996	Maturity stage	1997 Asian financial crisis & IMF bailout
1997–2007	The financial crisis and struggle period	–
2008 onwards	Continuity to maturity	2008 Global financial crisis &High Tech industry policy shift

descriptively and statistically through export and production patterns. The current research intended to econometrically validate these arguments of structural change and industrial strategy as reasons for South Korea's economic catch-up. Multiple nonlinear Granger causality tests were used for this purpose. The findings revealed structural breaks and nonlinearities in the dynamic link between South Korea's real GDP and real exports. In South Korean data, there are several structural fractures, according to the findings. These findings back up the descriptive evidence of structural change in South Korea, which favors industrial revolutions and value-added sector development.

Empirically two important objectives were achieved, one, exploration of causality between real exports and real GDP of South Korea under ELG and GLE arguments, and second, investigation of the existence of structural breaks in the years which were identified as the years of industrial policy and structural change in literature.

The pair-wise Granger causality test was used in this investigation. The results of this test revealed a two-way causal relationship between South Korea's real exports and real GDP. The Chow structural break test was used on the years that have historically been years of structural breaks in the second step of the analysis. For nearly six decades, the current paper econometrically investigated South Korea based on the occurrence of structural breaks in GDP growth rates and exports. Data from South Korea revealed three different structural splits in 1975, 1997, and 2008 as a result of changes in economic structure based on industrial strategy and planning. 1975 Structural break positively points towards HCI drive implemented in 1973 by President Park. The financial crisis of 1997 and the resulting policy changes are portrayed in the 1997 structural break. Finally, legislative adjustments in reaction to the global financial crisis of 2007–08 coincided with the structural split in 2008. This meant that South Korea was able to catch up by implementing industrial policies that encouraged manufacturing investment, resulting in increased productivity, economic growth, and catch-up. Furthermore, it was empirically discussed that the effectiveness of the ELG argument for South Korea was extremely strong. Furthermore, it was empirically discussed that the effectiveness of the ELG argument for South Korea was extremely strong.

South Korea's economic catch-up was the result of a constant reevaluation of industrial policies, readjustment, and structural change to constantly explore and utilize comparative advantage, realizing economies of scale at the global level, and reallocating and redistribution of resources towards productive sectors with high value-added output, according to econometric analysis. This miracle of escaping the middle-income trap would not have been feasible if South Korea had not made this structural change.

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