GREEN PRODUCTIVITY AND PRODUCTIVITY MEASUREMENT PROGRAM FOR MYANMAR

INDUSTRY

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Green Productivity and Productivity Measurement Program for Myanmar

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FOREWORD

Evaluating the efficiency of resource use and assessing areas for potential economic growth are pivotal in measuring national productivity performance. Studies on Myanmar's economic growth through the assessment of labor, capital, and energy productivity have raised questions about the reliability of its official system of national accounts. There is also a strong need for an effective transition to more secure, sustainable, and affordable energy systems for a country like Myanmar.

This publication is the result of an attempt to redefine Myanmar's economic progress through the development of a growth accounting framework. An in-depth examination of energy productivity issues and the measurement of energy productivity performance at aggregate and industry levels were conducted. More specifically, time-series data at industry level for Myanmar since 1990 were collected, and the national total energy supply and demand were analyzed. The question of how regional residential electricity demand would likely evolve with rapid urbanization was addressed. Empirical evidence for policy recommendations in the area of energy efficiency suggested that higher energy productivity with lower carbon emissions could be improved through viable eco-solutions and technology transfers by Japanese industries. International support for capacity building is extremely important to improve long-term energy productivity and lower CO_2 emissions in Myanmar.

The APO values the efforts made by all the contributors from Keio University and the Research Institute of Innovative Technology for the Earth to this publication. Sincere gratitude also goes to the Ministry of Foreign Affairs, Government of Japan, for providing a special cash grant to conduct the research. We hope that readers find the publication useful in providing insights on energy productivity in Myanmar which can be applied in other economies.

Dr. Santhi Kanoktanaporn
Secretary-General
Tokyo
September 2018

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The APO also acknowledges Keio University, Tokyo, where the first research was conducted, and RITE, Kyoto, where the second and third projects in the series were completed. Special thanks are extended to Keio Economic Observatory Researcher Hiroshi Shirane, Keio University, for his assistance in preparing this report.

1 Introduction

This project aims to measure the energy productivity performance of Myanmar at the aggregate and industry levels, to assess and suggest potential improvements in the country's energy productivity. Energy productivity is tied to the concept of green productivity (GP), on which the APO provides a wider perspective, including that of sustainable development. It is understood that energy productivity contributes to enhancing GP. The average energy productivity (AEP) is defined as the ratio of output per unit of energy consumed. Although it is simple to define AEP, it must be carefully measured in view of the limited availability and unreliable quality of data in Myanmar. Bearing in mind these constraints, this report consists of three researches.

The first research presented in Chapter 2 redefines Myanmar's economic growth. As pointed out by some international research projects in ADB [1] and The Economist Intelligence Unit [34], some questions have been raised about the reliability of Myanmar's official system of national accounts (MMSNA) under the military regime. In addition, Global Witness [16–17] and Dapice, et al. [12] pointed out that Myanmar's illegal exports of jade, prices of which began to surge in the latter half of the 2000s, have not been properly reflected in the MMSNA. According to these research findings, the total transaction value of jade reached around 48% of Myanmar's GDP in 2014. Chapter 2 tries to provide a comprehensive time-series output data at the industry level for Myanmar since 1990.

The second research, using a bottom-up end-use model, analyzes how the regional residential electricity demand is likely to evolve as a consequence of Myanmar's rapid urbanization. The pattern of ownership of appliances is empirically estimated with a large-scale survey while the appliance operation pattern is calibrated with 2015 residential consumption data. Compared with the traditional top-down model, this model provides abundant details pertaining to future electricity demand. In a rapid urbanization scenario, Myanmar's residential electricity demand could triple by 2030 when compared to 2015. Chapter 3 illustrates the huge potential, along with the high uncertainty of residential electricity demand, which needs to be considered in the electrification process and power planning.

The third research presented in Chapter 4 conducts Myanmar's energy supply-and-demand analysis, while considering the national aggregates. Myanmar's latest energy supply-and-demand conditions were determined using surveys involving face-to-face interviews and literature reviews. The surveys revealed the following:

1. Ongoing energy shortages.

2. Current energy policy: All large hydro development is pending, all coal power plant development is suspended, and natural gas power plant development has a mid-to-low priority.

3. Low efficiency, e.g., 20%, and low capacity factor, e.g., 30% to 40%, of thermal power plants.

Based on the survey, Myanmar's energy supply-and-demand analysis is conducted using a world energy systems model, DNE21+, for a period up to 2050. The simulation results from DNE21+ analysis indicate the importance of addressing energy shortage toward the future growth of Myanmar's economy. Predictable return on investment, based on stable supply of oil, natural gas, and coal is a requisite for stimulating further investments in high-efficiency and capital-intensive power plants. A large diffusion of high-efficiency power plants would accelerate the growth of energy productivity and strengthen the capability for long-term CO2 emission reductions in Myanmar.

The first research was conducted at Keio University, Tokyo, while the second and third researches were conducted at Research Institute of Innovative Technology for the Earth (RITE), Kyoto, within the Research on Green Productivity and Productivity Measurement Program for Myanmar, which is organized by the APO and granted by Ministry of Foreign Affairs, Government of Japan. Prof. Koji Nomura (Keio University), Dr. Keigo Akimoto (RITE), Dr. Junichiro Oda (RITE), and Dr. Nan Wang (RITE) conducted these studies and authored the report, coordinated by Yasuko Asano, officer for the Research and Planning Division, APO. The authors gratefully acknowledge the support of Hiroshi Shirane, researcher, Keio Economic Observatory, Keio University, for research assistance.

2 Redefinition of Economic Growth

2.1 Economic Growth

In March 2011, the civilian government of President Thein Sein took over from the State Peace and Development Council (SPDC), i.e., the military government, in Myanmar. Since then, various economic reforms have been implemented in the country. In April 2012, the government introduced a managed floating exchange rate system, under which the value of the Myanmar kyat is basically determined by the interbank market, though the central bank maintains a degree of influence. This was to unify several greatly different exchange rates (Figure 3), followed by the establishment of a new Foreign Investment Law. Although significant restrictions remain in those businesses that have an impact on subterranean resources and the natural environment as well as those that can be undertaken by Myanmar citizens such as agriculture, livestock breeding, and fisheries, the government is now heading in the direction of easing restrictions on foreign direct investments. In response to such political and economic reforms, the US lifted its ban on the import of goods from Myanmar, excluding gems such as jade, in November 2012. The European Union (EU) lifted is economic sanction, excluding the arms embargo, in April 2013.

In the general elections of November 2015, the National League for Democracy (NLD), led by Aung San Suu Kyi won a landslide victory by taking 80% of the contested seats. The transition from the Thein Sein government to the NLD-led government, leading to the transfer of power on March 30, 2016, was a further step toward democracy. Following the formation of the new government, the Myanmar Investment Commission (MIC), a government-appointed body that scrutinizes proposed inward investment projects from overseas, was temporarily paralyzed with no meeting held for about three months due to a delay in selecting new commission members. It resumed in June 2016.

In response to further progress in democratization, the US lifted all economic sanctions against Myanmar, including the embargo on jade and rubies, in October 2016. Further, the US reinstated Myanmar's eligibility for benefits under the Generalized System of Preferences (GSP) program to reduce or exempt tariffs on some imports from Myanmar, effective 13 November 2016. Until now, foreign direct investment projects in Myanmar have mostly been confined to those from Singapore, China, and other countries within Asia. However, the complete lifting of the US economic sanctions and the restatement of Myanmar's GSP status for trade with the US will likely boost foreign direct investments in Myanmar, not only from the US but also from other countries with an eye to exporting to the US market.

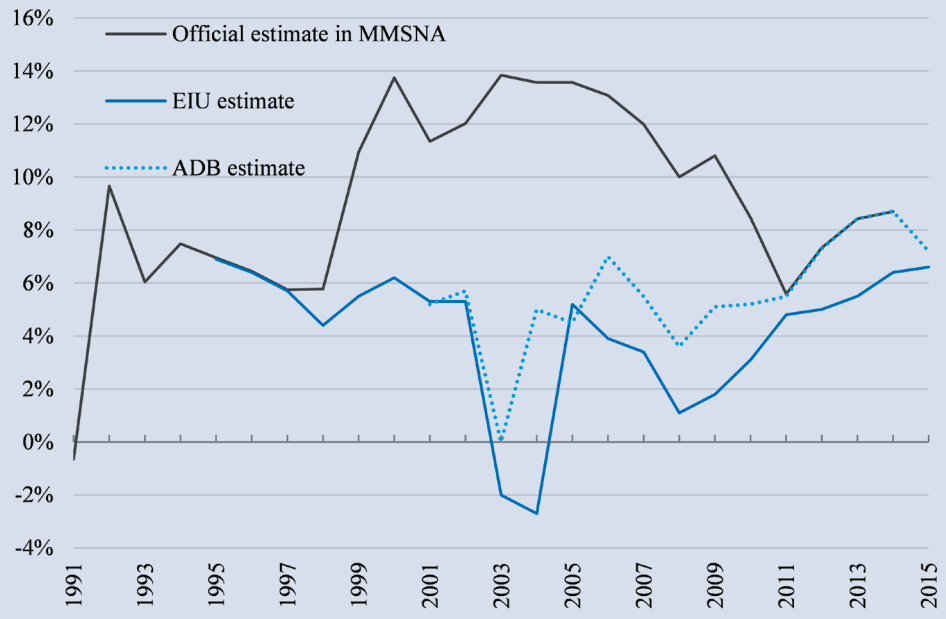
As democratization makes progress, the economic potential of Myanmar, which has a large number of quality young workers in a population of more than 50 million, is attracting significant attention. However, some questions have been raised about the reliability of Myanmar's official statistics on macroeconomic performance. First, it is suspected that under the military regime of the SPDC,

official economic growth rates might have been significantly overstated since the latter half of the 1990s. In forecasting Myanmar's future economic growth, The Economist Intelligence Unit (EIU) of The Economist Group of the UK has been releasing its own estimates of the real GDP growth by taking into account various other factors, i.e., electricity use, trade balance, and the impact of sanctions by the US and the EU in 2003 and later [34]. In Myanmar, the Central Statistical Organization (CSO) has compiled the Myanmar System of National Accounts (MMSNA).

Figure 1 compares the CSO's official GDP growth estimates as per the MMSNA and alternative estimates by the EIU. While the official GDP growth estimates peaked between 2002 and 2004, the EIU estimates show that Myanmar suffered negative growth during the same period due to the economic sanctions imposed by the US and Europe. Considerable deviations are also observed both before and after the period, and the EIU notes that the pace of economic growth as shown in Myanmar's official statistics has been overestimated by two fold. The Asian Development Bank (ADB) has also been publishing its own real GDP growth estimates [1–3]. As shown in Figure 1, growth estimates by the ADB slightly exceed those by the EIU but show that official growth figures based on the MMSNA have been grossly overestimated.[1]

FIGURE 1

OFFICIAL GDP GROWTH VS ALTERNATIVE ESTIMATES



The second problem with the official statistics is that until the shift to the managed floating exchange rate system in April 2012, the official exchange rate had been used in the MMSNA in converting international trade (mainly denominated in the US dollar) into the national currency. Under the official exchange rate, which set the value of the Myanmar kyat at a level far above the market exchange rate, the amounts of exports and imports were significantly undervalued, resulting

1 Currently, the official estimates provided in the MMSNA are used as GDP figures for Myanmar in the United Nations Statistics Division (UNSD)'s National Accounts Estimates, the International Monetary fund (IMF)'s World Economic Outlook Database, and the APO [4].

in a significant underestimation of GDP. The third problem with Myanmar's economic statistics is extensive illegal trade. In recent years, Global Witness [16–17] and a research team at Harvard University's ASH Center for Democratic Governance and Innovation [12] pointed out that illegal exports of jade, whose prices began to surge in the latter half of the 2000s, had not been properly reflected in the MMSNA. According to those recent research findings, the total transaction value of jade was estimated to be 48% of Myanmar's nominal GDP in 2014. While the EIU [34] pointed out the possibility of a significant overestimation of Myanmar's nominal GDP, the fact that illegal jade transactions were not properly accounted for (neither the MMSNA nor the EIU took this fact into consideration), indicates the possibility of an underestimation.

This paper tries to develop new estimates of GDP, from both production and demand sides, by revising Myanmar's system of national accounts based on existing studies, various available materials, and international comparisons. Section 2.2 provides an overview of the MMSNA data that are currently available, some minor revisions in MMSNA, and our adjustment process used in this paper. Specifically, we correct the amounts of exports and imports in Section 2.3, examine and correct data on gross output by industry in Section 2.4, and reassess the transaction value of jade in Section 2.5. Section 2.6 of this chapter summarizes our estimation results. Some figures and tables on the revised estimates are provided in the appendices.

2.2 Revision on National Accounts

2.2.1 Industry Outputs

In the MMSNA, GDP is measured by the production approach based on value added by the industry. The constraint is that the MMSNA provides data on nominal and real value added by industry but not on the corresponding gross outputs. Therefore, in this report, we use data on gross outputs by industry from the United Nations Statistics Division (UNSD)'s National Accounts Official Country Data. The MMSNA's value added by industry and the UNSD's gross output by industry are mostly consistent with each other but there are two points that require attention. First, energy and mining, and second, transportation and communications are further broken down into subcategories in the MMSNA (shown in the right column of Table 1) but not in the UNSD classification. Therefore, this report deals only with 12 broadly classified industries.

TABLE 1

INDUSTRY CLASSIFICATION

This study	MMSNA
1. Agriculture	1. Agriculture
2. Livestock and fishery	2. Livestock and fishery
3. Forestry	3. Forestry
4. Energy and Mining	4. Energy and mining
	4.1 Energy
	4.2 Mining
5. Manufacturing	5. Processing and manufacturing
6. Electricity	6. Electric power
7. Construction	7. Construction

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This study	MMSNA
8. Transportation and communications	8. Transportation and communications
	8.1 Transportation
	8.2 Communications
9. Financial institutions	9. Financial institutions
10. Social and administrative services	10. Social and administrative services
11. Rental and other services	11. Rental and other service
12. Wholesale and retail	12. Trade

Second, there are certain discrepancies between the two systems that may be regarded as time-series inconsistencies. Figure 2 shows changes over periods in the ratio of nominal value added to nominal gross output (value-added rate). This is calculated by using data on value added by industry from the MMSNA and data on gross output by industry from the UNSD. The two sets of data generally correspond fairly well but some irregularities are observed in certain years. In agriculture, the value-added rate dropped in 1993. However, as discussed later, we found no plausible factors in physical output data. The value-added rate remained stable even in 1991 and 2008 when agriculture suffered substantial damages due to cyclones. In this report, we will use MMSNA-based data on value added by industry as a benchmark and make adjustments to the UNSD-based data on gross output by industry to remove the irregularities in the time series of the value-added rate (see Rev-0, Table 2). In case of electricity, there were some periods in which the value-added rate for the industry fell sharply. However, as these are also the periods in which Myanmar increased its dependence on import-reliant coal power generation (Figure 25), we avoid making ad hoc adjustments here.

FIGURE 2-1

ADJUSTMENTS IN VALUE-ADDED RATIOS

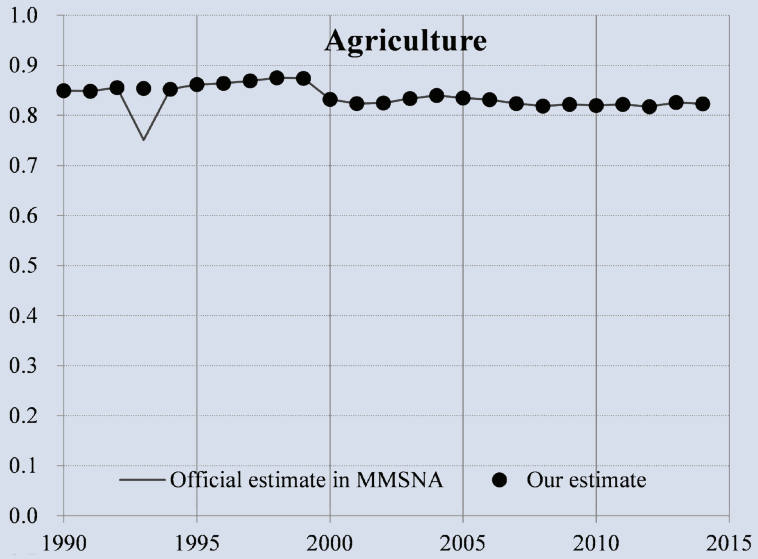


FIGURE 2-2

ADJUSTMENTS IN VALUE-ADDED RATIOS

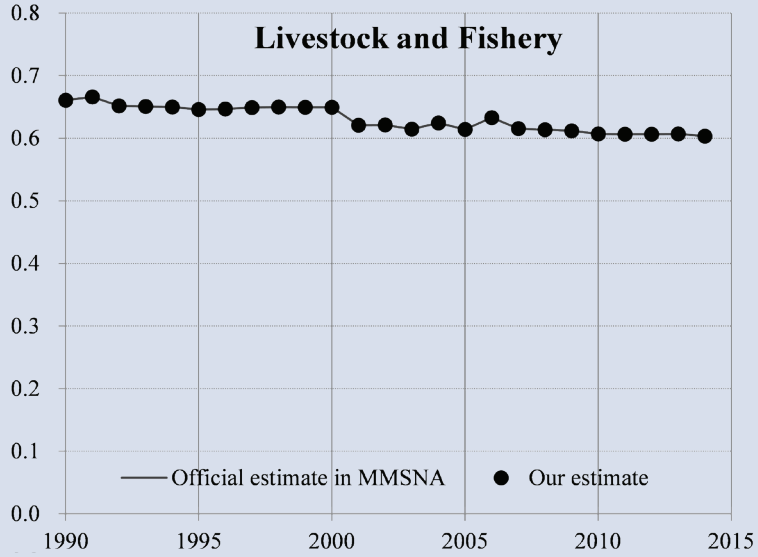


FIGURE 2-3

ADJUSTMENTS IN VALUE-ADDED RATIOS

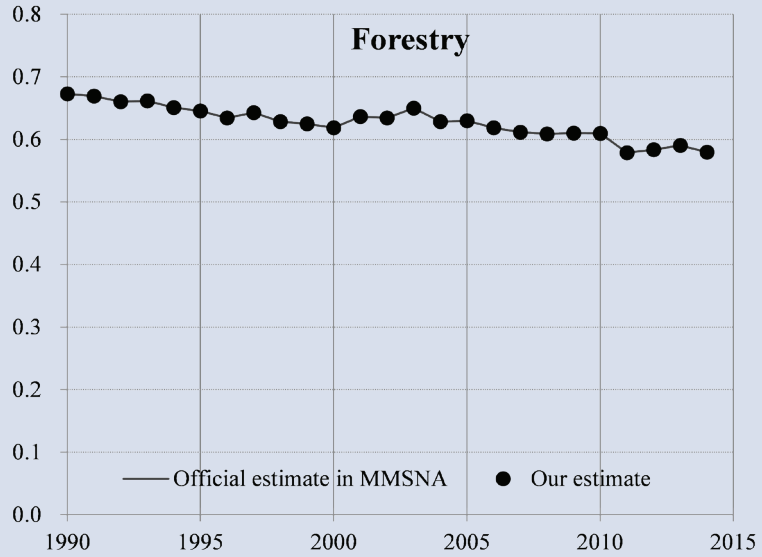


FIGURE 2-4

ADJUSTMENTS IN VALUE-ADDED RATIOS

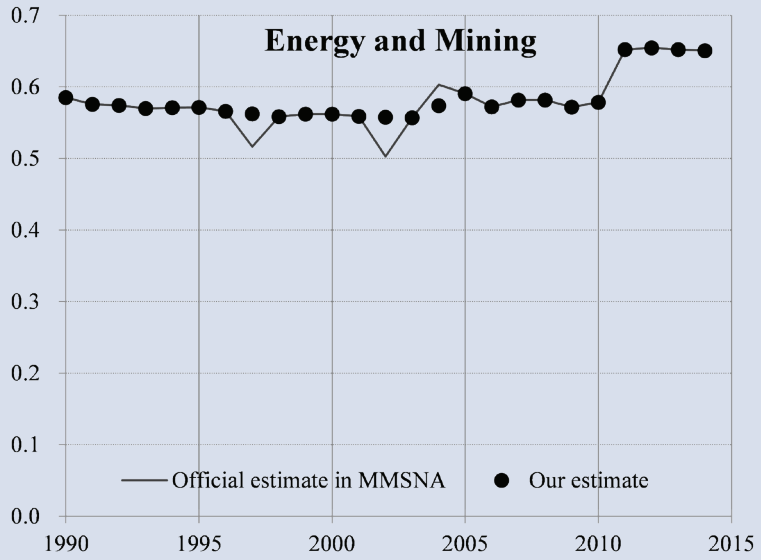


FIGURE 2-5

ADJUSTMENTS IN VALUE-ADDED RATIOS

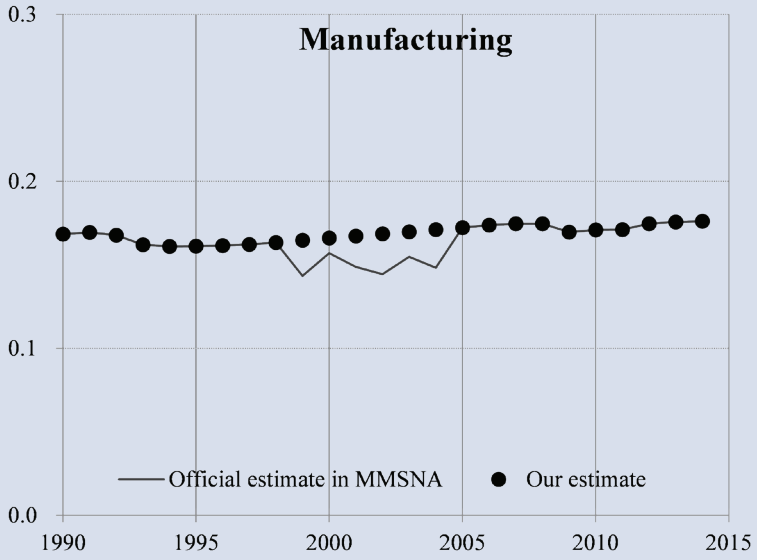


FIGURE 2-6

ADJUSTMENTS IN VALUE-ADDED RATIOS

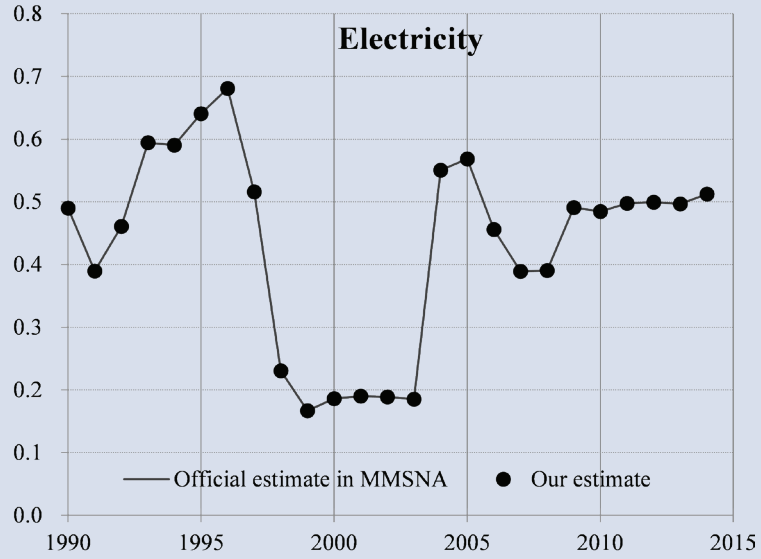


FIGURE 2-7

ADJUSTMENTS IN VALUE-ADDED RATIOS

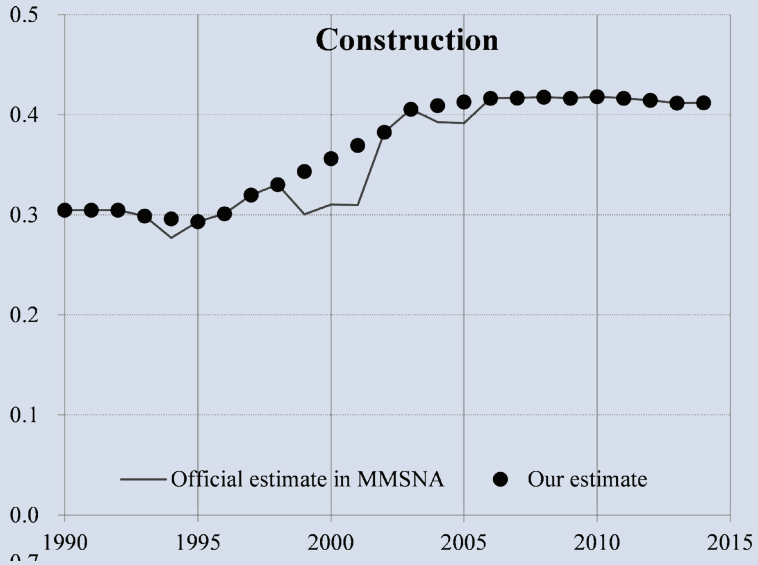


FIGURE 2-8

ADJUSTMENTS IN VALUE-ADDED RATIOS

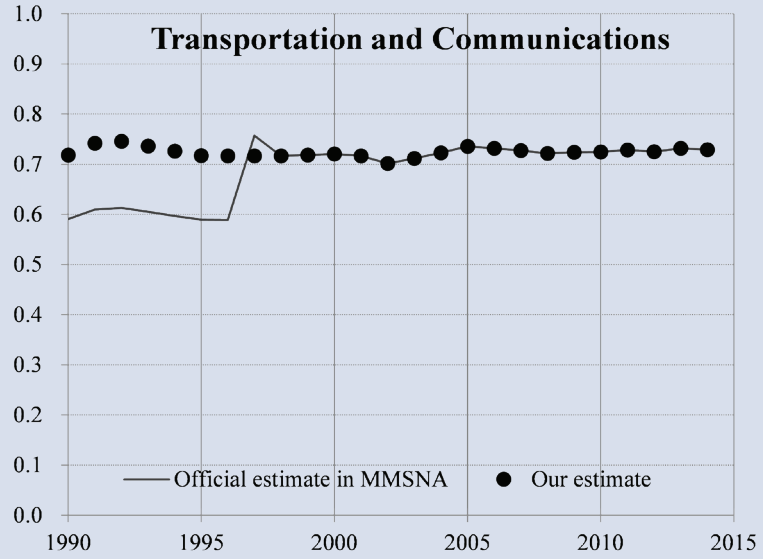


FIGURE 2-9

ADJUSTMENTS IN VALUE-ADDED RATIOS

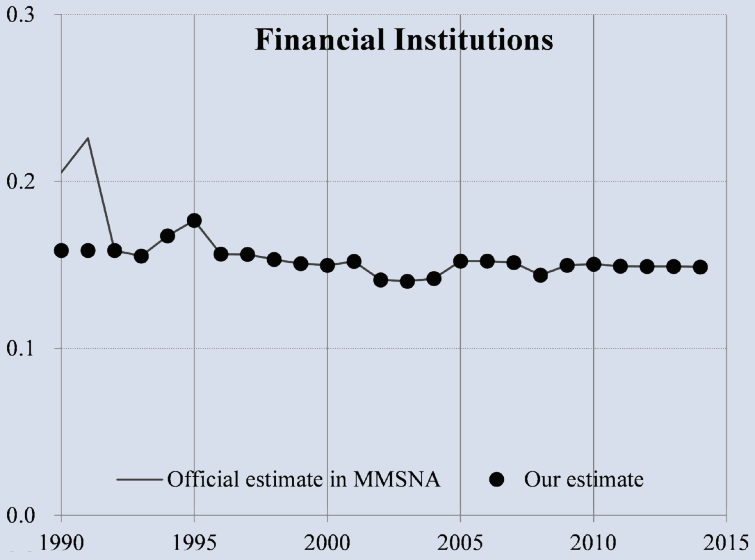


FIGURE 2-10

ADJUSTMENTS IN VALUE-ADDED RATIOS

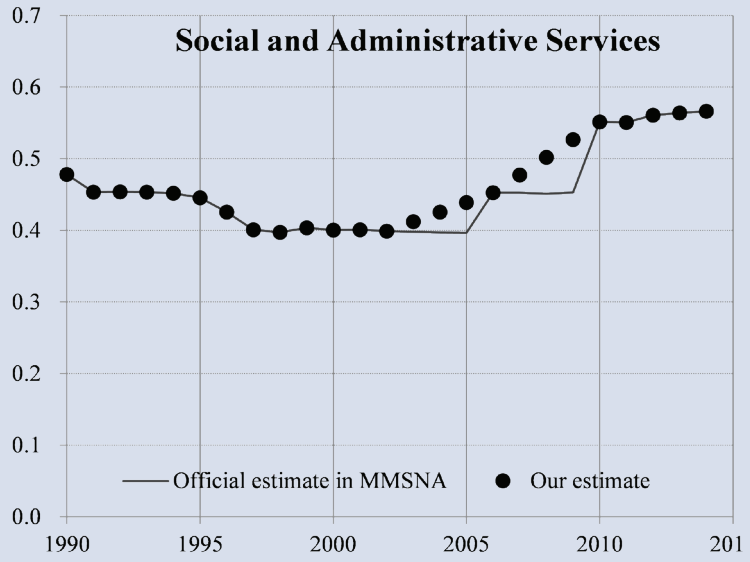


FIGURE 2-11

ADJUSTMENTS IN VALUE-ADDED RATIOS

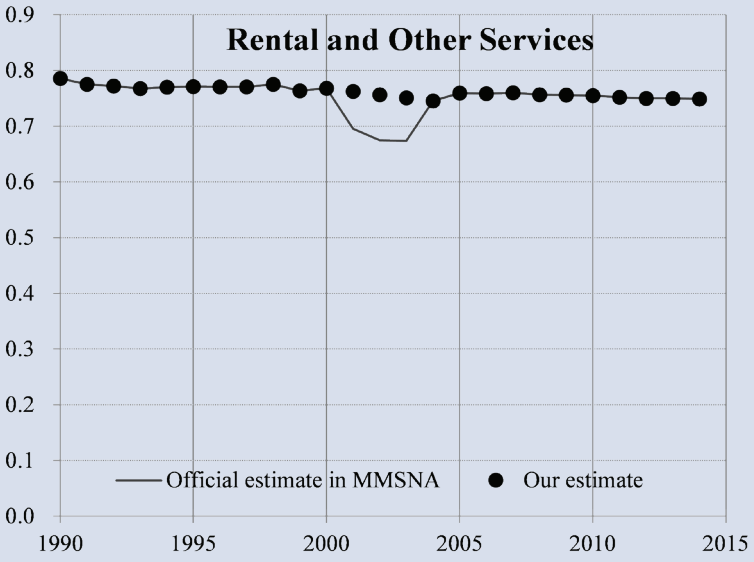
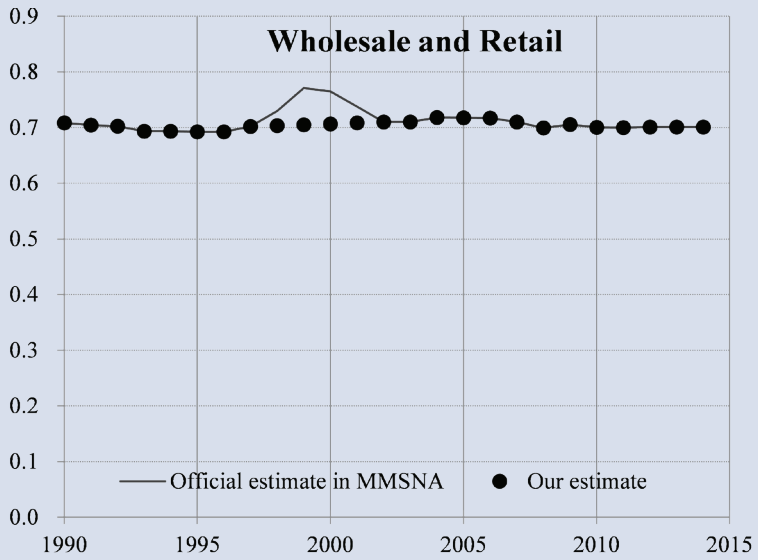


FIGURE 2-12

ADJUSTMENTS IN VALUE-ADDED RATIOS



2.2.2 Output Prices

The constraint on the side of price data is that neither the MMSNA nor the UNSD provides data on gross output prices by industry. Although we do not know how the MMSNA estimates the prices of value-added by industry, we treat the value-added price index for each industry as being equal to the gross output price index for that industry.[2] In Section 0, we make adjustments to data on real gross output by industry, based on official estimates (see Rev-2, Table 2). First, we compare official estimates for agriculture, and for energy and mining with corresponding estimates in physical units by external organizations. Second, for livestock and fishery, manufacturing, and electricity, we compare the official estimates in the MMSNA with corresponding estimates in physical units separately released by the CSO. Although it is possible that the quantitative data released by the CSO have been overestimated, the comparison shows that the two sets of data also differ in their trajectories over time. Third, for transportation and communications, and for wholesale and retail, where a demand is mainly a derived demand as it is dependent on activities in other industries, we make adjustments associated with the aforementioned adjustments to data on real gross output by industry. In each case, relevant data from neighboring countries such as Cambodia, Thailand, and Vietnam are used for reference and comparison.

These downward revisions to real gross outputs by industries result in upward revisions to costs of production, which are implicitly computed from MMSNA-based data on nominal gross output by industries. However, the resulting prices of production for most industries, except for energy and mining, appear to be significantly overestimated when compared to the consumer price index (CPI) and international prices. Therefore, data on nominal value of gross output are also adjusted for many industries. The adjustments to nominal gross output data revise the nominal and real value added via the value-added rate for each industry as seen in Figure 2, after rev-0 in Table 2.

2 Industry-level data on the values of gross output and value added (both in nominal and real terms) after these adjustments are hereinafter referred to as 'official estimates' in the MMSNA.

TABLE 2

OUR REVISIONS TO THE MMSNA

		Gross output (GO)			Value added (VA)	
		value (v)	quantity (q)	price (p)	value (vv)	quantity (vq)
1. Agriculture	if rev-2	p*q	rev-2	rev-1	rev-0,1,2	vv/p
	otherwise	rev-0,1	v/p	rev-1	rev-1	-
2. Livestock and fishery		p*q	rev-2	rev-1	rev-1,2	vv/p
3. Forestry		p*q	-	rev-1	rev-1	-
4. Energy and mining	if rev-2,3	rev-0,1,3	rev-2,3	v/q	rev-1,3	vv/p
	otherwise	rev-0,1	v/p	rev-1	rev-1	vv/p
5. Manufacturing	if rev-2	p*q	rev-2	rev-1	rev-0,1,2	vv/p
	otherwise	rev-0,1	v/p	rev-1	rev-1	-
6. Electricity		-	-	-	-	-
7. Construction		rev-0	v/p	-	-	-
8. Transportation and communications		p*q	rev-2	-	rev-0,2	vv/p
9. Financial institutions		rev-0	v/p	-	-	-
10. Social and Administrative Service		rev-0	v/p	-	-	-
11. Rental and other services		rev-0	v/p	-	-	-
12. Wholesale and retail		p*q	rev-2	-	rev-0,2	vv/p

Note: In revision of gross output, 0=adjustment in irregular changes in value-added rates by industry, 1=revision in trade (Section 2.3), 2=revision in output (Section 0), and 3=revision in jade value (Section 0)

2.2.3 Final Demand

In the MMSNA, final demand is composed of five components: gross fixed capital formation (GFCF), net increase in stock (INV), export (EX), import (IM), and total consumption.[3] Here, total consumption is defined as the difference between market price-based GDP for the country and the sum of the remaining four components of final demand, and no further breakdowns are provided in the MMSNA. As for government consumption (GC), relevant data from the UNSD's National Accounts Estimates of Main Aggregates (UN estimates) can be used. However, in recent years, the amount of government consumption based on the UN estimates has increased two- to three-times the nominal value of gross output in the case of social and administrative services, supposed to be conceptually similar to government consumption. In our estimation, we assume that the nominal value of gross output for social and administrative services equals the amount of government consumption. Household consumption (HC) is therefore defined as total consumption net of government consumption, which amounts to the final demand getting broken into six components.

As the first step toward revising data on final demand, we make adjustments to the values of import and export (see Rev-1, Table 2) in Section 2.3. This involves converting amounts based on the official exchange rate to those based on the market exchange rate, by checking Myanmar's trade statistics against those of its major trade partners and adding the amounts of trades in services and direct purchases that are not included in the MMSNA. Then, in Section 0, we reassess the values of jade exports and have those reflected in the GDP statistics (see Rev-3, Table 2). Data used for revising the MMSNA are as shown in Table 3.

3 From 2005 onward, final demand in the MMSNA includes statistical discrepancy, in addition to the five components stated above.

TABLE 3

LIST OF DATA USED FOR REVISING MMSNA

Variables	Periods	Unit	Sources
Official estimate in MMSNA			
1 Final demands (C, GFCF, INV, EX, IM)	2010–2014	At current and 2010 prices	MMSNA (2015), CSO
2 Final demands (C, GFCF, INV, EX, IM)	2005–2010	At current and 2005 prices	MMSNA (2011), CSO
3 Final demands (C, GFCF, INV, EX, IM)	2000–2005	At current and 2000 prices	MMSNA (2006), CSO
4 Final demands (C, GFCF, INV, EX, IM)	1987–2000	At current and 1985 prices	MMSNA (2003), CSO
5 Gross value added (VA) by industry	2010–2014	At current and 2010 prices	MMSNA (2015), CSO
6 Gross value added (VA) by industry	2005–2010	At current and 2005 prices	MMSNA (2011), CSO
7 Gross value added (VA) by industry	2000–2005	At current and 2000 prices	MMSNA (2006), CSO
8 Gross value added (VA) by industry	1987–2000	At current and 1985 prices	MMSNA (2003), CSO
9 Gross output (GO) by industry	1998–2014	At current prices	National Accounts Official Country Data, UNSD
10 Gross output (GO) by industry	1974–1998	At current prices	National Accounts Official Country Data, UNSD
Revision in trade			
11 Official exchange rate	1960–2014	At current prices	World Development Indicators, WB
12 Market exchange rate	1970–2014	At current prices	National Accounts Estimates of Main Aggregates, UNSD
13 Trade in services	1980–2014	At current prices	WTO Statistics Database, WTO
14 Trade by type of principal commodities	1990–2014	At current prices	Myanmar Statistical Yearbook, CSO
15 Trade by commodity section (by B-SITC)*	1990–2014	At current prices	Myanmar Statistical Yearbook, CSO
16 Trade by commodity section (by HS)*	2001–2014	At current prices	Myanmar Statistical Yearbook, CSO
17 Trade by country*	1990–2014	At current prices	Myanmar Statistical Yearbook, CSO
18 Trade by commodity section	1990–2014	At current prices	UN Comtrade, UNSD
19 Trade by country	1990–2014	At current prices	UN Comtrade, UNSD
20 Composition of imports	1990–2014	At current prices	Myanmar Statistical Yearbook, CSO
21 Trade by country*	1990–2014	At current prices	Myanmar Statistical Yearbook, CSO

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Variables	Periods	Unit	Sources
22 Freight and insurance	2005	At current prices	Asian International Input-Output Table, JETRO
Revision in output			
23 Sown area of selected crops*	1990–2014	At acres	Myanmar Statistical Yearbook, CSO
24 Harvested area of selected crops*	1990–2014	At acres	Myanmar Statistical Yearbook, CSO
25 Production of selected crops*	1990–2014	At physical unit	Myanmar Statistical Yearbook, CSO
26 Prices of selected crops at harvest time*	1990–2014	At current prices	Myanmar Statistical Yearbook, CSO
27 Agricultural production by country*	1961–2013	At constant prices	FAOSTAT, FAO
28 Agricultural area by country*	1961–2013	At acres	FAOSTAT, FAO
29 Production of grains	1960–2015	At physical unit	Production, Supply and Distribution, USDA
30 Primary livestock production by country*	1961–2013	At physical unit	FAOSTAT, FAO
31 Production of fish and prawns*	1990–2014	At number of unit	Myanmar Statistical Yearbook, CSO
32 Livestock breeding	1990–2014	At number of unit	Myanmar Statistical Yearbook, CSO
33 Volume of production of selected commodities	1990–2014	At physical unit	Myanmar Statistical Yearbook, CSO
34 Electric power generation by type and location*	1990–2014	At physical unit	Myanmar Statistical Yearbook, CSO
35 Production of electric power*	1990–2014	At physical unit	Myanmar Statistical Yearbook, CSO
36 Sales of electric power by type*	1990–2014	At current prices	Myanmar Statistical Yearbook, CSO
37 Retail prices of selected commodities in Yangon*	1990–2014	At current prices	Myanmar Statistical Yearbook, CSO
38 Wholesale prices of selected commodities in Yangon	1990–2014	At current prices	Myanmar Statistical Yearbook, CSO
39 Energy demand and production	1990–2014	At oil equivalent tonnes	Energy Balance Table, IEA
Revision in jade value			
40 Jade production	1990–2014	At physical unit	Myanmar Statistical Yearbook, CSO
41 Jade production*	1996–2013	At physical unit	U.S. Geological Survey, USGS
42 Jade sales*	1995–2014	At current prices	Burma Gem Sales and Statistics, Pala International
43 Jade sales	2005–2014	At current prices	Global Witness

Note: * indicates the data used for reference.

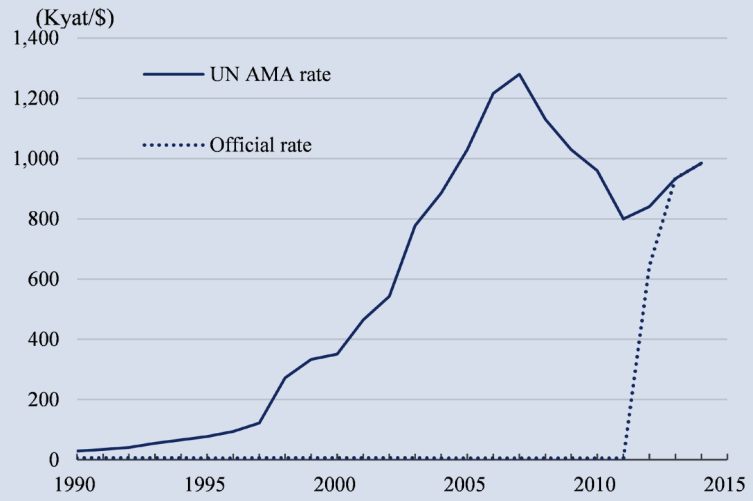
2.3 Revision in Trade

2.3.1 Revaluation of Exports

Until April 2012, multiple exchange rates were used in Myanmar. Basically, the US dollar is and has been the currency of settlement, though the euro is used in some transactions while the Chinese yuan is used in border trades. However, prior to the shift to managed floating exchange rate system, the official exchange rate had been used to convert trade values in the currency of settlement into trade values in the domestic currency in MMSNA and the balance of payment (BOP). Figure 3 shows a comparative view of changes in time series of the official exchange rate and the UNSD AMA rate, which can be regarded as the market exchange rate. Prior to the shift to the managed floating exchange rate system, the two exchange rates were deviating significantly from each other. In 2007, the official exchange rate was 5.78 kyat per US dollar, overvalued by more than 220 times compared to the market exchange rate of 1,280 kyat per US dollar. Accordingly, trade values were grossly underestimated.

FIGURE 3

MARKET AND OFFICIAL EXCHANGE RATES



The underestimation of export values results in an underestimation of the gross output and value added of industries producing goods for exports. Figure 4 illustrates how the gross output of each industry is absorbed in part by the domestic demand[4] and in part by the export demand (as converted into domestic currency value by the official exchange rate) before making any adjustments. In the energy and mining industry, where the share of export demand is particularly high, the underestimation of trade value due to the use of official exchange rate is a major factor explaining the discontinuity in time-series trend of nominal gross output between 2010 and 2011. A similar gap is also observed in nominal value added for the industry, indicating that the underestimation of export values caused the underestimation of nominal GDP.

4 Export values are based on the values of exports by commodities in the Myanmar Statistical Yearbook (MSY) published by the CSO. The value of exports of each commodity, denominated in the US dollar, has been converted into kyat terms and applied to the relevant industry, assuming that each of the 20 commodities corresponds to an industry. The value of an industry's gross output accounted for by domestic demand is defined as the difference between the nominal value of gross output (Subsection 2.2.1) and the value of exports for the corresponding industry.

FIGURE 4-1

NOMINAL GROSS OUTPUT (BEFORE REVISION)

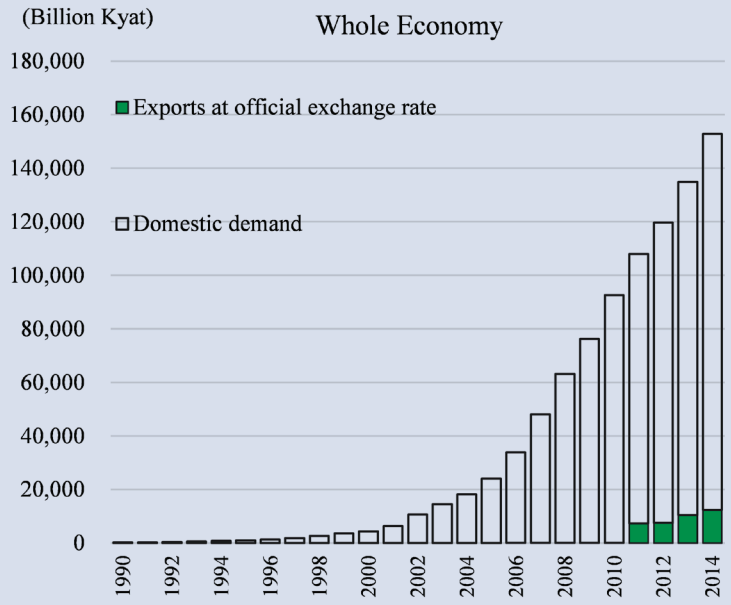


FIGURE 4-2

NOMINAL GROSS OUTPUT (BEFORE REVISION)

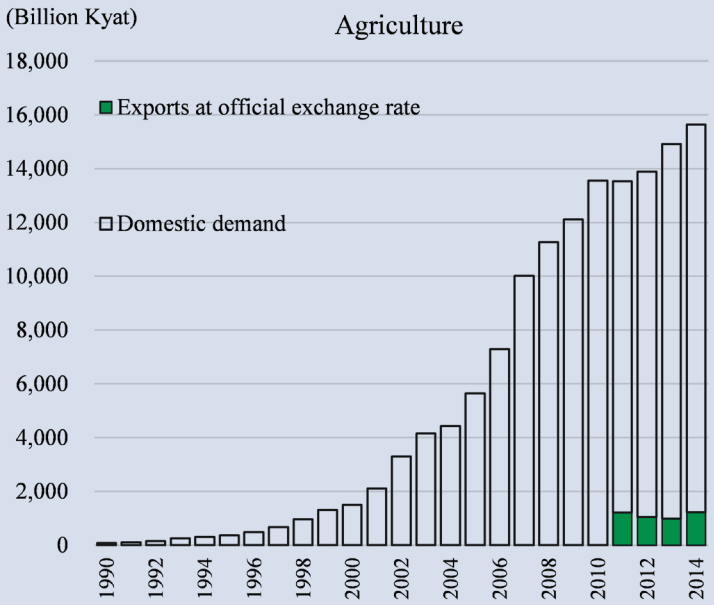


FIGURE 4-3

NOMINAL GROSS OUTPUT (BEFORE REVISION)

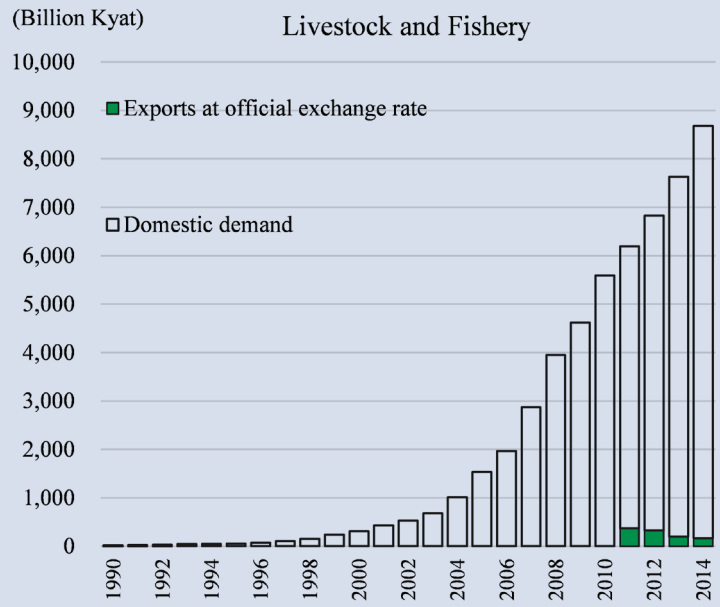


FIGURE 4-4

NOMINAL GROSS OUTPUT (BEFORE REVISION)

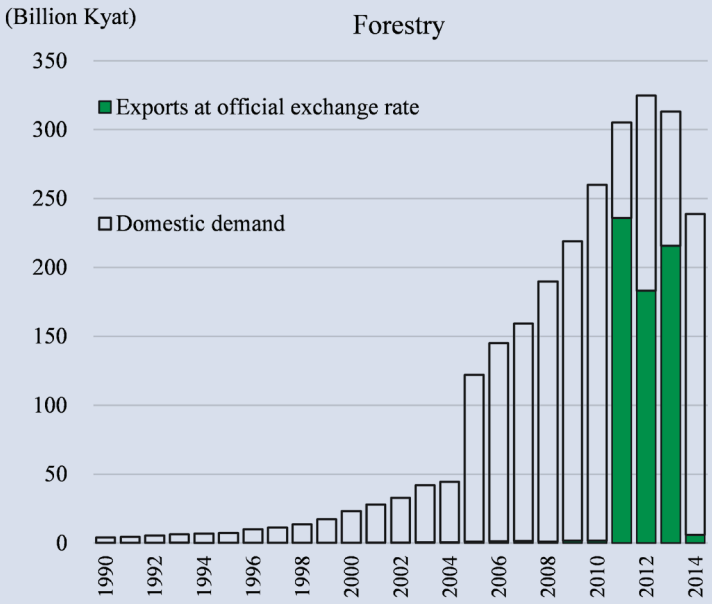


FIGURE 4-5

NOMINAL GROSS OUTPUT (BEFORE REVISION)

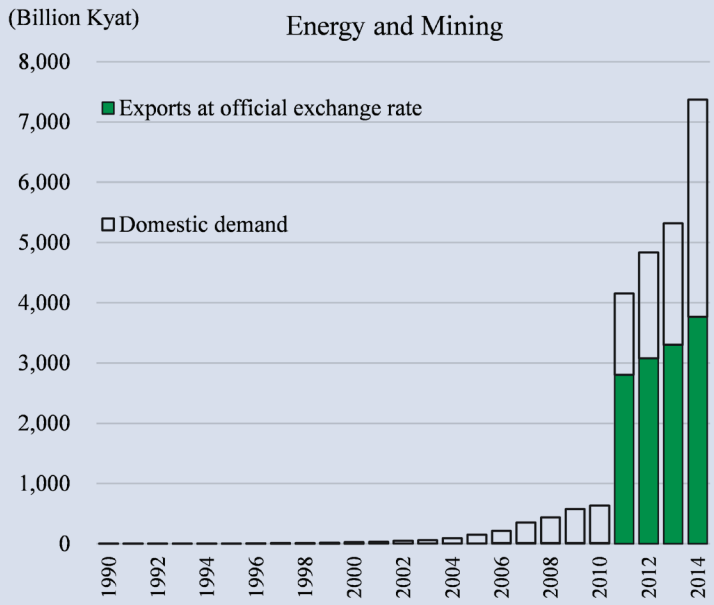


FIGURE 4-6

NOMINAL GROSS OUTPUT (BEFORE REVISION)

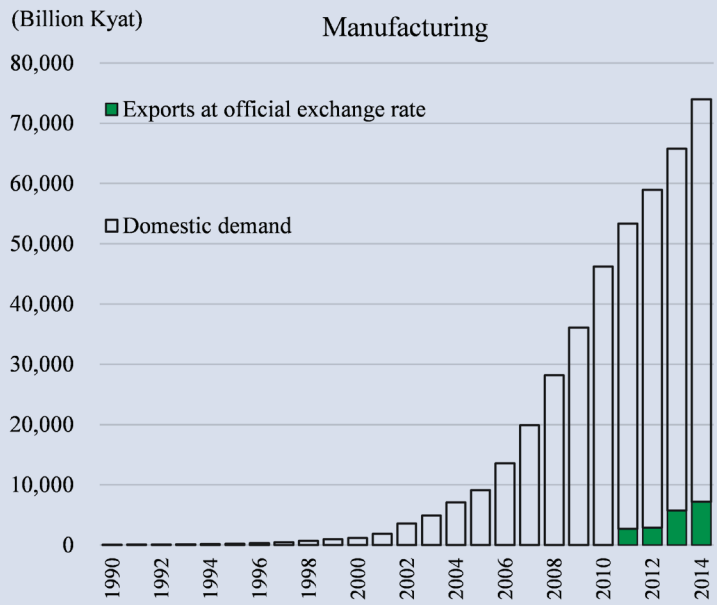


FIGURE 5-1

NOMINAL GROSS OUTPUT (BEFORE REVISION)

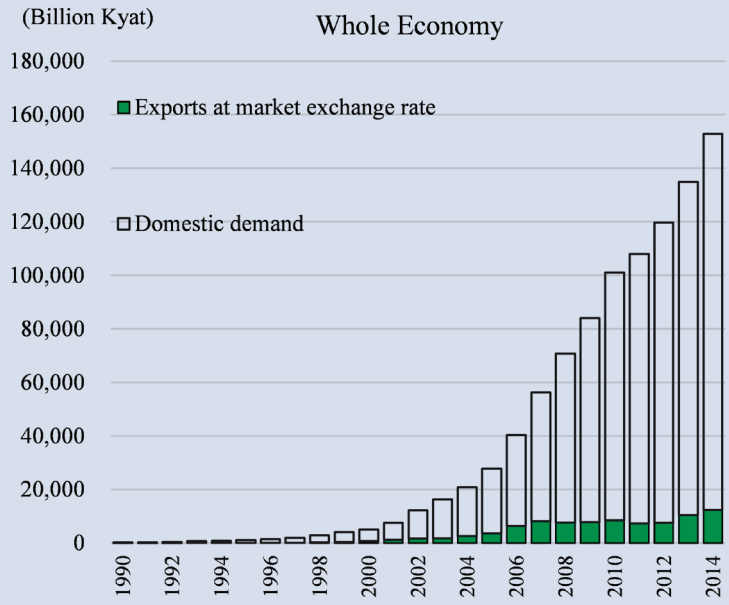


FIGURE 5-2

NOMINAL GROSS OUTPUT (BEFORE REVISION)

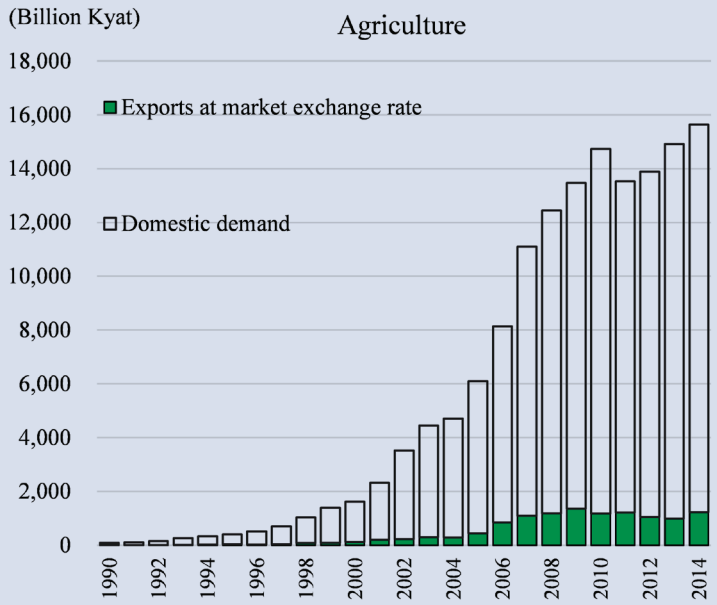


FIGURE 5-3

NOMINAL GROSS OUTPUT (BEFORE REVISION)

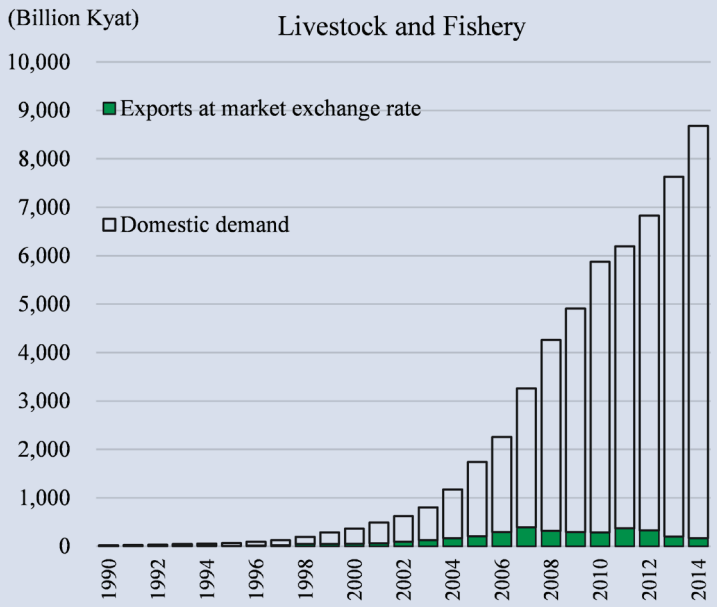


FIGURE 5-4

NOMINAL GROSS OUTPUT (BEFORE REVISION)

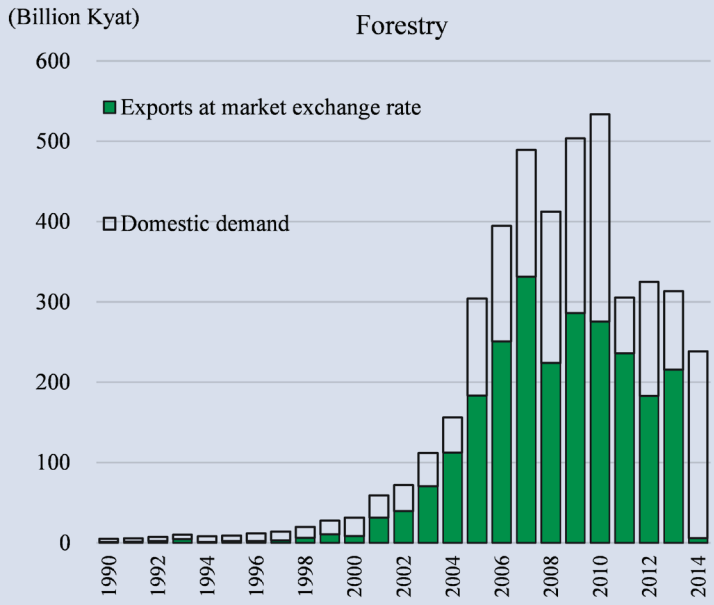


FIGURE 5-5

NOMINAL GROSS OUTPUT (BEFORE REVISION)

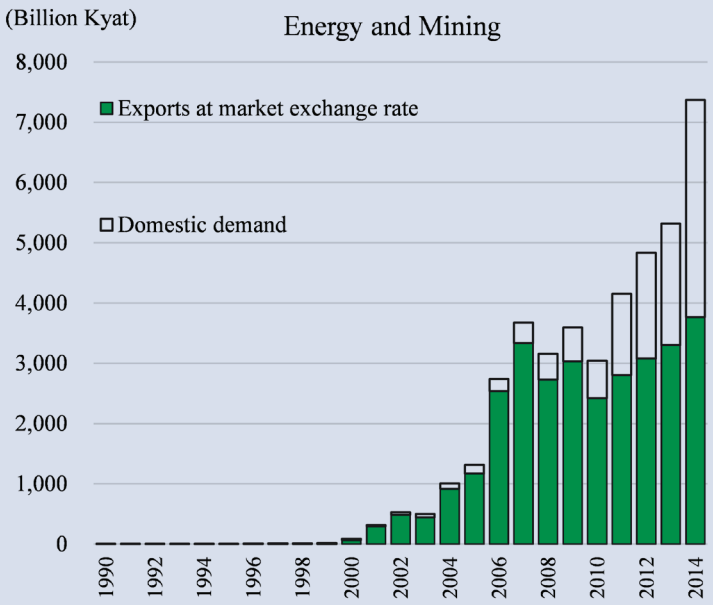


FIGURE 5-6

NOMINAL GROSS OUTPUT (BEFORE REVISION)

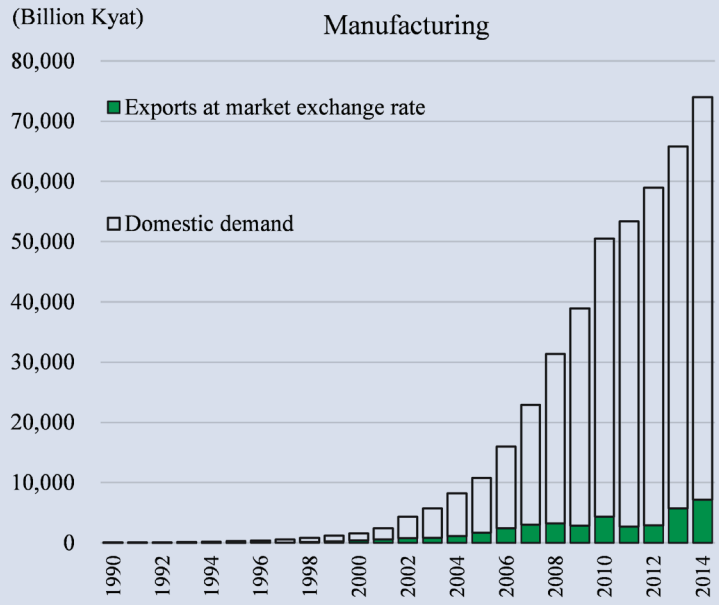


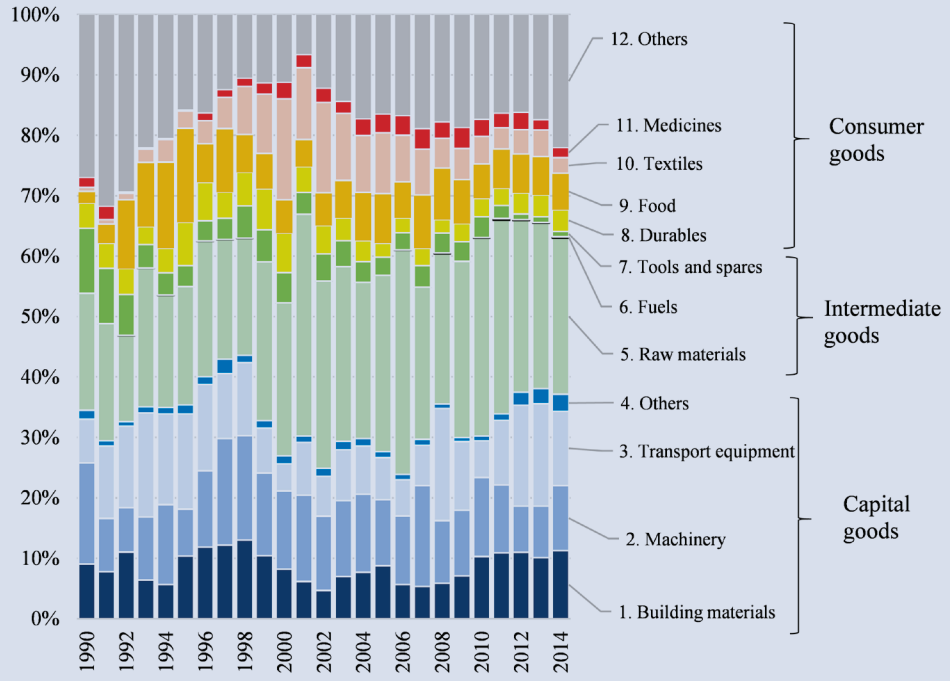
Figure 5 shows the gross output values, recalculated by using the adjusted export values based on the market exchange rate. We can see that the discontinuity observed for the energy and mining industry has been resolved by revaluing the exchange rate. Meanwhile, although no particular discontinuity is observed in the graph for forestry in Figure 4, which depicts preadjustment values, the trend of gross domestic values as seen in Figure 5 is quite different. The upward revision of gross output in the industry resulting from the revaluation of exports by the industry leads to an increase in nominal GDP for the country, given that the value-added rate of the industry is constant. Specifically, this necessitates an upward revision of nominal GDP every five years, starting from 1990 through 2010, by 3.3%, 6.0%, 9.5%, 12.9%, and 8.6%, successively.

2.3.2 Revaluation of Imports

In case of import of intermediate goods, the underestimation of the values of imports denominated in the domestic currency may lead to an underestimation in the value of GDP. Figure 6 shows the composition of imports by types of commodities in value terms, based on data provided in the Myanmar Statistical Yearbook (MSY). Commodities are classified into three broad categories: capital goods, intermediate goods, and consumer goods. These are further broken down into 12 subcategories. Among the imported goods, 20% to 30% are considered to be intermediate goods.

FIGURE 6

COMPOSITION OF IMPORT



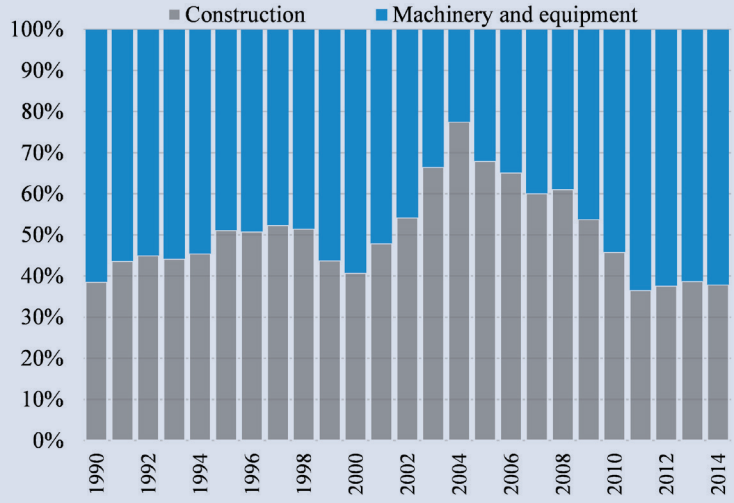
Revaluing the intermediate goods, based on the market exchange rate would create a significant discontinuity in the time-series trend of the value-added rate at the aggregate level. Also,

allocating the values of imports by commodities to the corresponding industries under certain assumptions would result in negative value-added rates for some industries. Based on these considerations, we refrain from making GDP adjustments in the revaluation of imports of intermediate goods.

Considering that Myanmar is dependent on imports for most of the machinery and equipment as capital goods, if such imports are measured in kyat terms converted from the US dollar at the official exchange rate, the construction industry's share in gross fixed capital formation (GFCF) can be presumed to be nearly 100%. Figure 7-1 plots the construction industry's share in GFCF, assuming that 95% of the nominal gross output of the industry is capital formation, while the remainder is accounted for maintenance and repair, and hence treated as intermediate consumption. The construction industry's share generally falls in the range of 40–50%, showing no indication of an undervaluation of machinery and equipment imports. Meanwhile, an estimation based on data on imports (after adjustments as discussed in Subsection 2.3.3), shows that investments in machinery and equipment amounted to 4.8 trillion kyat in 2014,[5] which represented only one-third of 14.3 trillion kyat of such investments presented in the MMSNA. It is therefore highly likely that the nominal GFCF in the MMSNA has been overestimated along with the overestimation of nominal GDP. In our estimation, based on data on imports as the amount of investment in machinery and equipment, the construction industry's share in GFCF expands to 50–70% (Figure 7-2).

FIGURE 7-1

CONSTRUCTION INDUSTRY'S SHARE IN GFCF

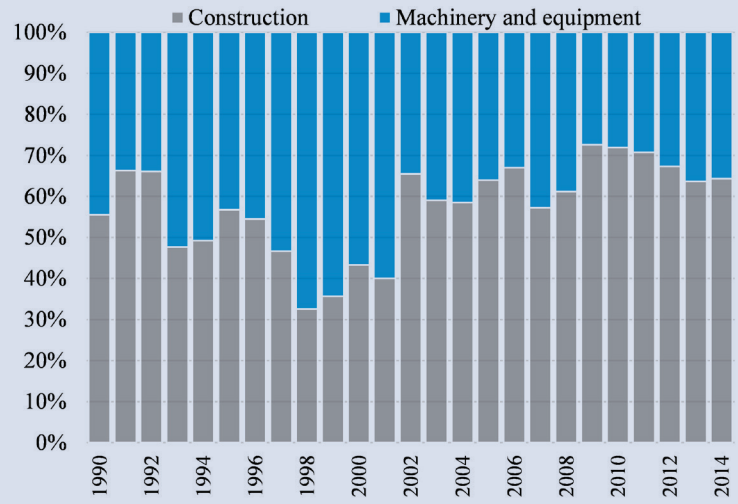


Before revision

5 The amount of investment is estimated at purchaser's prices, calculated as the sum of the gross outputs that are assumed to be accounted for by GFCF, i.e., 80% of machinery and 50% each of transport equipment, and others in Figure 6, plus commercial margins and the estimated cost of transportation.

FIGURE 7-2

CONSTRUCTION INDUSTRY'S SHARE IN GFCF



After revision

Now, consider that the balance between output and final demand measured at the market exchange rate is described by the following equation:

$$(1)\ GDP = HC + GC + GFCF + INV + EX - IM$$

The values of exports (EX*) and imports (IM*) measured at the official exchange rate are defined as:

$$(2)\ EX = EX^{*} + R^{EX} \text{ and } IM = IM^{*} + R^{IM}$$

In the MMSNA, household consumption (HC) is defined as the difference between GDP and the total of the final non-HC demand. Therefore, the aggregate balance in the MMSNA for the periods in which export values were measured at the official exchange rate can be described as:

$$(3)\ (GDP - R^{EX}) = (HC - R^{IM}) + GC + GFCF + INV + EX^{*} - IM^{*}$$

As such, in the current MMSNA, nominal GDP is measured as (GDP – R^{EX}) and underestimated by R^{EX}. Likewise, household consumption is measured as (HC – R^{IM}) and underestimated by R^{IM}. In this section, we use equation (3) as the basis and revise it into equation (1) by reassessing values measured against the official exchange rate at the market exchange rate.

Figure 8 compares the official estimates of export and import values in the MMSNA, measured at the official exchange rate, with our estimates (measured at the market exchange rate). The discontinuity in the trend between 2010 and 2011 observed in the official MMSNA estimates, shown through the dotted line in Figure 8, is resolved in our estimates measured at the market exchange rate. The revaluation of import values at the market exchange rate does not affect GDP

as shown in equation (3). Although household consumption is affected by the revaluation of import values, the revision is made under the influence of various factors to be discussed later.

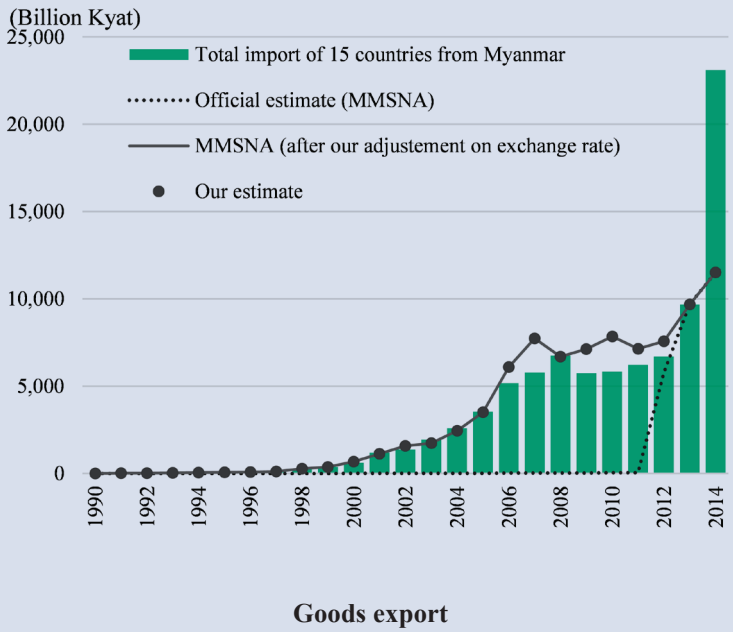
2.3.3 Other Revisions in Trade

In addition to the revaluation at the market exchange rate in the preceding subsection, we have also made revisions pertaining to two aspects, namely, the reexamination of import values in trade statistics, and adjustments to the SNA concept. By examining trade between pairs of countries, based on the customs data on exports reported by one country and the corresponding imports data reported by its trade partners, Kellenberg [21] found that lower the level of economic development and greater the level of corruption, more likely was the country to underreport exports. Meanwhile, with regard to the case of Myanmar, Ebashi [13] pointed out the possibility of underreporting the amounts of exports and imports in a bid to evade the export taxes and import tariffs, respectively. Figure 8 compares trade values reported in the MMSNA and the sums of corresponding trade figures reported by Myanmar's 15 major trade partners and published on the UN Comtrade.[6] As shown in Figure 8-1, the value of exports reported in the MMSNA has generally been consistent with the sum of corresponding imports reported by the trade partners, with the former slightly exceeding the latter 2006 onward. Thus, as far as export values are concerned, we do not find any underreporting tendency in the MMSNA.[7]

Meanwhile, imports reported in the MMSNA include cost, insurance, and freight (CIF), whereas exports reported by the trade partners are free on board (FOB). Accordingly, the value of

FIGURE 8-1

GOODS TRADE, COMPARISON WITH VALUES IN MAJOR TRADING NATIONS

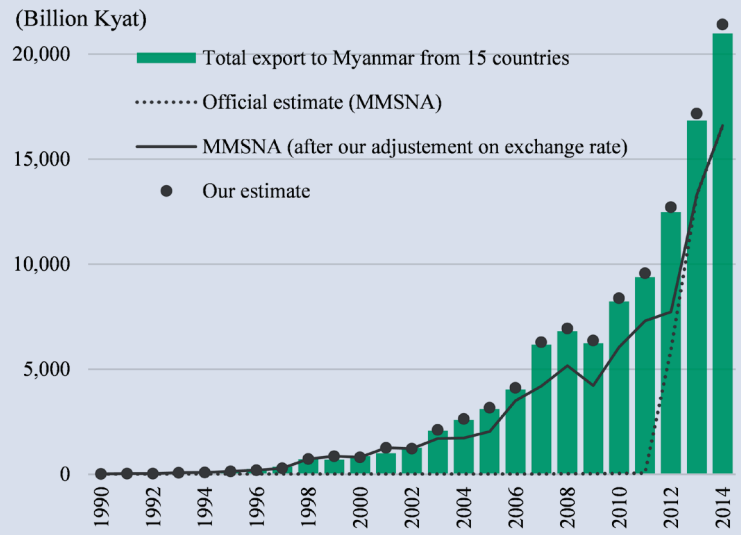


6 Myanmar's 15 major trade partners are: PR China, Hong Kong, India, Indonesia, Japan, Malaysia, the ROK, Singapore, Thailand, the US, France, Italy, the UK, Vietnam, and Germany.

7 Although the sum of imports reported by the trading partners for 2014 was twice the corresponding value of exports reported in the MMSNA, this is attributable to PR China's import of jade from Myanmar, as discussed in detail in Section 0.

FIGURE 8-2

GOODS TRADE, COMPARISON WITH VALUES IN MAJOR TRADING NATIONS



Goods import

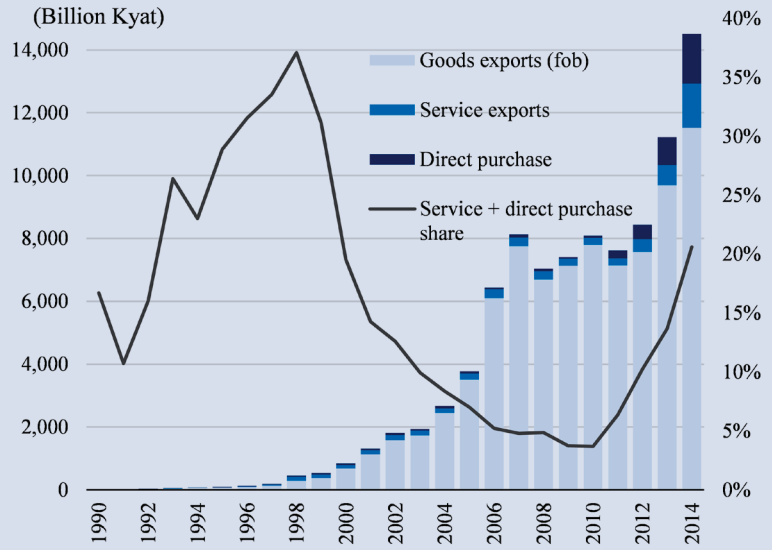
imports in the MMSNA is supposed to exceed the sum of corresponding exports reported by the trade partners. However, as shown in Figure 8-2, the sum of corresponding exports reported by the trade partners has been exceeding the value of imports reported in the MMSNA by 20–60%. Thus, in our estimation, we adjust Myanmar's import data for 2003 and onward based on the sum of corresponding exports reported by its trade partners. Since freight and insurance rates charged in Myanmar are not available, we apply the factor applicable to Thailand at the national aggregate level (2.0%) in IDE [22] to convert FOB-based values into CIF-based values. As a result of this revision, Myanmar's trade deficit in 2014 expands from 5.1 trillion kyat to 9.9 trillion kyat.

The values of exports and imports reported in the MMSNA are consistent with figures in customs clearance-based trade statistics. In the national accounts, however, it is desirable to include, not only the trade in goods recorded in customs clearance-based trade statistics, but also the trade in services and direct purchases. We estimated the values of trade in services and direct purchases based on balance of payments (BOP) data provided in the WTO [40] and added those to the value of trade in goods.[8] The results are shown in Figure 9. The combined share of trade in services and direct purchases in total exports varies significantly depending on the year. After peaking at 37% in 1998, the share dropped to 4% in 2009 and 2010, the final years of the military regime, but rebounded following the transfer of power to the civilian government in 2011. It rose to 21% in 2014. In contrast, the combined share of trade in services and direct purchases in total imports has been relatively stable, ranging between 5% and 15% for the past 25 years.

8 Trade in services corresponds to trade in commercial services, net of construction, royalties, and license fees, and travel in BOP, whereas direct purchases correspond to travel in BOP.

FIGURE 9-1

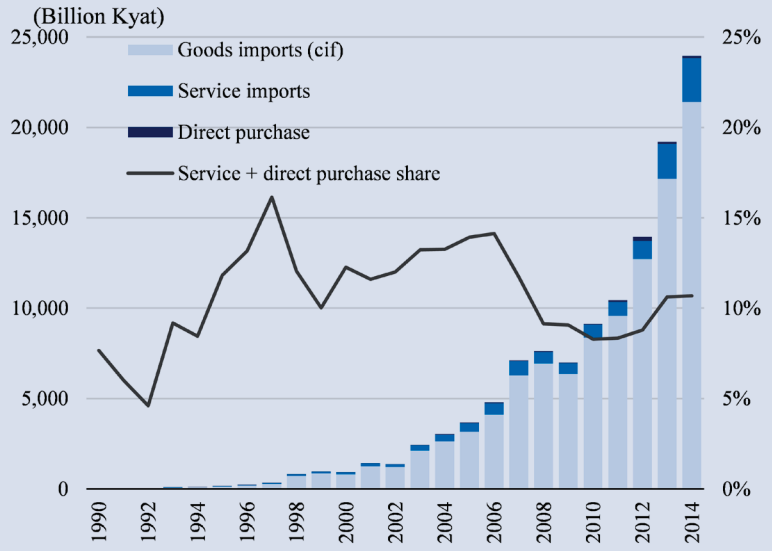
SERVICE TRADE AND DIRECT PURCHASE



Export

FIGURE 9-2

SERVICE TRADE AND DIRECT PURCHASE



Import

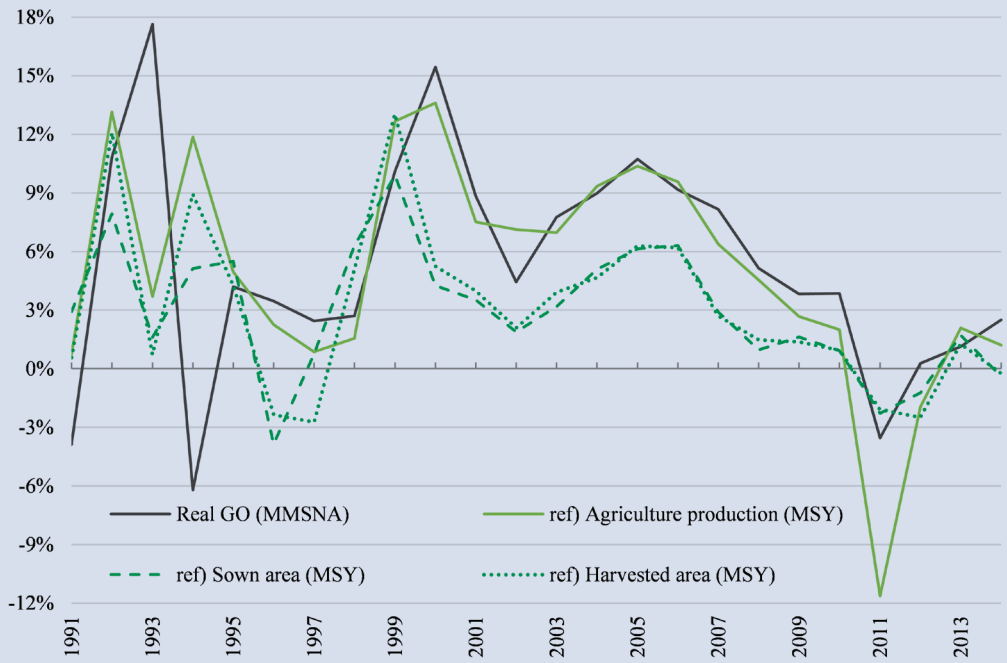
2.4 Revision in Production

2.4.1 Agriculture

According to the MMSNA data, agriculture used to account for roughly half of Myanmar's GDP in the 1990s. Although its share in GDP has declined to around 20% in recent years, it remains the country's mainstay industry. Figure 10 shows changes in the growth rates of agriculture production, sown area, and harvested area, based on data published in the CSO's Myanmar Statistical Yearbook (MSY), as compared to changes in growth rates of real gross outputs for agriculture.[9] Significant changes were observed in the 1990s but relatively high growth rates were maintained across all indicators in the 2000s.

FIGURE 10

COMPARISON OF AGRICULTURE INDICATORS



However, those high growth rates are questionable. Okamoto [26] points out that rice, which is the staple crop of Myanmar, has been subject to overstatement as it has been used as a measure of the performance of local governments. This tendency got accelerated 2004 onward, following the abolition of a compulsory rice procurement system, under which farmers were required to deliver to the government a quota of rice set per unit sown area at a lower-than-market price. With no delivery required, nothing stopped local government officials from overstating the sown area under their controls to inflate their administrative performances.

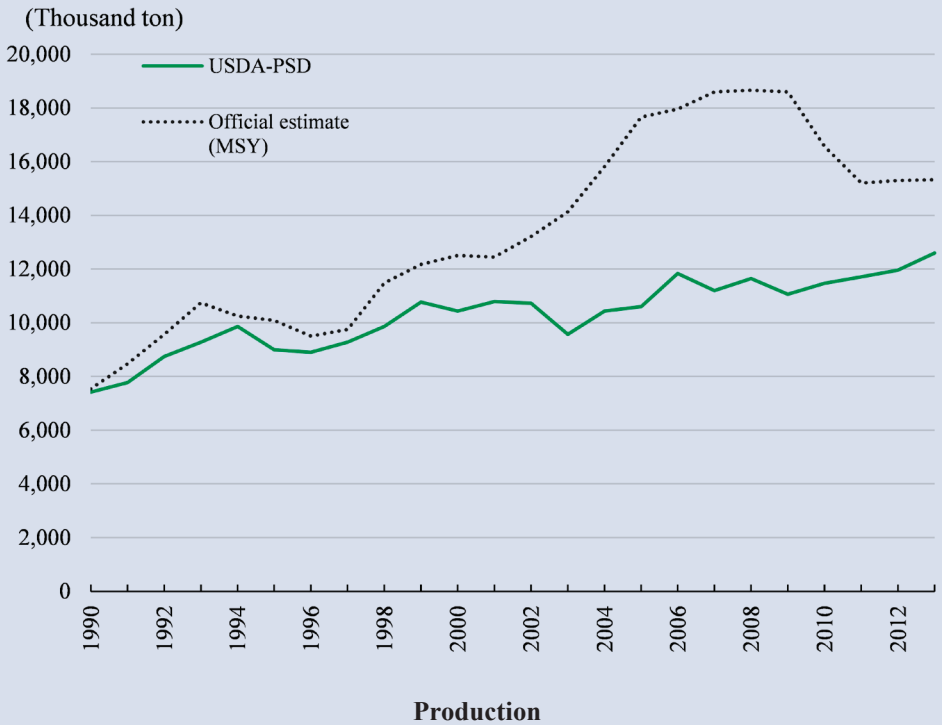
9 The MSY provides data on production, sown area, and harvested area for each of the 49 agricultural products. The growth rate of agricultural production is a weighted average of the growth rates of the 49 agricultural products, based on their two-period average shares in the total in value terms. The value of production for each product is calculated by multiplying the yield by the price at harvest. Harvested area is defined as follows: sown area + area under multiple cropping – non-harvested area.

Harvard University's ASH Center [11] also pointed out that the production of milled rice in Myanmar had been significantly overstated. By comparing data from FAOSTAT based on the CSO's official estimates and data from the US Department of Agriculture (USDA)'s Production, Supply and Distribution (PSD) database, ASH Center concluded that the latter was more in line with the reality. In the 2001–09 period, annual rice yield per capita ranged between 200 kg and 300 kg as per FAOSTAT data, compared with 200–220 kg according to the USDA-PSD data. The annual yield of 300 kg per capita as shown by FAOSTAT data would have translated into a daily calorie intake of 3,000 kcal per capita, exceeding the 2,800 kcal required by an adult male living in a rural area. Given the fact that Myanmar's population includes women, children, and urban dwellers, who need less calories, it was maintained that the FAOSTAT-based average yield of rice could not be considered realistic. It was noted that an annual consumption of 180–200 kg per capita would be a reasonable estimate. ASH Center said that this estimate was roughly in line with the USDA-PSD-based annual yield of 200–220 kg when netted with the perceived unrecorded exports amounting to 500,000 tons per year or 10 kg per capita per year.

Figure 11 shows changes in the level and growth rate of rice production, comparing how these differ depending on whether the basis is data from USDA-PSD or from the MSY.[10] In term of growth rate, particularly large gaps were observed in 1998 and the mid-2000s. The gap peaked in 2009, with the level of production based on MSY data exceeding the one based on USDA-

FIGURE 11-1

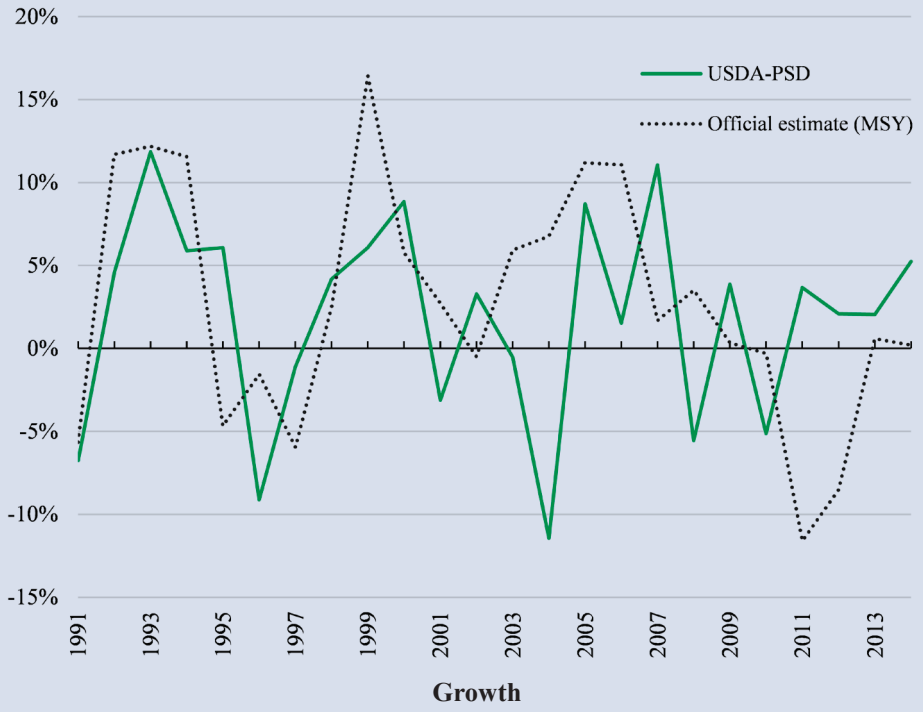
RICE PRODUCTION: OFFICIAL AND USDA-PSD ESTIMATES



10 The MSY does not provide data on milled rice. As in Dapice, et al. [11], we estimate the production of milled rice by multiplying paddy output by 0.58.

FIGURE 11-2

RICE PRODUCTION: OFFICIAL AND USDA-PSD ESTIMATES



PSD data by roughly 70%. From 2010 onward, the former declined in a way to close the gap with the latter.

An overestimation of quantitative data may be found in other agricultural products. Figure 12 shows agricultural output growth by types of products in three different periods (1990–97, 1997–2010, and 2010–14), classifying the 49 agricultural products in the MSY into seven groups. The number provided in the brackets following each type of product is the number of products classified into the type. Product-level data are aggregated for each group as measured in the translog index using the product prices at harvest. A comparison of the seven groups reveals that some types of agricultural products show greater growth than cereals, which include rice. Particularly high growth was seen in the period 1997–2010, during which MSY-based rice production data exceeded the one based on USDA-PSD by a significant margin, thus indicating the possibility of an overestimation.

In our estimation, we first replace the growth rates based on MSY data with those based on USDA-PSD data for three of the 49 agricultural products, namely, paddy, wheat, and millet. Second, for the remaining 46 products, for which no substitute estimates are available, we adjust MSY-based growth rates for the years in which the MSY-based growth rate for rice exceeds that based on USDA-PSD. This is done by reducing the growth rate for each of the 46 products by the percentage-point difference observed in the growth rate for rice. The years from 1998 through 2010 are subject to this adjustment. Revised real gross output is estimated by aggregating the thus-adjusted outputs by products as measured in the translog index. Figure 13 shows the growth of revised real gross output for agriculture.

FIGURE 12

AGRICULTURE OUTPUT GROWTH BY PRODUCT

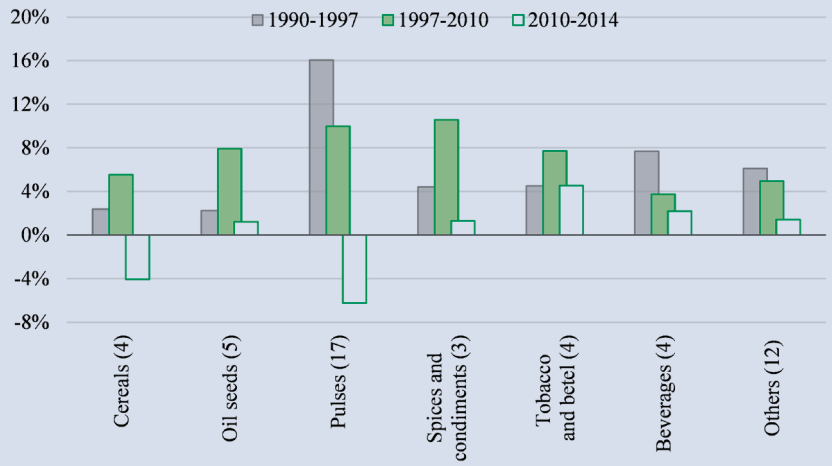
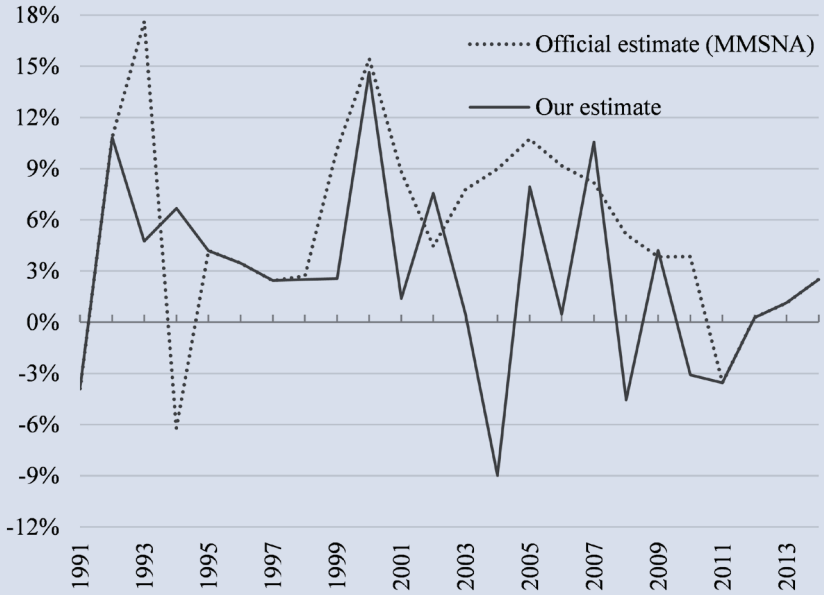


FIGURE 13

OFFICIAL VS OWN ESTIMATES FOR AGRICULTURAL PRODUCTION



Based on the revised production data, we calculated average growth rates for agricultural production and land productivity in three different periods, 1990–97, 1997–2010, and 2010–13, and plotted the results in Figure 14. (Land productivity is defined as agricultural production per unit sown area.)

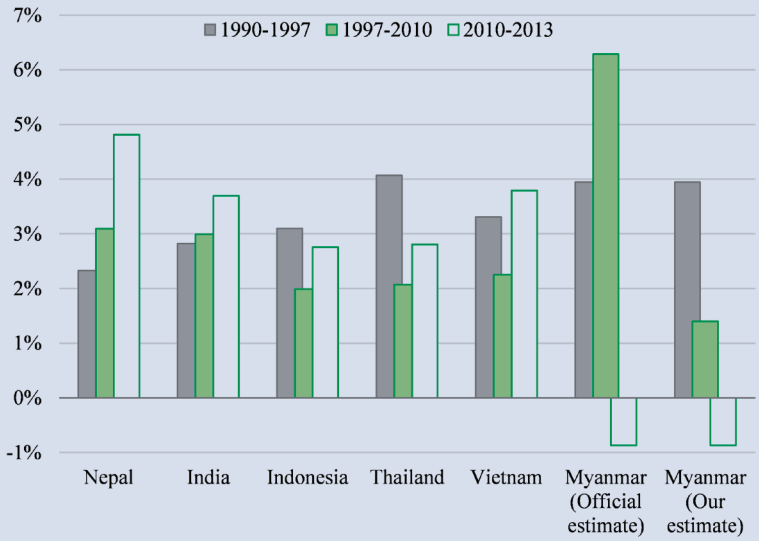
FIGURE 14-1

COMPARISONS OF AGRICULTURAL PRODUCTION AND LAND PRODUCTIVITY WITH NEIGHBORING COUNTRIES

Production growth

FIGURE 14-2

COMPARISONS OF AGRICULTURAL PRODUCTION AND LAND PRODUCTIVITY WITH NEIGHBORING COUNTRIES



Land productivity growth

Except for Myanmar, data was taken from FAOSTAT. Based on official estimates, i.e., before adjustments, Myanmar's agricultural production and land productivity for the period 1997–2010 were extremely high relative to those of its neighboring countries. After adjustments, these became generally in line with those of the neighboring countries.

2.4.2 Livestock and Fishery

Livestock and fishery account for approximately 6–9% of Myanmar's value added. As per the data from the MMSNA, livestock and fishery production grew by an average of 11% per year for 25 years. A particularly high average growth of 15% per year was recorded from the latter half of the 1990s through the 2000s. Figure 15 compares Myanmar's annual livestock production per capita with those of its neighboring countries, all based on data from FAOSTAT. In 1990, Myanmar's meat production (Figure 15-1) stood at 5 kg per capita, slightly above that of India but only one-sixth the level of Thailand. However, 1999 onward, Myanmar's meat production data grew rapidly to exceed that of Thailand in 2009. The average growth rate for the period 1998–2010 was 13%, which was more than twice of Vietnam's growth of 6% per year. Notably, Vietnam had the second-highest growth among the neighboring countries. Likewise, Myanmar's milk and egg productions (Figure 15-2 and Figure 15-3) grew rapidly, at rates of 7% and 13%, respectively, during the same period. These indicated high likelihoods of overestimation.

FIGURE 15-1

LIVESTOCK PRODUCTION PER CAPITA

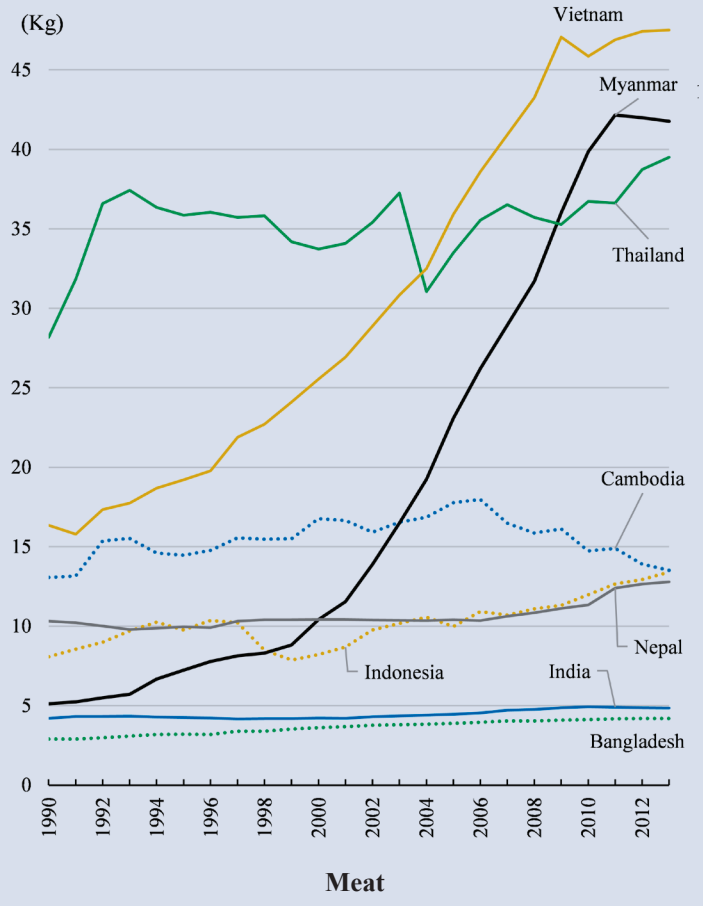
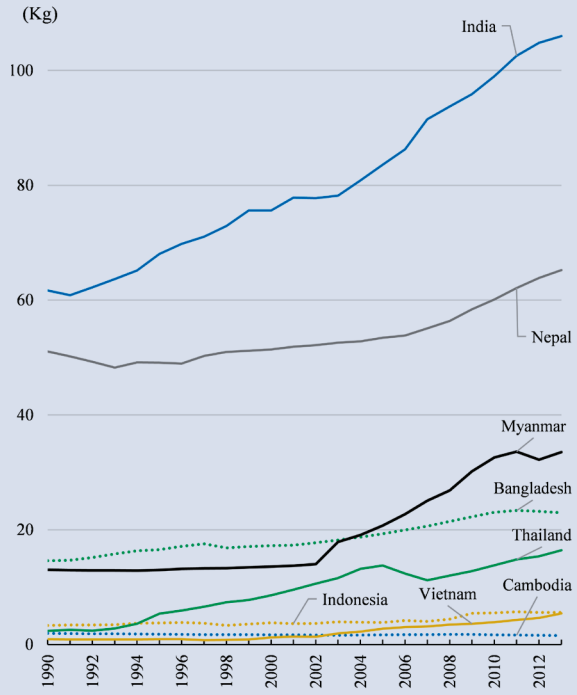


FIGURE 15-2

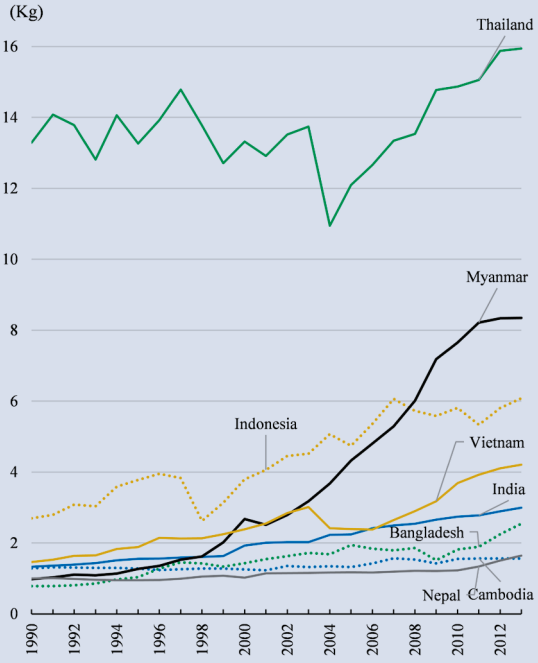
LIVESTOCK PRODUCTION PER CAPITA



Milk

FIGURE 15-3

LIVESTOCK PRODUCTION PER CAPITA



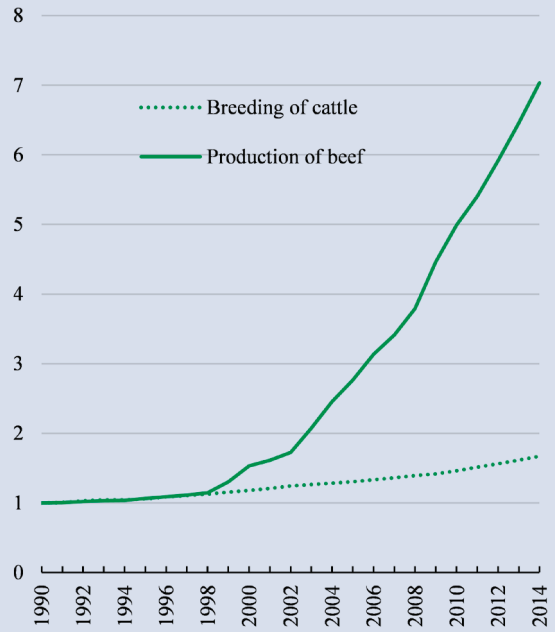
Egg

Figure 16 compares the number of breeding animals for beef, pork, and fowl meat production (expressed in the number of heads) and the corresponding livestock production, as measured in indices (1990 = 1.0) based on data from the MYS. In context of SNA, the production of cultivated assets or cultivated biological resources, which include livestock, is measured in terms of growth of breeding animals and not in terms of shipment of meat. Thus, it is assumed that the number of breeding animals for meat production and the production of livestock are closely correlated with each other. However, the production of livestock grew far more rapidly than the number of all three breeding animals mentioned above, particularly 1999 onward.

Figure 17 shows the average production growth rates for nine types of livestock in three different periods (1990–98, 1998–2010, and 2010–14) based on data from the MSY. In the period 1998–2010, almost all products posted double-digit growths that were sharply higher than the growth rates recorded in the preceding and subsequent periods. Thus, in our estimation, we adjust production data for the period 1998–2010, for which particularly high growth was recorded, assuming that livestock production for each of the nine products grew at the same pace as the number of breeding animals.[11] As a result of this adjustment, average production growth rates for all nine types of livestock are revised downwardly, for instance, from 16% to 8% for pork.

FIGURE 16-1

PRODUCTION AND BREEDING OF LIVESTOCK



11 Productions of beef and fresh milk, mutton, pork, fowl egg, and duck egg corresponded to the number of cattle bred, and the total number of sheep and goat, pig, fowl, and duck, respectively.

FIGURE 16-2

PRODUCTION AND BREEDING OF LIVESTOCK

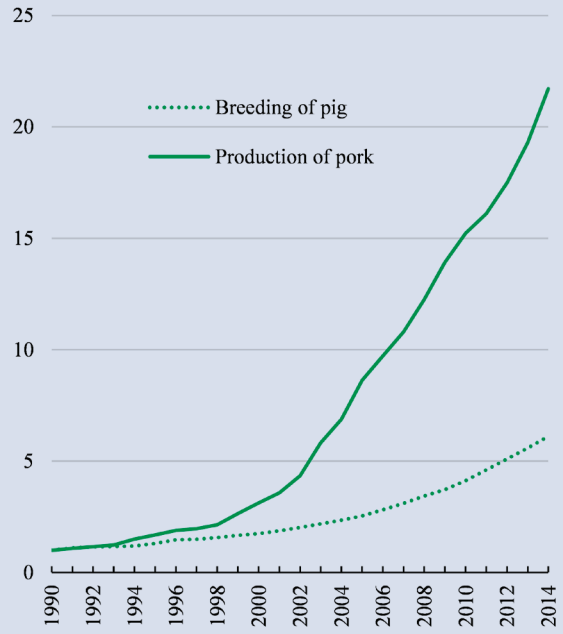


FIGURE 16-3

PRODUCTION AND BREEDING OF LIVESTOCK

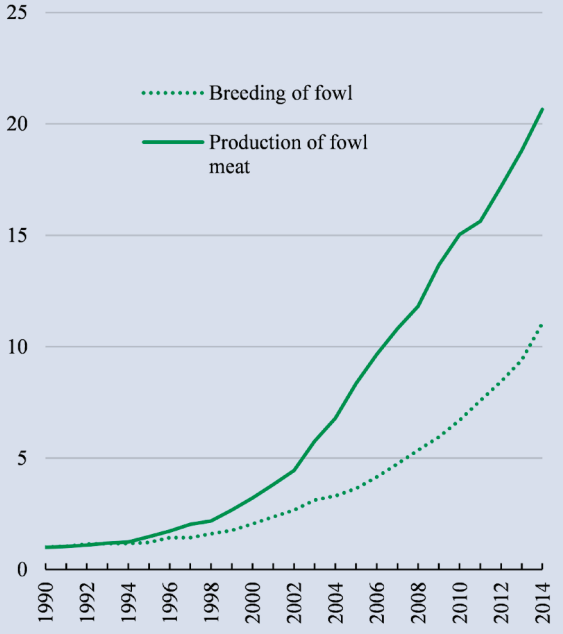
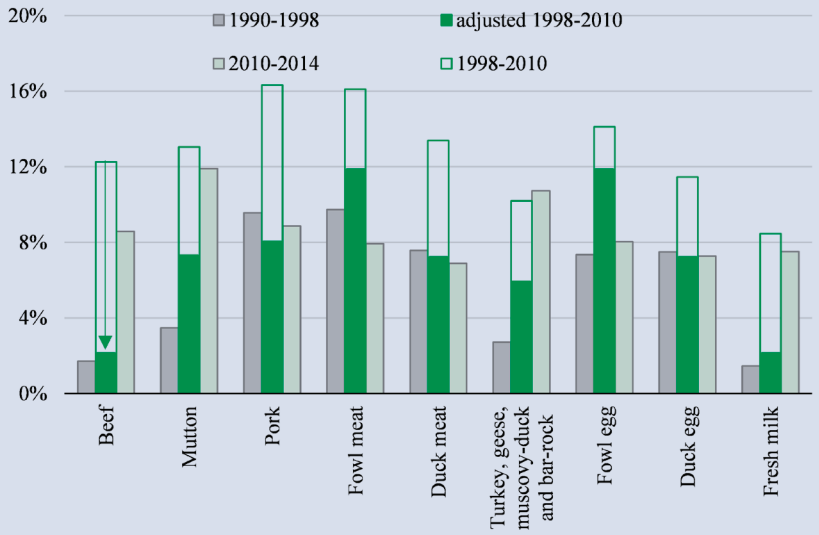


FIGURE 17

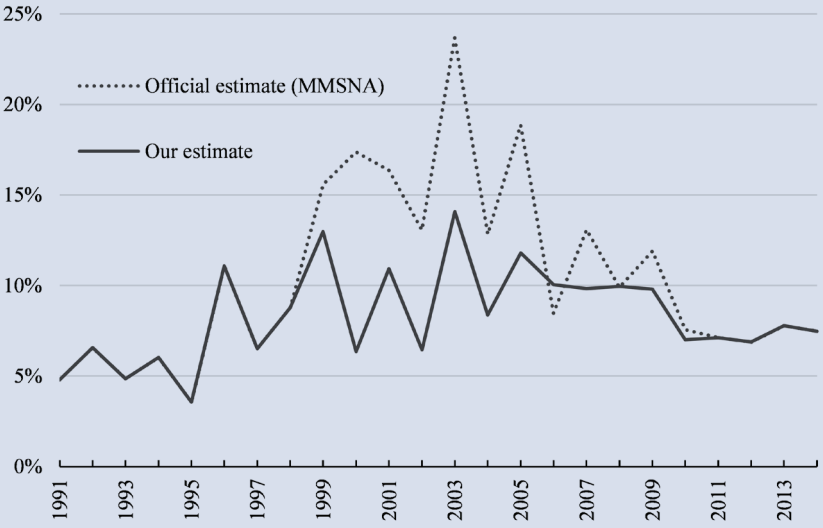
PRODUCTION GROWTH BY TYPE OF LIVESTOCK



Although unrealistically high growth is observed in a certain period, no adjustments are made to data on fishery production as no substitute data are available. Figure 18 compares the rates of growth in real gross output for livestock and fishery based on official estimates with those based on our estimates.[12] As a result of adjustments made above, the average annual growth rate for the period 1998–2010 is revised from 15% to 10%.

FIGURE 18

REVISION OF OUTPUT GROWTH IN LIVESTOCK AND FISHERY



12 The outputs in livestock and fishery are aggregated by the translog index using the wholesale price indices in Yangon city in MSY.

2.4.3 Energy and Mining

Since 2000, approximately 90% of output in energy and mining has been for export, most of which is accounted for by natural gas (Figure 19). As Thailand is the largest destination for Myanmar's exports in energy and mining, Thailand's data on imports from Myanmar provides an effective

FIGURE 19

EXPORT SHARE OF OUTPUT IN ENERGY AND MINING

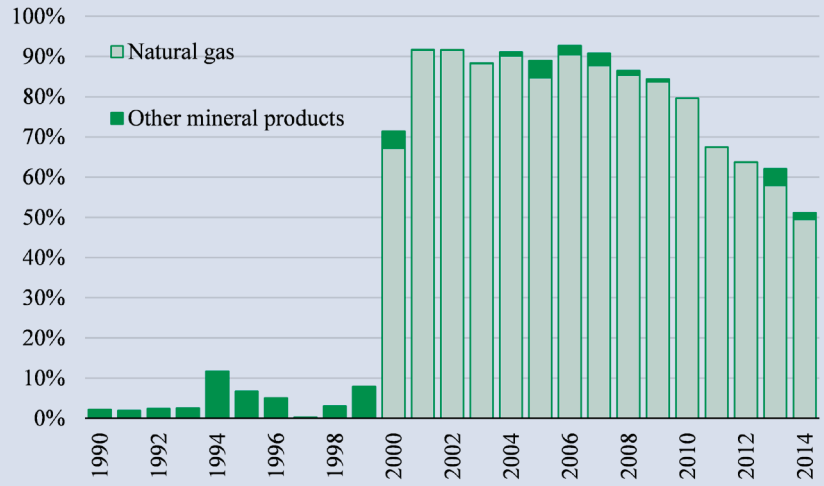
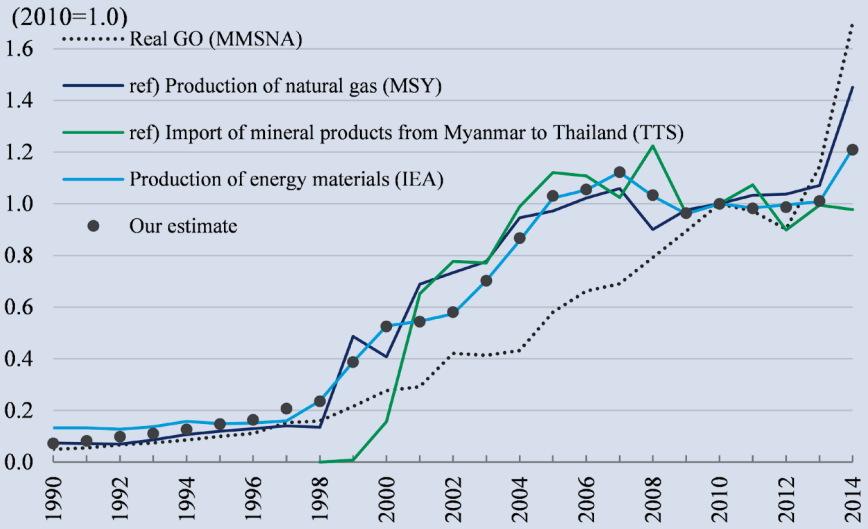


FIGURE 20

OUTPUT AND EXPORT IN ENERGY AND MINING

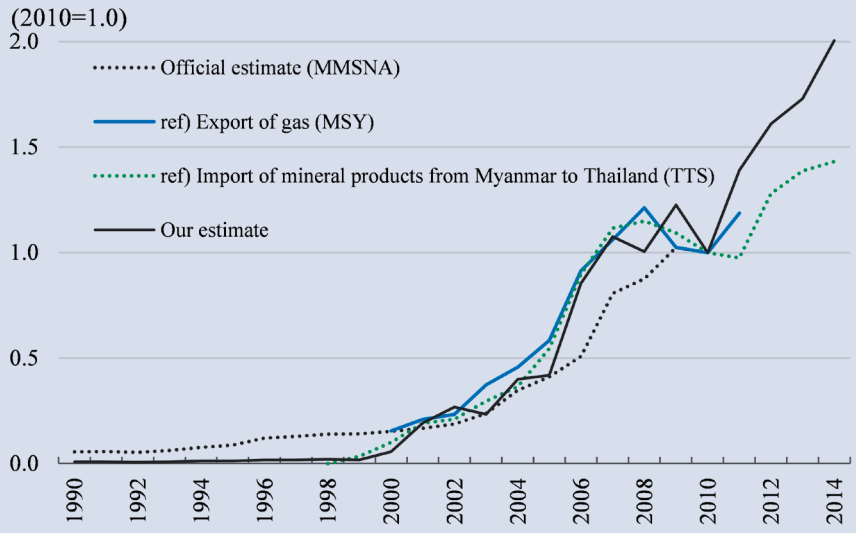


benchmark against which to examine output in Myanmar in quantity terms.[13] Figure 20 shows real gross output based on data from the MMSNA, natural gas output reported in the MSY, Thailand's import of mineral products from Myanmar reported in the Thailand Trade Statistics (TTS), and energy production in oil equivalent as shown on the International Energy Agency (IEA)'s Energy Balance Table. All data are in quantity terms and measured in indices (2010 = 1.0). As the trend of real gross output deviates from others 1999 onward, we adjust the MMSNA-based data on real gross output based on IEA data.

Figure 21 compares value added based on data from the MMSNA, natural gas exports reported in the MSY, Thailand's import of mineral products from Myanmar reported in the TTS, and revised gross output (calculated from the above adjusted real gross output and the adjusted nominal gross output in Subsection 2.3.1), all in value terms and measured in indices (2010 = 1.0). We can see that the value of gross output based on our estimates, as compared to that based on official estimates, is more in line with the trends in the trade values reported in the MSY and the TTS.

FIGURE 21

OUTPUT AND EXPORT PRICES OF ENERGY AND MINING



2.4.4 Manufacturing

In order to examine the validity of the production index for manufacturing, based on data from the MMSNA, we compare average growth rates of real gross output based on data from the MMSNA, industrial electricity demand reported in the MSY[14] as well as in the IEA's Energy Balance Table, and the production index[15] calculated from quantitative data on manufacturing production reported

13 Based on traded statistics of Myanmar's major trade partners (the US, Thailand, Singapore, Malaysia, Japan, India, Hong Kong, and PR China), Thailand accounted for 90% or more of Myanmar's export of mineral products (including natural gas) through 2012. From 2013 onward, PR China's share increased to 35% in 2014 as compared to Thailand's share of 64%.

14 The sales and consumption data of electricity are provided by types of purposes (general, industrial, bulk, and other in MSY. In this comparison, electricity consumption for only industrial purpose is used.

15 The number of production items published in MSY is different for different periods. The total output of manufacturing is measured as the translog index based on production data at the physical units of all available items (30–50 items) until 2010.

in the MSY, for three different periods of 1990–98, 1998–2010, and 2010–14 (Figure 22). In the period 1998–2010, real gross output increased at the rate of 19% per year, more than twice the growth rates of other indices. Manufacturing production and industrial electricity demand showed strong correlations in the period 1990–98 (correlation coefficient = 0.90) and 2010–14 (correlation coefficient = 0.86). However, in the period 1998–2010, the two variables deviated from each other, showing a negative correlation coefficient of –0.22.

The MMSNA-based real gross output in this particular period deviated greatly not only from industrial electricity demand but also from the production index based on quantitative data in the MSY. Since production in physical unit does not reflect quality improvement, growth in the MSY-based production index is supposed to fall below that in the MMSNA-based real gross output index. Even so, however, the difference observed in the period 1998–2010 seems too big, reaching 15.2% compared to 2.7% in the period 1990–98. Thus, we revise real gross output data for the period 1998–2010 by applying an average annual growth rate calculated by adding 2.7 percentage points to the growth rate of the production index based on the MSY quantitative data.

FIGURE 22

GROWTH OF OUTPUT AND ENERGY DEMAND IN MANUFACTURING

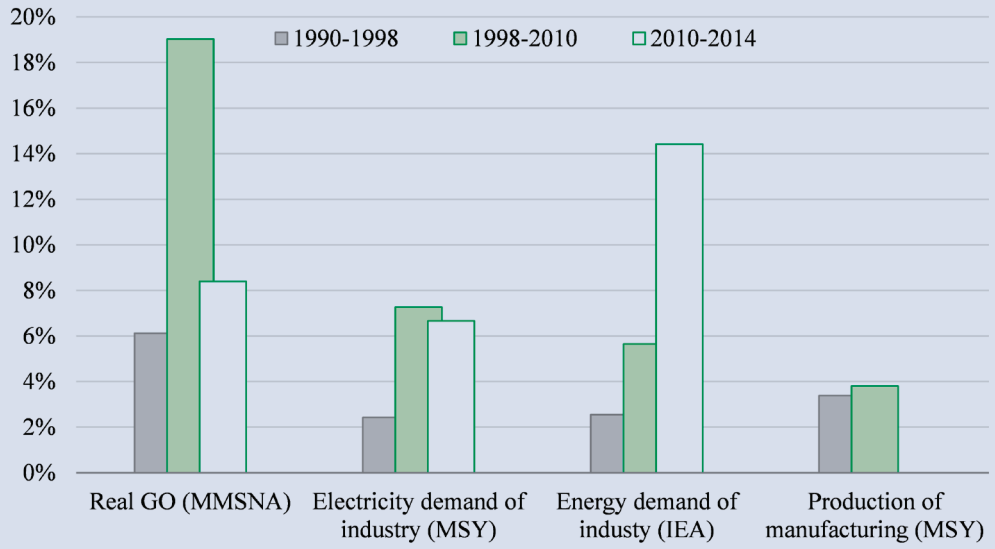
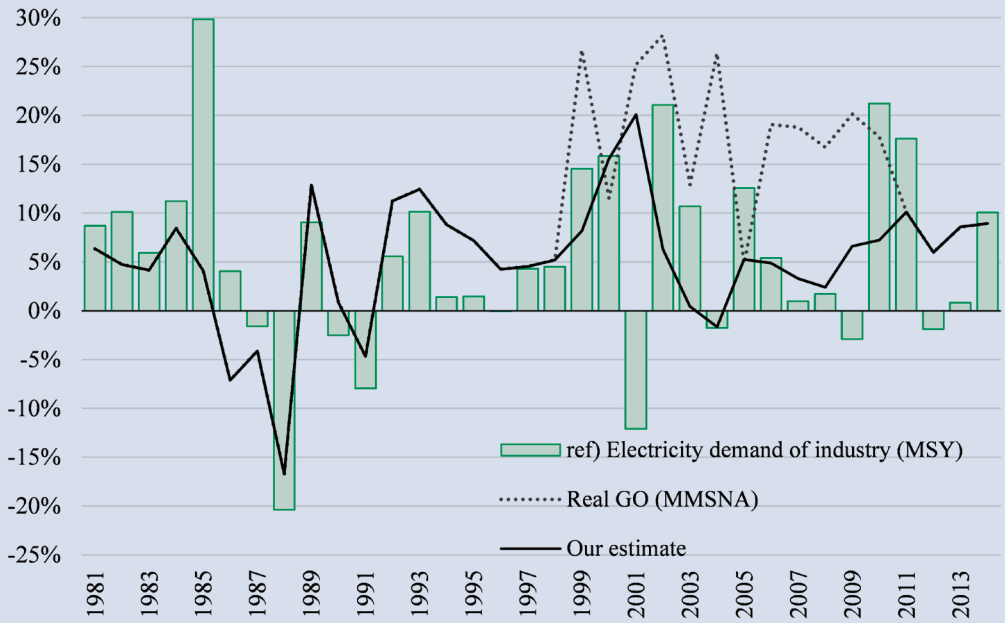


Figure 23 compares the growth rates of the MMSNA-based real gross output, the MSY-based industrial electricity demand, and the adjusted real gross output based on our estimates. The adjusted real gross output recorded negative growth of –1.7% in 2003–04, which is probably attributable to economic sanctions imposed by the US and the EU.[16] The US trade statistics show that its import of manufacturing products from Myanmar, which stood at USD329 million in 2002, decreased to USD251 million in 2003 and to zero in 2004.

16 Kudo (2005) indicates that the garment industry in Myanmar lost 70,000–80,000 jobs with the closure of about 150 firms and factories since its peak to mid-2005, mainly caused by the US sanctions of 2003.

FIGURE 23

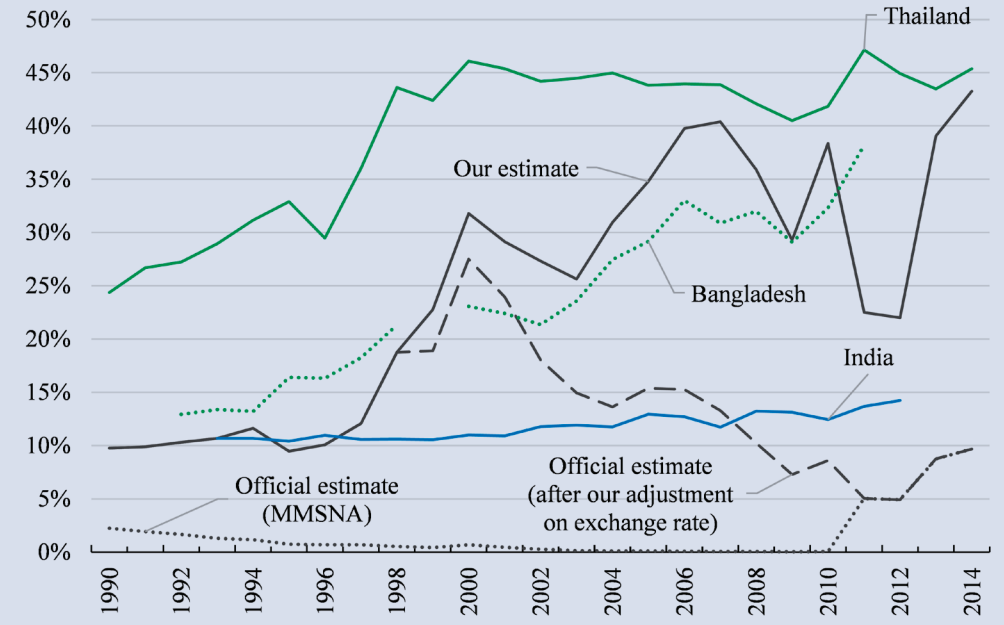
GROWTH OF OUTPUT AND ELECTRICITY DEMAND IN MANUFACTURING



We revise nominal gross output downward, using the value calculated by multiplying the adjusted real gross output by the MMSNA-based price index. As a result, the export share of production is revised upward. Figure 24 compares changes in the export share of the nominal gross output of the

FIGURE 24

COMPARISON OF EXPORT SHARE OF MANUFACTURING WITH OTHER COUNTRIES



manufacturing sector in Myanmar before making the above adjustment with those of other Asian countries based on data provided by the APO [4]. The MMSNA-based export share before the above adjustment (after the exchange rate adjustments in Subsection 2.3.1) shows a sharp downward trend in the 2000s. In contrast, the export share after the above adjustment shows an upward trend, following a trajectory similar to that of Bangladesh that has been expanding its exports, particularly in textiles.

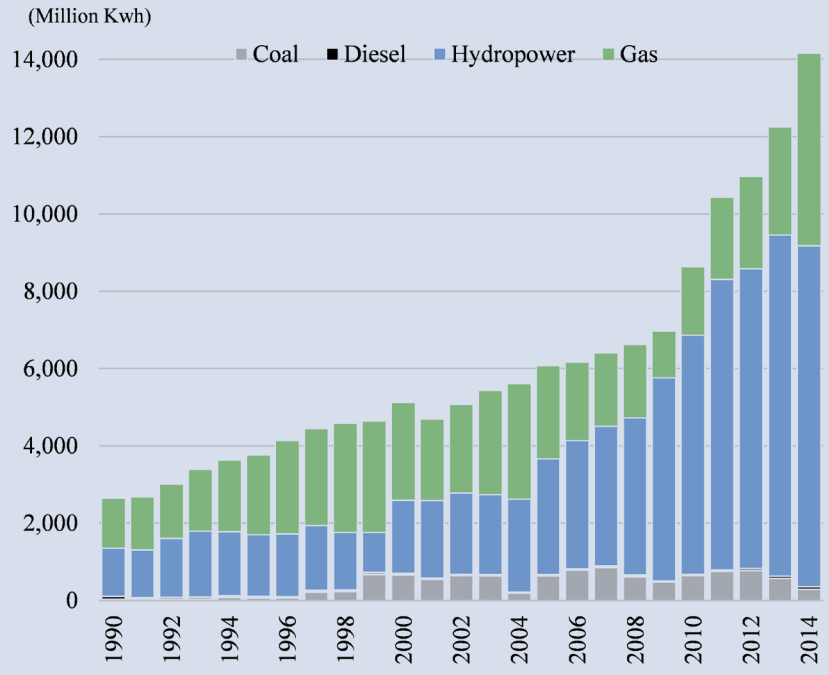
2.4.5 Electricity

Hydro and natural gas-fired thermal power accounts for approximately 90% of total power generation in Myanmar. As shown in Figure 25, the share of natural gas in the energy mix peaked at 62% in 1999. Subsequently, hydropower overtook as the main source for generating electricity, with its share rising from 22% in 1999 to 75% in 2009.

Figure 26 compares the value of nominal gross output in the electricity industry based on data from the MMSNA and that of electricity sales reported in the MSY. The trajectories of the two variables were almost identical from 1990 through 1998. After that, however, the two began to deviate from each other and the gap expanded gradually in the period 1999–2005. Both the value of the nominal output and that of electricity sales increased sharply, by fourfold and more than threefold, respectively, during 2005–06. While the increase in electricity sales is attributable to higher electricity prices,[17] one contributing factor for the sharper increase in the nominal output was structural changes in the electricity sector.

FIGURE 25-1

ELECTRICITY GENERATION BY TYPE OF ENERGY



17 The price of electricity increased from 8.65 kyat/kWh to 27.69 kyat/kWh for general purpose users, from 10.62 kyat/kWh to 32.57 kyat/kWh for industrial users, from 6.35 kyat/kWh to 25.76 kyat/kWh for bulk users, and 2.64 kyat/kWh to 24.33 kyat/kWh for others. On average, the price of electricity increased threefold from 8.96 kyat/kWh to 29.35 kyat/kWh.

FIGURE 25-2

ELECTRICITY GENERATION BY TYPE OF ENERGY

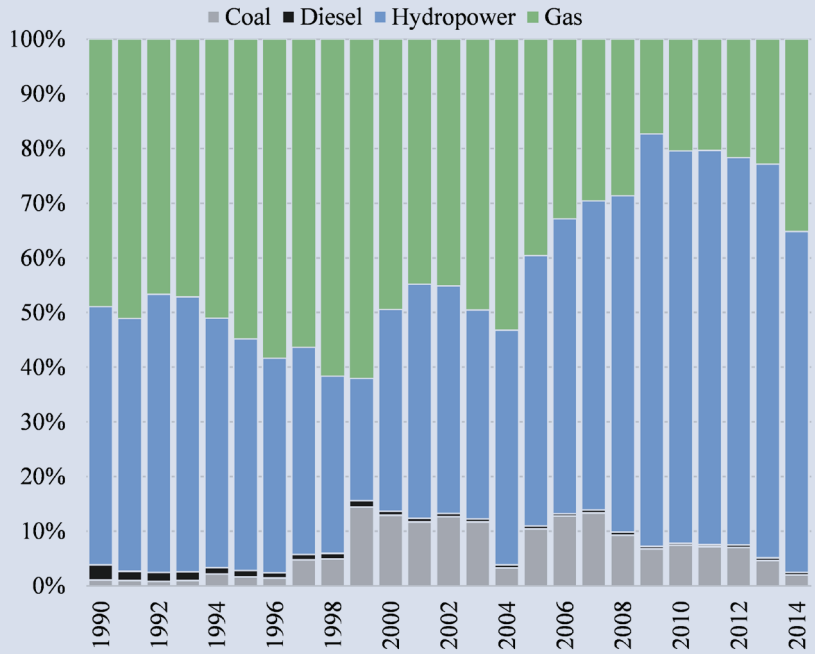


FIGURE 26-1

NOMINAL OUTPUT AND SALE OF ELECTRICITY

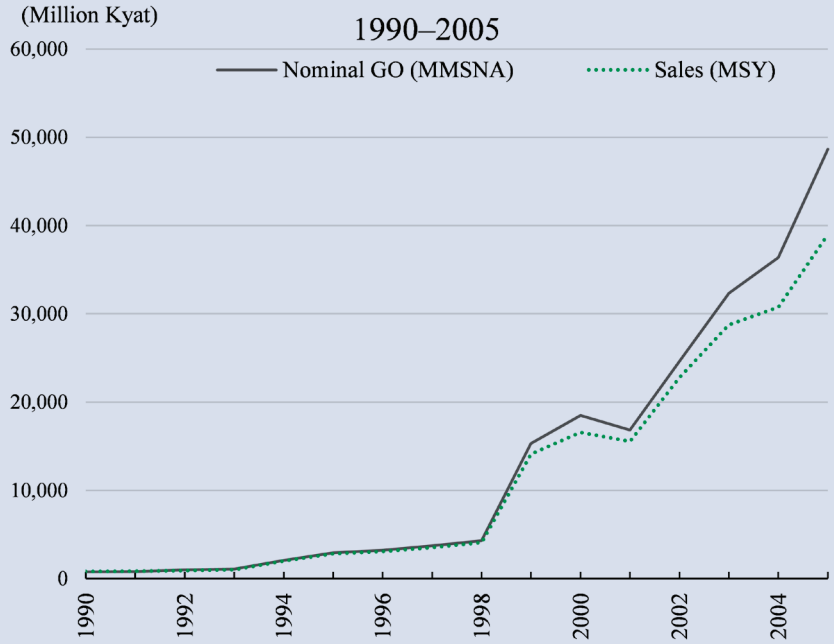
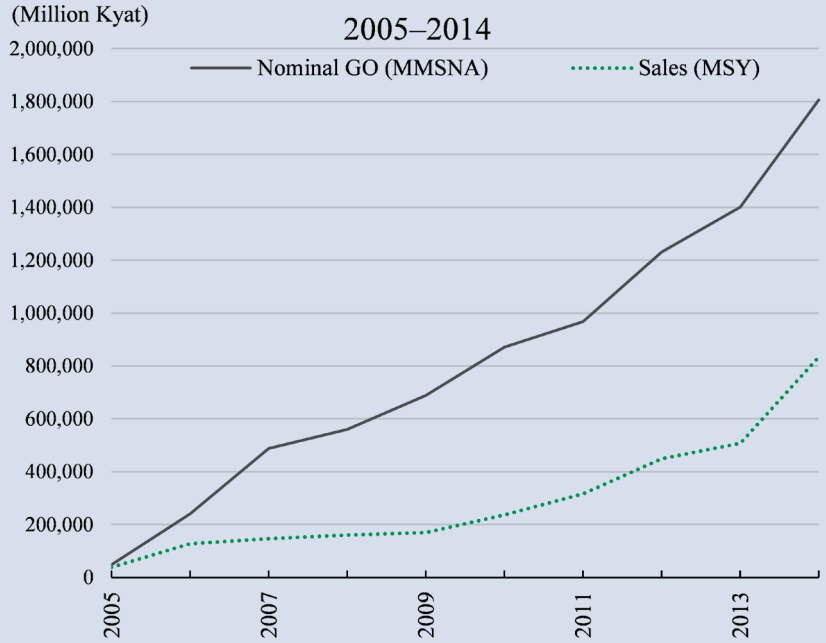


FIGURE 26-2

NOMINAL OUTPUT AND SALE OF ELECTRICITY



According to JICA [20], the Ministry of Electric Power (MOEP) was divided into the Ministry of Electric Power No. 1 (MOEP-1) and the Ministry of Electric Power No. 2 (MOEP-2) in 2006. The Myanmar Electric Power Enterprise (MEPE), which had been the sole power generator and distributor of the country, was split into four companies, namely, Hydropower Generation Enterprise (HPGE), Electricity Supply Enterprise (ESE), Yangon City Electricity Supply Board (YESB), and what was left of MEPE.[18] The gross output after this restructuring reflected the sum of electricity sales of the four companies, including sales between themselves, instead of the sales of MEPE as the sole power generator and distributor. Given that, it seems reasonable that the value of the nominal gross output after the restructuring has been three to four times that of electricity sales. Also, the long-term trend of the producer price index for electricity, which is calculated based on data from the MMSNA, has been generally consistent with the trends of electricity prices shown in the MSY. Thus, we do not make any adjustments to data on production values for electricity.

2.4.6 Transportation and Communications

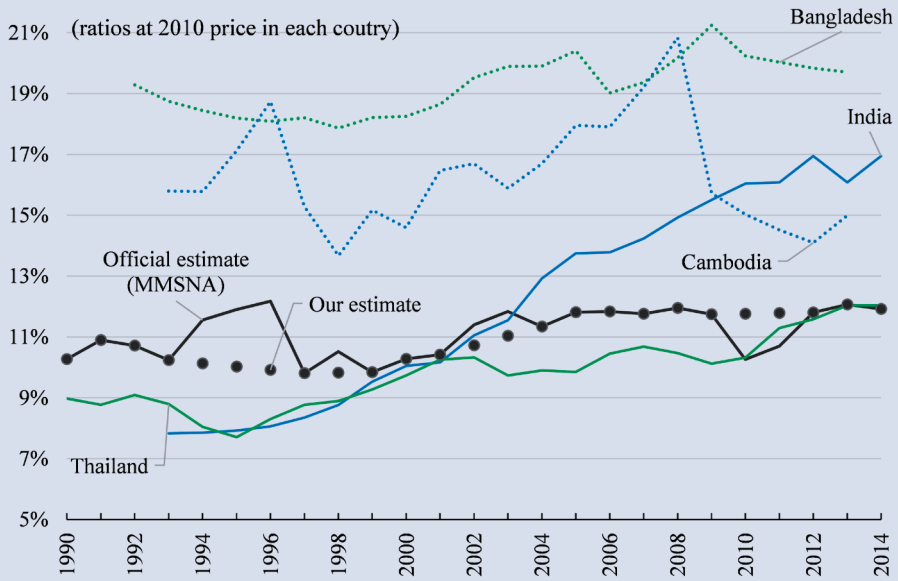
For transportation and communications, some quantitative data on services provided in the MSY are available but the coverage is very limited. Figure 27 compares five Asian countries including Myanmar in the cost of transportation and communications measured as a ratio (in percentage) to the total gross output of the first five industries in Table 1, namely, agriculture; livestock and fishery; forestry; energy and mining; and manufacturing. For each country, we first calculate the nominal ratio for 2010 and develop estimates for other years by applying the growth rate of the indices of production in the five industries and in the transportation and communications industry. Translog aggregate production index is calculated from production data for each of the five industries, with the MMSNA-based data before adjustments used for Myanmar.

The cost of transportation and communications has been an upward trend in India and Thailand. However, in Myanmar, it has generally been flat as has been the case with Bangladesh and Cambodia. Here, we adjust some of the changes in the cost. Then, we multiply the adjusted ratio by the adjusted

18 The MOEP-1 and the MOEP-2 merged in 2012, but the four power companies have remained separated.

FIGURE 27

TRANSPORTATION AND COMMUNICATION COST (DEFINED AS A RATIO)



gross output of the five industries (our estimate) to generate the value of the real gross output for the transportation and communications industry. As a result of this adjustment, the negative growth in 1997 based on data from the MMSNA is revised to a positive growth and the average growth for the period 1998–2010 is revised from 15.4% per year to 5.6% per year (Figure 28).

FIGURE 28

REVISION OF OUTPUT GROWTH IN TRANSPORTATION AND COMMUNICATION

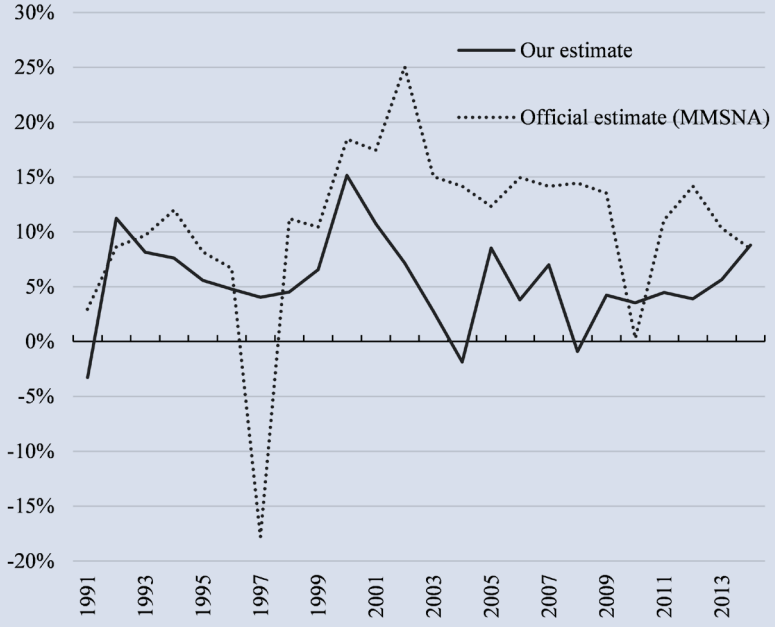
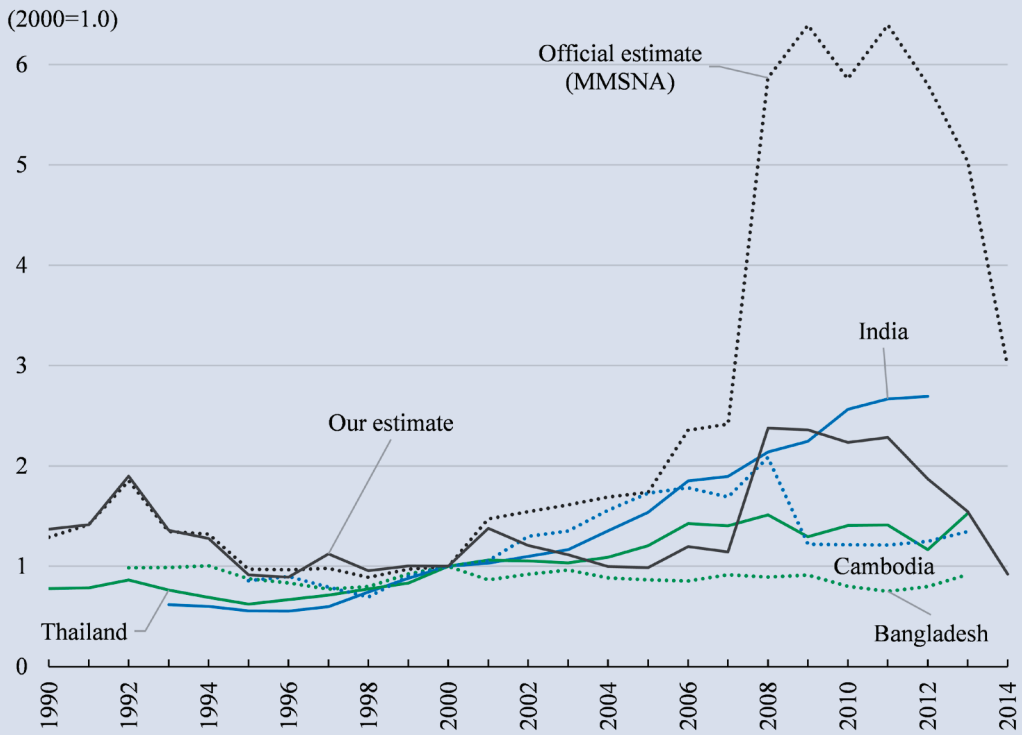


Figure 29 compares Myanmar and four neighboring countries in the energy productivity of the transportation industry measured in an index, taking energy consumption in the transportation sector reported in the IEA's Energy Balance Table as input and real gross output for transportation and communications as output. While the energy productivity has generally been flat in the neighboring countries except India, the index for Myanmar, based on the MMSNA-based data before adjustments, jumped sixfold between 2000 and 2008. This is suggestive of the possibility of an overestimation of the output. We can see that the abnormal tendency is reduced with the adjustment to quantitaive production data.

FIGURE 29

ENERGY PRODUCTIVITY IN TRANSPORTATION AND COMMUNICATION



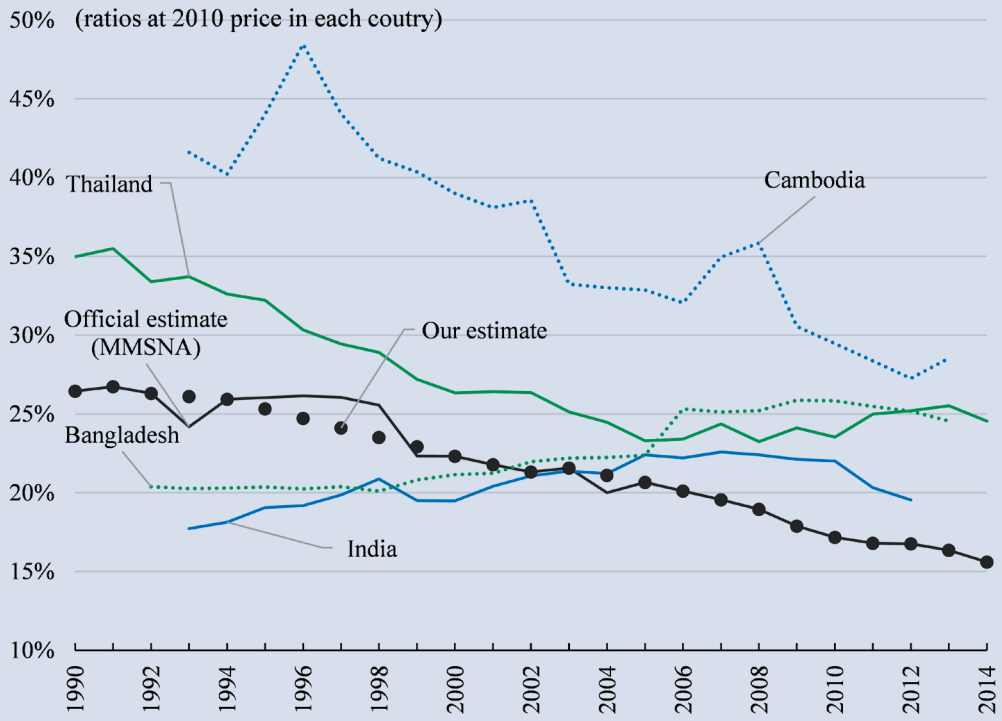
2.4.7 Wholesale and Retail

Just as we have done for the transportation and communications industry, we first calculate the ratio of wholesale and retail margin to the total output of the five industries, namely, agriculture; livestock and fishery; forestry; energy and mining; and manufacturing for the year 2010. We then develop estimates for other years by applying the growth rate of the index of production in the five industries. The translog aggregate production index is calculated from production data for each of the five industries and that of the index of production in the wholesale and retail industry, as shown in Figure 30.[19] The MMSNA-based data before adjustments are used for Myanmar. The ratio has been generally flat in India and Bangladesh, but exhibits similar

19 In countries except Myanmar, the outputs in repair of motor vehicles and hotels and restaurants are included in the output of wholesale and retail.

FIGURE 30

RATIO OF WHOLESALE AND RETAIL MARGIN



downward trends for Myanmar, Thailand, and Cambodia, all of which belong to the Mekong Economic Zone.

Again, just as in the case of transportation and communications, we make some adjustments to the ratio of wholesale and retail margin to the gross output of the five industries. Then, by applying the adjusted ratio and replacing the MMSNA-based index of production in the five industries with the one based on our estimates as adjusted in this report, we revise data on production values in the wholesale and retail industry. Figure 31 compares changes in the growth of real gross output of wholesale and retail before and after adjustments. As a result of the downward revision of data on production values in the five industries, the average growth of the real gross output of the wholesale and retail industry for the period 1990–2010 is lowered significantly from 11.8% per year to 2.7% per year.

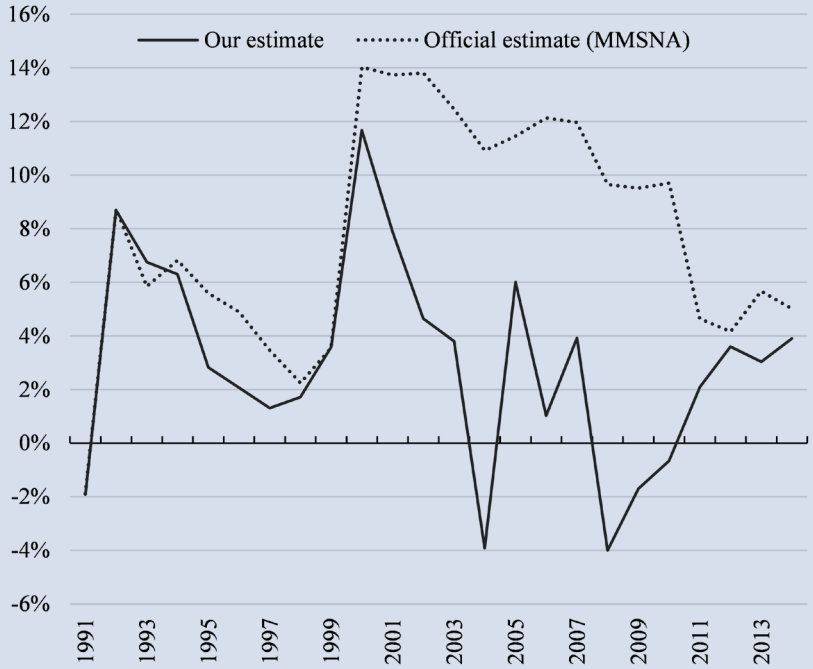
2.5 Revision in Jade Value

Several researchers have been investigating the production of jade in Myanmar. It is possible that a large amount of the country's jade sales and production has been dropped because of political or economic reasons, one of which would be smuggling.[20] An astonishing estimated

20 Shor [32] indicates, "In China, the ultimate destination for most of Myanmar's jadeite, the price can jump as much as twentyfold. According to a September 2013 Reuters report, however, Myanmar's jadeite exports to China totaled only $34 million in 2011. Official Chinese figures list $293 million worth of precious stones and metals imported from Myanmar. So, out of a potential jadeite market of $7.8 billion, only a fraction was actually declared. Some, as noted above, is in limbo in customs warehouses, but the Harvard report found that the vast majority remains unaccounted for."

FIGURE 31

REVISION OF OUTPUT GROWTH IN WHOLESALE AND RETAIL



production of jade is calculated by the Global Witness [16], which indicates that the value of "Jade production was worth up to $30.8 billion in 2014 alone: equivalent to almost half of Myanmar's officially recorded GDP." The Government of Myanmar has not officially issued the precise details of any values in jade production and sales so far. This section tries to reconcile the time-series estimates of jade production and export in Myanmar based on various sources including the reports of the Global Witness, Myanmar Statistical Yearbook, Mineral Yearbook issued by the US Geological Survey, and the Harvard ASH Center's research [12].

The MSY provides quantitative data on jade production, which is generally consistent with estimates in the US Geological Survey, 2016 (Figure 32). As for the value of jade production, Global Witness [17] provides its estimates for 2005–14, employing the composition of jade production by grade estimated by Harvard University's ASH Center. In this report, we calculate jade's average unit price based on these estimates and the quantitative data from the MSY. The average unit price of jade shows significant fluctuations over the years but it has followed a trajectory similar to that of the average unit price at which jade is traded on the Gems Emporium (Figure 33).[21] For the years through 2004, no price data on jade are available. Thus, we applied the average growth rate for all of the mineral resources to develop our estimates. Our estimates for the years through 1995 are extrapolations based on the trends of prices on the Gems Emporium.

21 The Gems Emporium is held every year in Yangon and Naypyidaw. Here, market prices for jade are estimated from data on the value of trade, the number of transactions (lots), and the volume of trade (kg) provided in NNA (http://www.nna.jp/).

FIGURE 32

PRODUCTION OF JADE

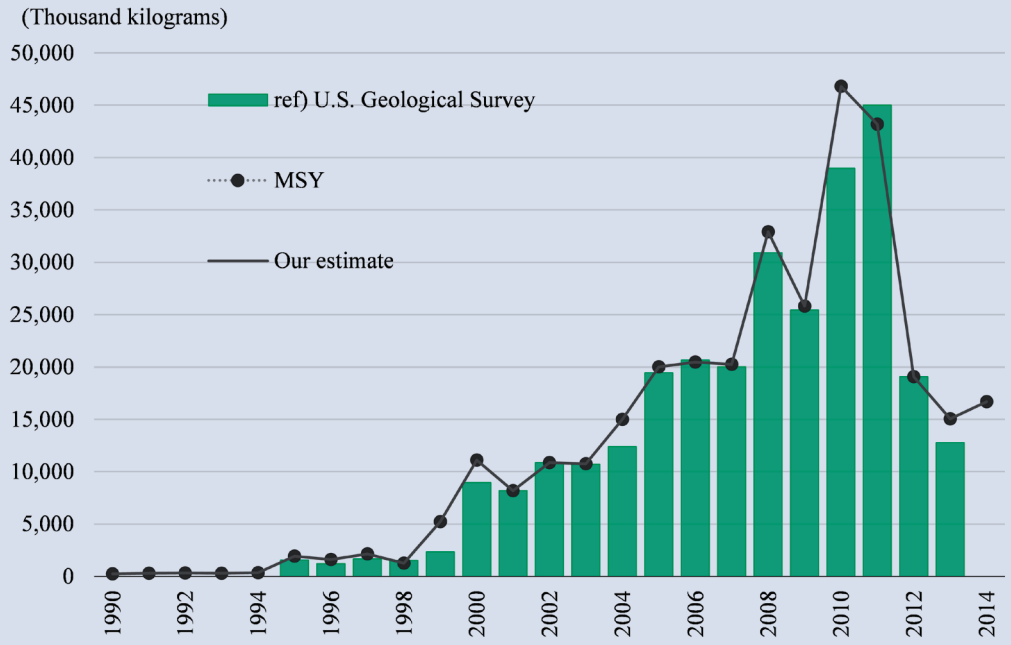
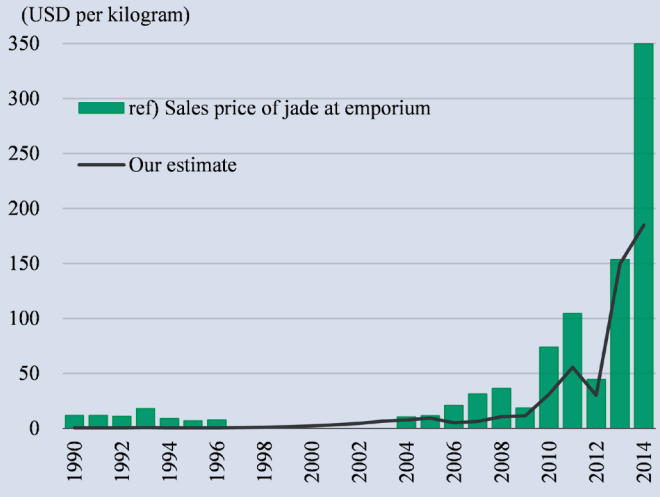


FIGURE 33-1

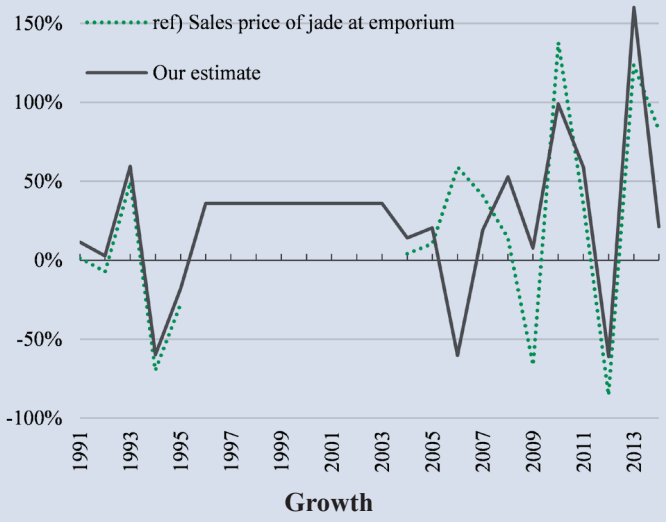
PRICE OF JADE



Unit Price

FIGURE 33-2

PRICE OF JADE

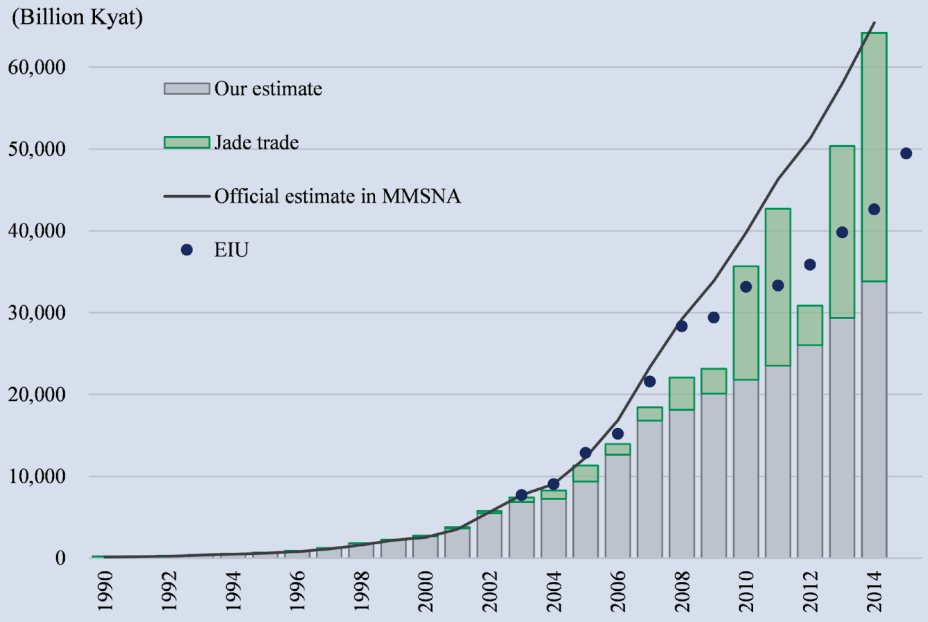


2.6 Results

Figure 34 illustrates the impact of our adjustments on Myanmar's nominal GDP. Our adjustments, except for the revaluation of jade production, translated into a significant downward revision of the nominal GDP, bringing it down to a level below the EIU's estimates. Meanwhile, the revaluation of jade leads to an upward revision, boosting the value of nominal GDP in 2014 by 90% to a level close to the size of the

FIGURE 34

REVISION IN NOMINAL GDP

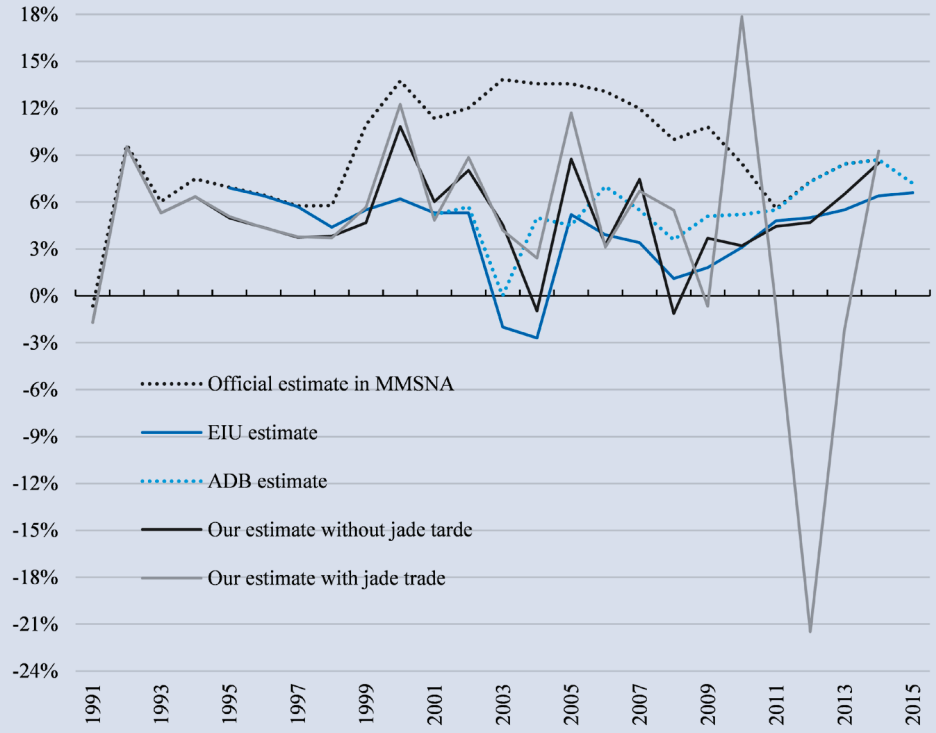


economy shown in the latest data in the MMSNA. Myanmar's nominal GDP is greatly affected by fluctuations in jade prices. For instance, in 2012, when the average jade price fell sharply (Figure 33), nominal GDP dropped by 28%, falling 40% below the estimate based on data from the MMSNA.

Figure 35 shows a comparison in real GDP growth. In this report, we did not make any adjustments to real value added for the period 1990–98, except for the industries of transportation and communications, and wholesale and retail.[22] However, as a result of the exchange rate adjustments (Subsection 2.3.1), industry shares in nominal value added were revised, and hence, the country's real GDP measured in the translog index was revised as well. As a result, the rate of real GDP growth for the period 1990–98 based on our estimates falls below that based on official estimates in the MMSNA by 1.3 percentage points. In the period after 1998, our estimates show that Myanmar's real GDP growth turned negative twice, first in 2003–04 and then in 2007–08. Our estimates of real GDP growth in 2003–04 are very much in line with the EIU's estimates, both reflecting the impacts of economic sanctions by the US and Europe. For 2007 and 2008, however, while our estimates show negative growth, the EIU's estimates show slower but positive growth. The negative or slower real GDP growth in 2008 is attributable to Cyclone Nargis that hit Myanmar in May 2008 (Table 4) and the fallouts of the global financial crisis.[23] In terms of the average growth rate for the period 1998–2010, our estimate of 4.9% represents a downward revision of 7.0 percentage points compared with the MMSNA-based estimate of 11.9%. Our estimate is higher than the EIU's estimate of 3.0% but close to the ADB's estimate of an average 4.7% per year for the period 2001–10.

FIGURE 35-1

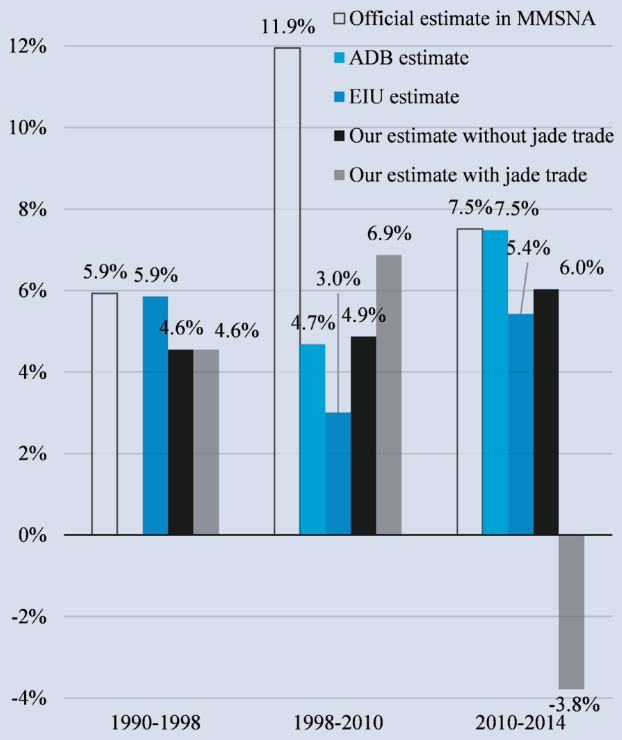
REVISIONS IN REAL GDP GROWTH



22 Exceptionally, the value added in agriculture is revised from 1998.
23 Thailand's economic growth slowed from 5.3% in 2007 to 1.7% in 2008 and turned negative in 2009, contracting by 0.7%.

FIGURE 35-2

REVISIONS IN REAL GDP GROWTH



Meanwhile, the impact of revaluing jade transactions on macroeconomic growth is observed from the mid-2000s. A negative growth is estimated for 2004 before reflecting the reassessed values of jade transactions. The impact of revaluation of jade is even more conspicuous in 2008 and thereafter with jade production accounting for more than 10% of Myanmar's GDP. Notably, the revaluation of jade results in a significant upward revision in 2009–10, from 3.2% (before revaluation) to 17.9% (after revaluation). On the other hand, real GDP dropped 21.5% in 2012 as jade production decreased by half following the transfer of power to the civilian government. The drop was sharper than the negative growth of 12% recorded in 1988–89 following the coup led by General Saw Maung.

Figure 36 and 37 compare select Asian countries in terms of their real GDP growths and the growth rates of labor productivity (defined as real GDP per worker). The downward revision to economic growth in 1998–2010 based on our estimates brings Myanmar's real GDP growth and labor productivity growth closer to those of Thailand and Bangladesh. Although Cambodia showed a relatively higher economic growth, it is attributable to an increase in its labor force. In terms of labor productivity growth, it is not much different from other low-income countries in Asia. Based on our estimates reflecting the revaluation of jade, Myanmar was comparable to India and Vietnam, both in terms of real GDP growth and labor productivity growth, for the period 1998–2010. However, Myanmar was alone to fall into negative growth during 2010–14.

FIGURE 36

COUNTRY-WISE COMPARISON OF GDP GROWTH

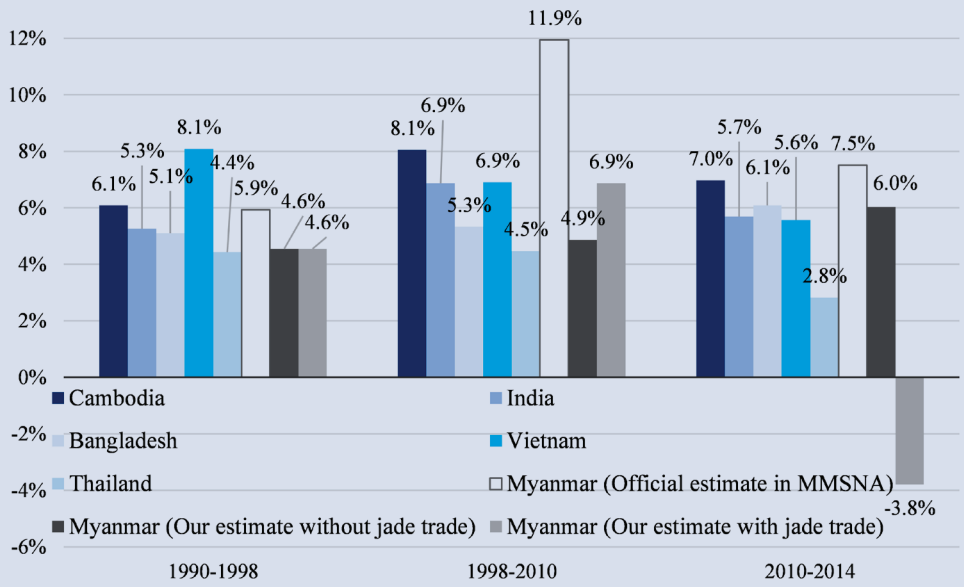


FIGURE 37

COUNTRY-WISE COMPARISON OF LABOR PRODUCTIVITY GROWTH

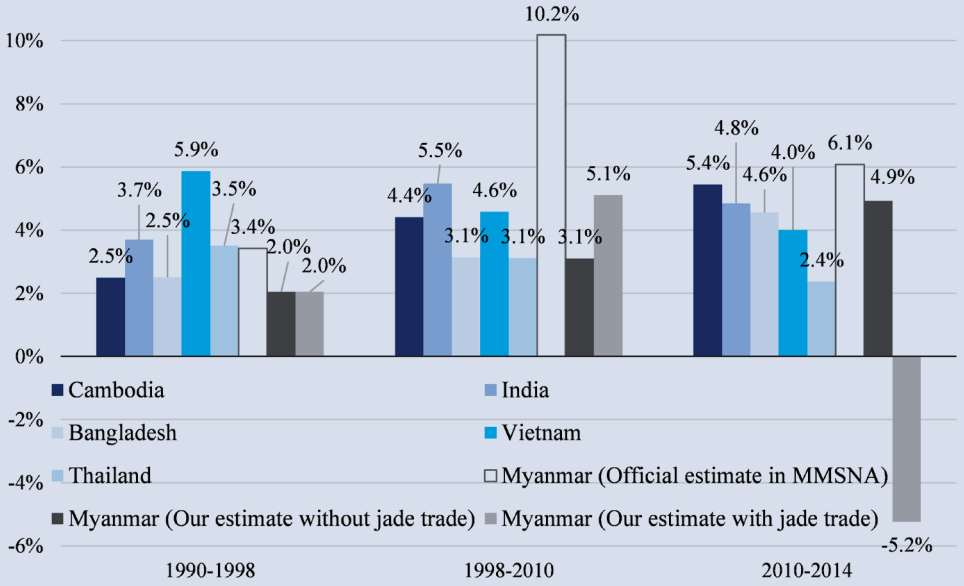
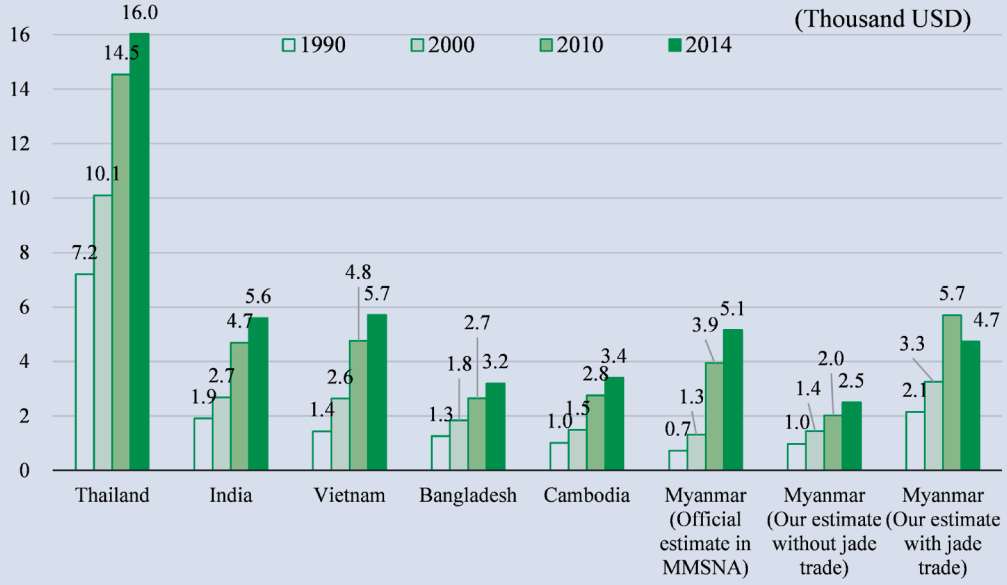


FIGURE 38

COUNTRY-WISE COMPARISON OF PER CAPITA GDP



Note: GDP at constant market prices per person, using 2011 PPP. Reference year is 2014.

Figure 38 shows a comparison of five countries in terms of GDP per capita on a purchasing power parity (PPP) basis. According to official estimates in the MMSNA, Myanmar, whose per capita GDP was lower than that of Cambodia in 1990, overtook Cambodia and Bangladesh in 2010. Myanmar's per capita GDP in 2014 stood at USD 5,100, significantly higher than those of Cambodia and Bangladesh. However, based on our estimates, before reflecting the revaluation of jade, Myanmar's per capita GDP in 2014 stood at USD 2,500, lower than Cambodia's USD 3,400 and Bangladesh's USD 3,200. In the US Central Intelligence Agency (CIA)'s World Factbook 2016, Myanmar's per capita GDP in 2013 was estimated at USD 1,700, which was lower than Cambodia's USD 2,600 and Bangladesh's USD 2,100. These figures are consistent with our estimates for 2014 before the revaluation of jade. In the latest Factbook, Myanmar's per capita GDP in 2015 has been revised to USD 5,500, exceeding Cambodia's USD 3,500 and Bangladesh's USD 3,600. The revised figure for Myanmar exceeds our estimate reflecting the revaluation of jade (USD 4,700 for 2014).

Figure 39 shows each industry's contribution and share of contribution to Myanmar's real GDP growth. According to official estimates in the MMSNA, agriculture and many other industries have achieved steady growth over the years. However, our revised estimates show that there have been significant ups and downs, particularly in agriculture. Located in the tropical monsoon climate zone, Myanmar is subject to frequent natural disasters such as cyclones. Shown in Table 4 are major disasters since 1990 and the estimates of economic losses caused by those disasters. According to the Centre for Research on the Epidemiology of Disasters [10], the damage caused by Cyclone Nargis in 2008 totaled USD 4 billion, which amounts to 15.5% of the MMSNA-based nominal GDP. The 2004 Indian Ocean earthquake and tsunami also caused significant damage, which equaled to 4.9% of the MMSNA-based nominal GDP. Those significant economic losses could not be found in the real GDP estimates in the MMSNA but are reflected in our estimates.

FIGURE 39-1

INDUSTRY CONTRIBUTIONS TO MYANMAR'S GDP GROWTH

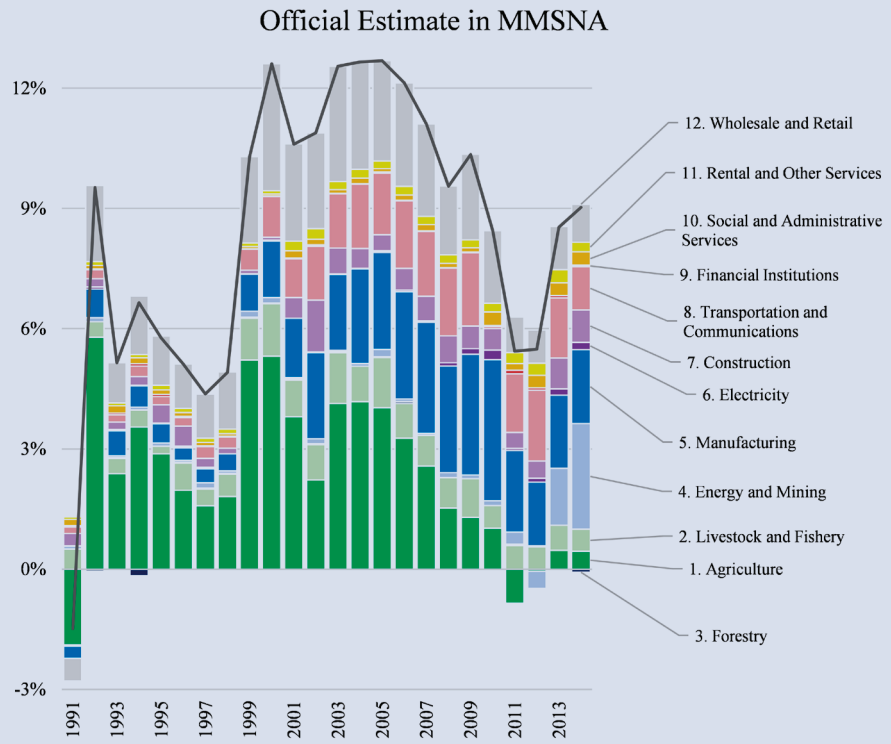


FIGURE 39-2

INDUSTRY CONTRIBUTIONS TO MYANMAR'S GDP GROWTH

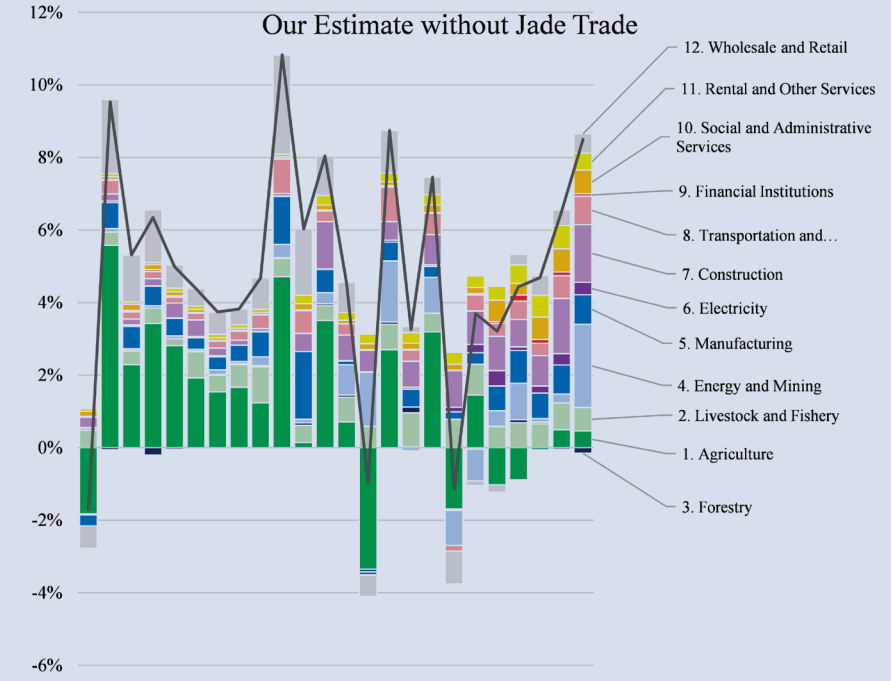


FIGURE 39-3

INDUSTRY CONTRIBUTIONS TO MYANMAR'S GDP GROWTH

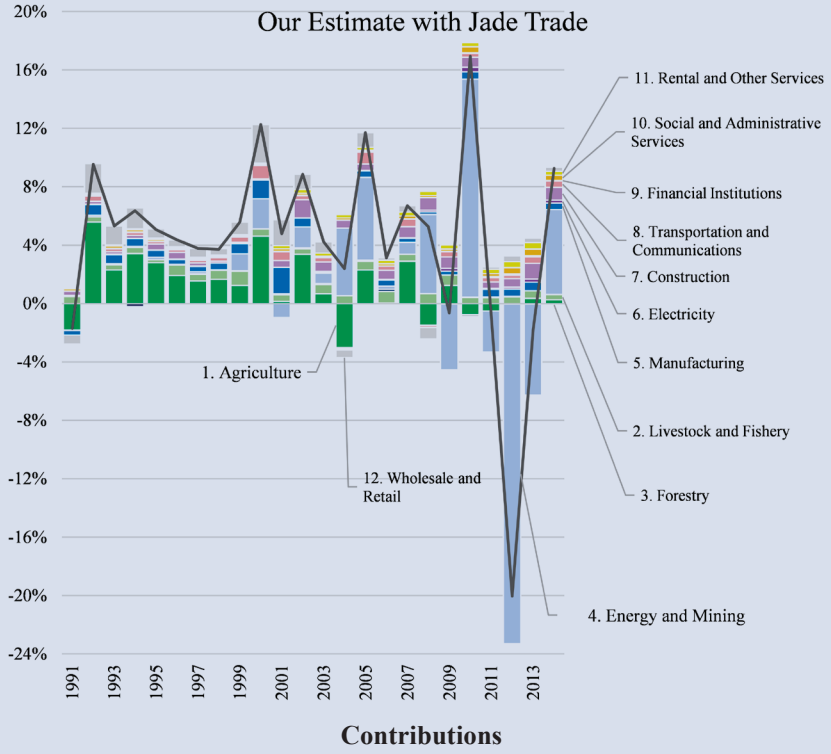


FIGURE 39-4

INDUSTRY CONTRIBUTIONS TO MYANMAR'S GDP GROWTH

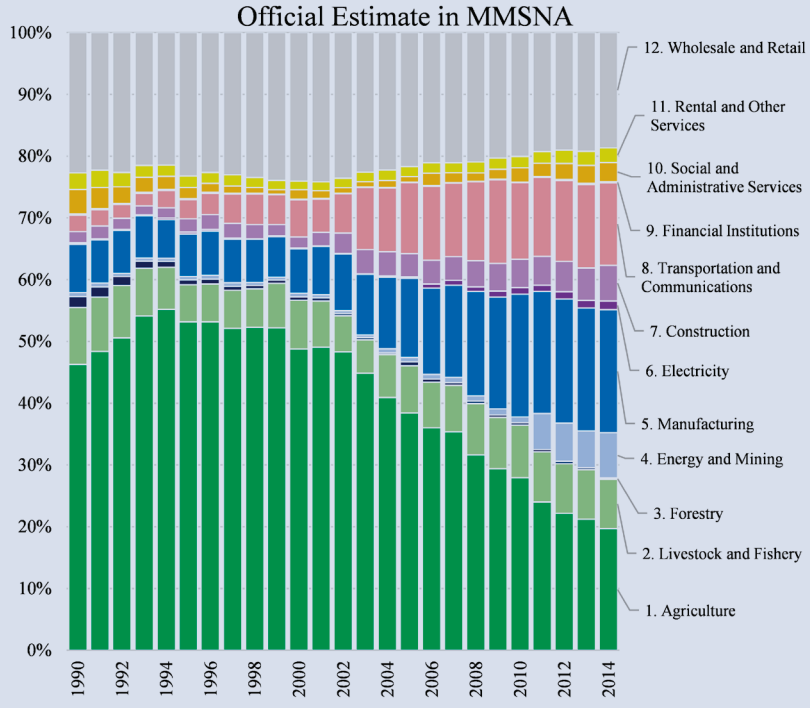


FIGURE 39-5

INDUSTRY CONTRIBUTIONS TO MYANMAR'S GDP GROWTH

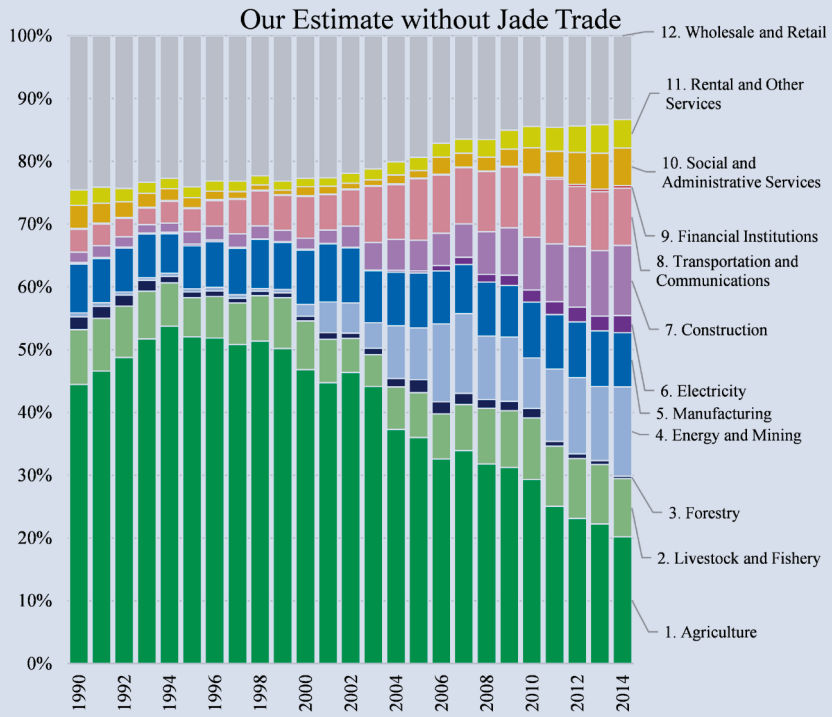


FIGURE 39-6

INDUSTRY CONTRIBUTIONS TO MYANMAR'S GDP GROWTH

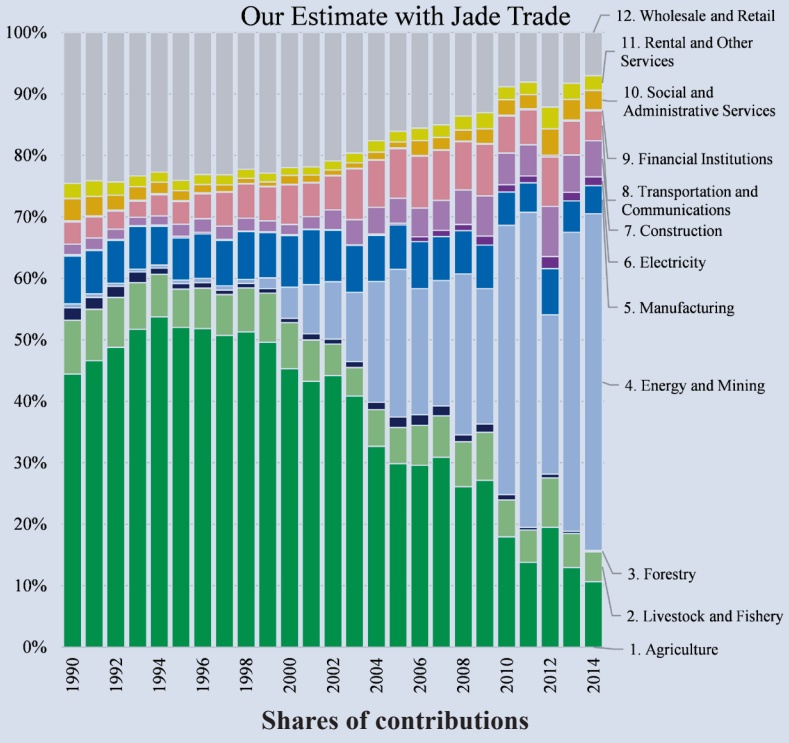


TABLE 4

ECONOMIC DAMAGES CAUSED BY NATURAL DISASTERS

Type	Date	Total damage ('000 US$)	Total damage (Mil kyat)	Damage/GDP (MMSNA) at market exchange rate
Storm	May 2008	4,000,000	4,521,000	15.5%
Earthquake	Dec 2004	500,000	442,708	4.9%
Flood	Jul 1991	79,840	2,800	1.5%
Storm	Oct 2010	57,000	54,706	0.1%
Flood	May 1992	55,115	2,301	0.9%
Storm	May 1994	10,000	664	0.1%
Earthquake	Mar 2011	3,600	2,880	0.0%
Flood	Oct 2011	1,700	1,360	0.0%
Earthquake	Nov 2012	1,170	983	0.0%
Storm	May 2004	688	609	0.0%

Source: Centre for Research on the Epidemiology of Disasters (2016).

Also, the impact of natural gas exports is underestimated in the MMSNA, which is dependent on the official exchange rate. According to our estimates, the energy and mining industry became a factor that explains approximately one-third of Myanmar's economic growth in the latter half of the 2000s and half of the economic growth in 2010, as a result of natural gas exports and revaluation of jade. Contributions to economic growth by industry vary significantly depending on how data is revised. Based on our estimates, Myanmar's economic growth in recent years has been reliant on natural resources.

FIGURE 40-1

FINAL DEMAND SHARES IN GDP

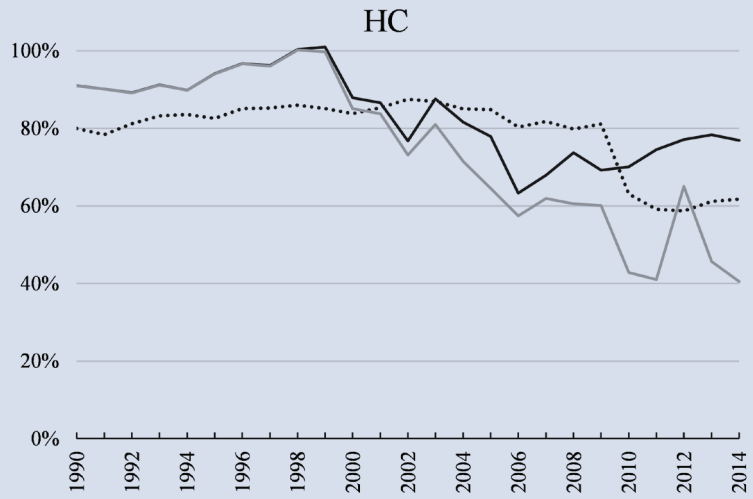


FIGURE 40-2

FINAL DEMAND SHARES IN GDP

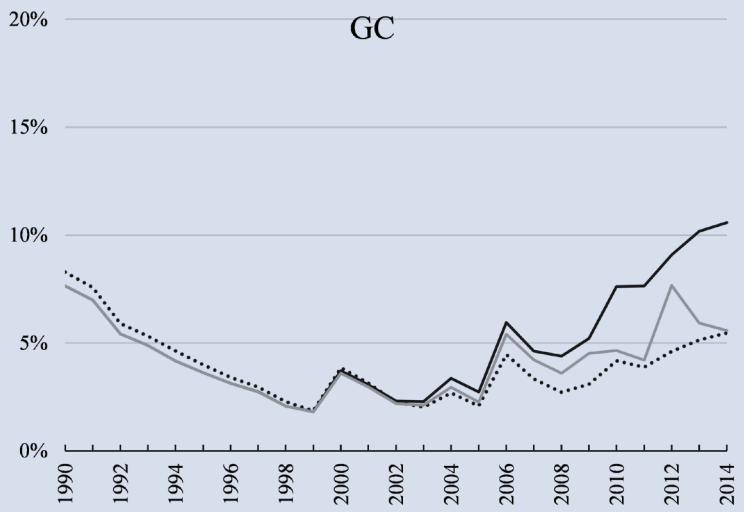


FIGURE 40-3

FINAL DEMAND SHARES IN GDP

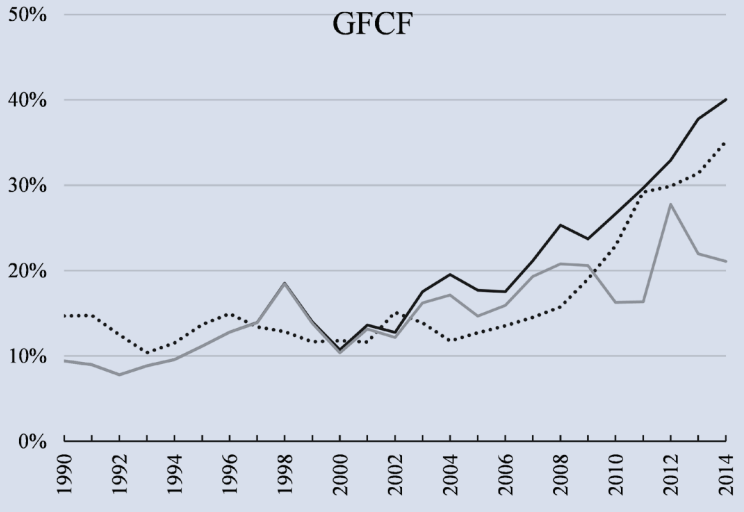


FIGURE 40-4

FINAL DEMAND SHARES IN GDP

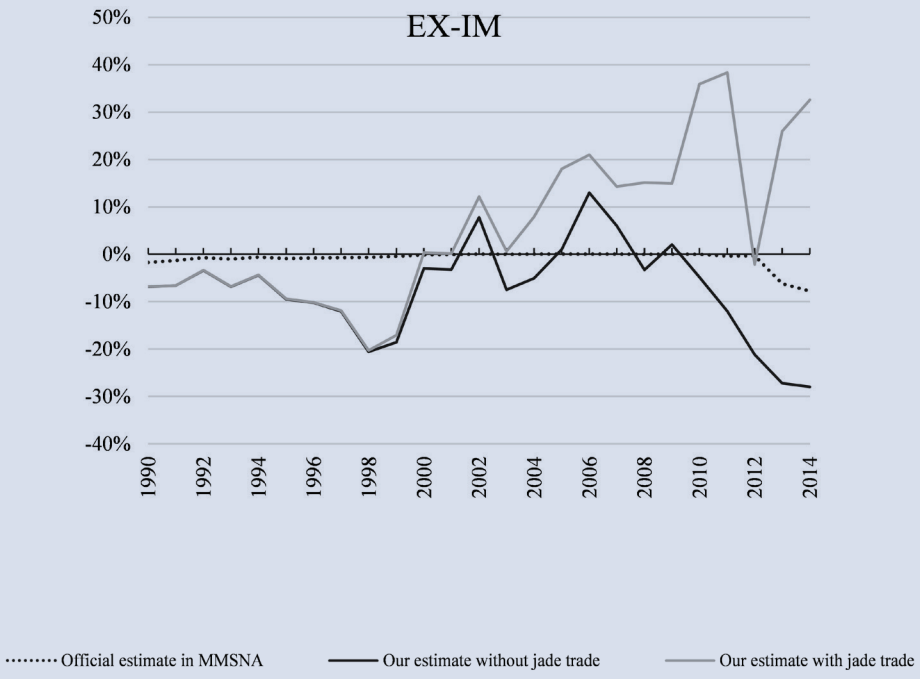


Figure 40 shows the impact of our revisions on final demand. Our estimates before the revaluation of jade show that household consumption (HC) accounted for about 77% of nominal GDP in 2014. However, the share of HC is decreased to 41% when the revaluation of jade is reflected. We compared Myanmar with its neighboring countries in HC and gross fixed capital formation (GFCF) as a share of domestic final demand, as shown in Figure 41- Myanmar's HC decreased from around 85% of final demand in the latter half of the 1990s to around 60% in 2014, falling below those of Bangladesh and Vietnam. This was due to an increase in the share of GFCF, which reached 30% in recent years. While the MMSNA-based official estimates show that the share of HC dropped sharply and that of GFCF rose rapidly 2010 onward, no such drastic changes in the composition of domestic final demand were observed in our estimates.

2.7 Conclusion

The research has attempted to interpret a more realistic interpretation of Myanmar's economic growth, with a view to capturing energy and productivity measures. In the course of research, we revised Myanmar's GDP statistics in the MMSNA by adjusting estimates from the production and expenditure sides. More specifically, this research paper reported on statistical adjustments. The research reviewed and revised data on trade, production, and jade transactions to recapture Myanmar's economic growth 1990s onward. Due to various problems with primary data such as limited availability of production data, our estimates made in the course of this research are no more than pro forma estimates. The estimation of items on the income side, such as compensation of employees and consumption of fixed capital, along with the development of

FIGURE 41-1

COUNTRY-WISE COMPARISON OF HC AND GFCF SHARES IN DOMESTIC FINAL DEMAND

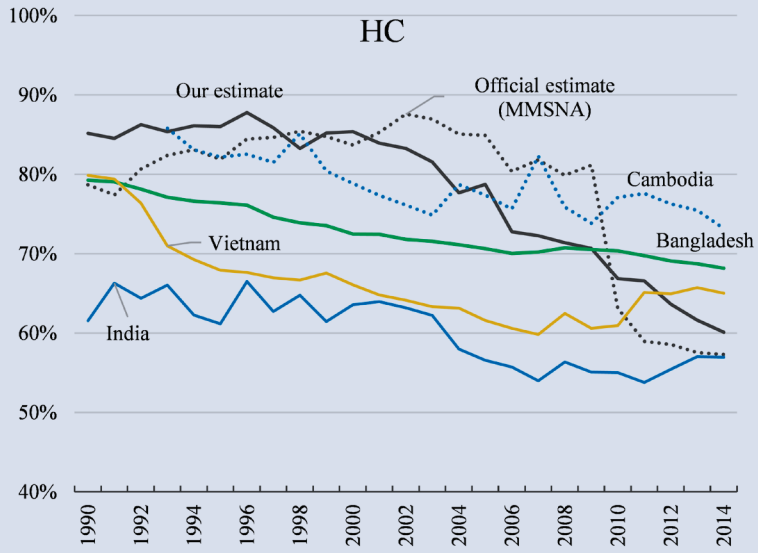
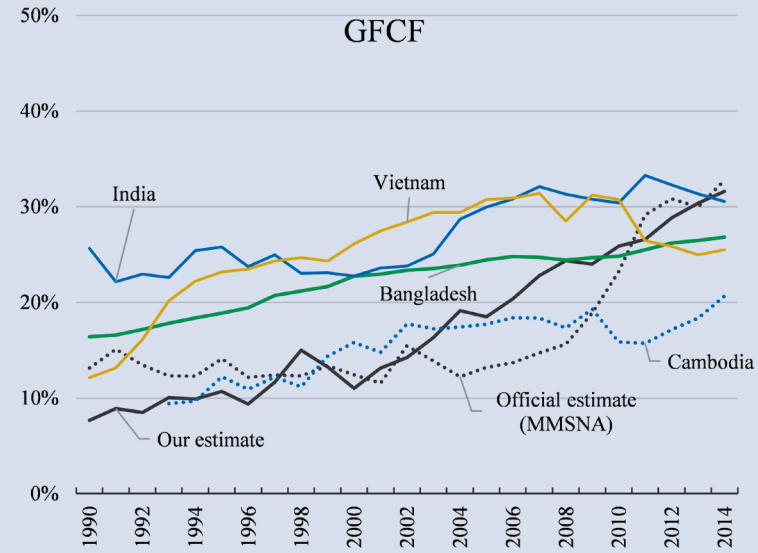


FIGURE 41-2

COUNTRY-WISE COMPARISON OF HC AND GFCF SHARES IN DOMESTIC FINAL DEMAND



data on labor and capital inputs, remain future challenges. Such data points would help develop a growth accounting framework for evaluating energy productivity improvement for Myanmar. The research work provides a good foundation to depict real-term economic growth of Myanmar and would eventually allow to construct energy and productivity measures for the country.

3 A Bottom-up End-Use Model for Residential Electricity Demand

3.1 Background and Motivation

Myanmar is the largest country in mainland southeast Asia. It has a population of more than 50 million and is distributed across 653,080 km^2. The country is divided into 14 administrative divisions comprising 135 different recognized ethnic groups. The majority, Burmese, account for roughly 70% of the total population. The relation between minority and majority groups varies. In general, there has been a long-time armed conflict between the Burmese living in the central part of the country and the minorities in the border areas. In particular, the conflict with the Rohingyas in the Rakhine state recently captured the attention of the international media. Myanmar is eminently rural, with the exception of Yangon, the former capital city and still the major economic center of the country.

The recent transformation of Myanmar has been twofold: from a military regime to an open democracy, and from a closed agriculture system to a relatively open industrialized economic system. The energy and power sector plays a central role in this transition.

The Myanmar government has set an ambitious goal to reach 100% electricity accessibility by 2030. However, without proper estimation of the electricity demand, the power planning and electrification process can become difficult and inefficient. The residential electricity sector dominates electricity consumption in most of the areas except Yangon. Due to data limitation, academic studies on Myanmar's residential electricity demand are rare. To the best of knowledge, this paper is the first study on Myanmar's residential electricity demand with a bottom-up approach.

Electric appliance diffusion in Myanmar has grown rapidly in recent years. A dramatic increase in the mobile industry's penetration was observed after 2014. The penetration rate of mobile phones, which was only 6.99% in 2011–12, increased to 89.38% by 2016. Myanmar needs to increase its power generation capacity to meet the needs of the population to be electrified, particularly in view of the rapid increase in its urban population. Also, the economic development of the country ould accelerate the household energy usage.

Figure 42 illustrates two energy transition models of the household energy use, namely the energy ladder model and the energy stacking model.

The idea of classic energy ladder model is simple: households tend to use more advanced energy source when their incomes grow. However, this model was criticized as it lacked details on the energy use patterns and household behaviors. More recently, the energy stacking model captured greater details on usage of energy based on the appliances and their services. This model too is far from perfect as it cannot include or interpret the phenomenon of 'energy leapfrog.' It is quite clear that the energy transition of households is from the end-use side. Scholars are more and more interested in the details on household behaviors.

FIGURE 42-1

THE CLASSIC ENERGY LADDER MODEL AND THE ENERGY STACKING MODEL

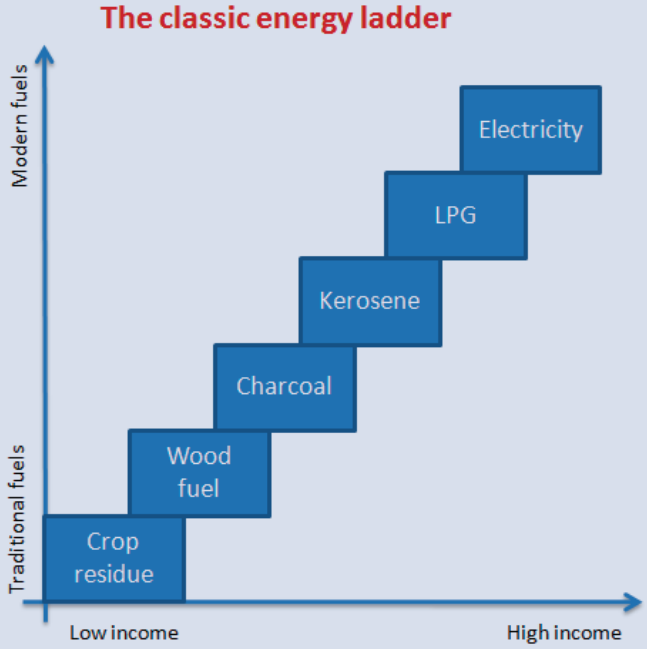
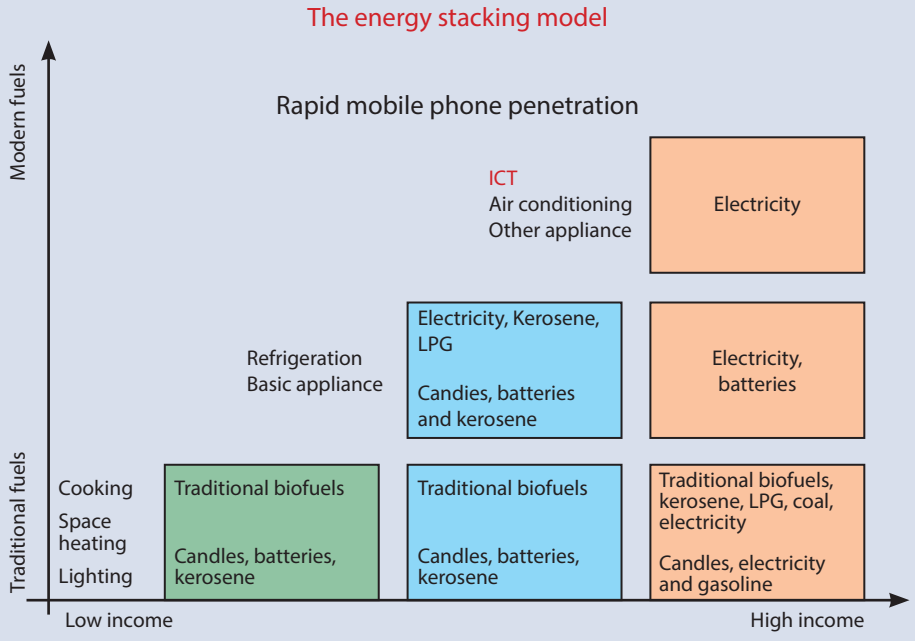


FIGURE 42-2

THE CLASSIC ENERGY LADDER MODEL AND THE ENERGY STACKING MODEL



Recently, there is also a growing academic interest in the estimation of electricity demand in developing countries. Recent literature focuses on the behavioral aspects. Wolfram, et al. [38] argue that electricity demand is highly underestimated due to the neglection of the dramatic increase in demand associated with poverty reduction. They argue that the main drivers of growth are likely to be the poor and near-poor as they acquire appliances for the first time. Gertler, et al. [15] developed a theoretical framework to characterize the effect of income growth on asset purchases when consumers face credit constraints. Their results suggest that the credit constraints and the pace of income growth are important determinants of the household asset acquisition behaviors. Following their ideas, a bottom-up end-use model was developed to capture the pattern of electric appliance acquisition behavior of the household using empirical data. It was analyzed how the occupation ratio of electric appliances would grow until 2030 and drive the evolution of regional residential electricity demand. Using the model, we tried to interpret the transition of energy use from the change of appliance ownership and link it to a broader socioeconomic background, to project the electricity demand. According to the results, it is quite clear that fast urbanization would greatly increase the electricity demand of the household.

3.2 Literature Review

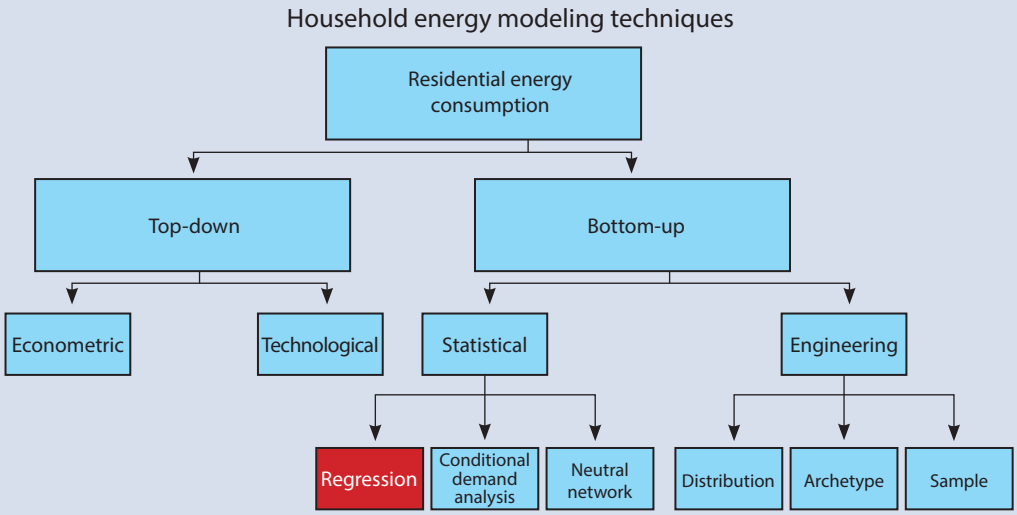
The availability of data and the levels of its details determine the model techniques of residential electricity demand. Swan and Ugursal [33] provide a detailed review of the modeling techniques for residential sector energy usage. Figure 43 illustrates the groups and categories of current modeling techniques.

The top-down model does not distinguish between energy users. It measures the changes of computation with macroeconomic indicators (gross domestic product, employment rates, and energy price), climatic conditions (heating days/cooling days), and housing conditions with econometric analysis. The advantage of the top-down model is that it only needs aggregate historical data, which is widely available. However, the details on the heterogeneity of households are largely unobserved in the top-down model. As Chapter 2 indicates, the reliability of macro data in Myanmar during the military regime is highly questionable. ADB energy master plan [2] and JICA electricity master plan [20] adopt this approach due to its simplicity. However, relying on the top-down model may introduce significant errors when it comes to future projections.

The bottom-up model has been developed to identify the contribution of each end-use appliance toward aggregate consumption. The bottom-up engineering model is widely adopted in developed countries due to the recent development and diffusion of smart meters. However, in developing countries, a lag in technological innovation and diffusion of advanced new products limits the possibility of using the engineering model to estimate electricity demand. Thus, in this research, we build a bottom-up statistical model considering the data availability in Myanmar. This approach enables analysis across different heterogeneous household subgroups and takes into account a number of household characteristics. Examples include Ruijven, et al. [30], and Bhattacharyya [6]. A key advantage of end-use model over other approaches is that it allows the assessment of scenarios for technological advancement in electrical appliances, their acquisition and usage, as well as the impacts of economic (GDP growth, prices), demographic (population growth, urbanization), and geographical (rural/urban and regional/state dummies) factors.

FIGURE 43

REVIEW OF RESIDENTIAL ENERGY MODELING METHODS



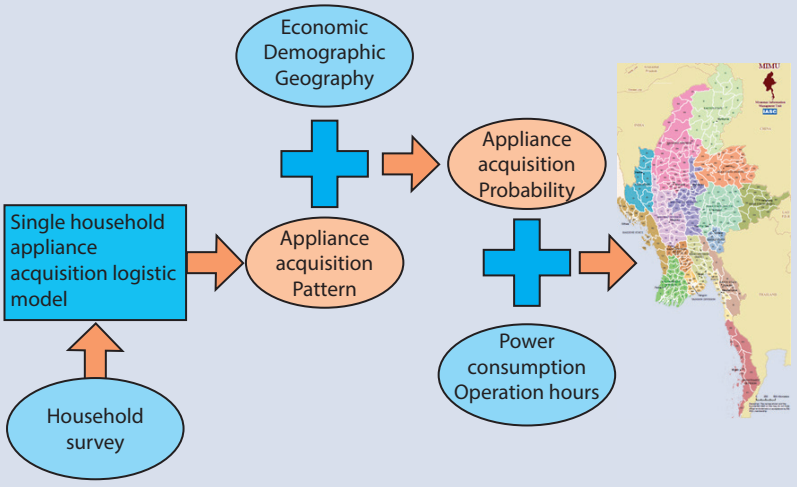
3.3 Modeling

3.3.1 Framework

Figure 44 illustrates the modeling framework adopted in this study. There are three main steps in forecasting residential electricity consumption. The first is to find the household appliance occupation pattern. This is calculated by applying the single household acquisition logistic model using data from a recent household survey. The second step is to calculate the appliance occupation probability using the real economic, demographic, and geographic data of households. The last step is to compute the electricity consumption by incorporating the hourly power consumption of

FIGURE 44

FRAMEWORK OF THE BOTTOM-UP END-USE MODEL



each appliance and operation hour of each kind of electricity appliance. The model projects regional residential electricity demand from 2017 to 2030. The electricity demand is aggregated at the state level. It is also possible to estimate demand at the town level and even at the village level when data is provided.

Based on the discussions above, regional electricity consumption can be calculated by the equation given below, where I stands for the states, j represents each household, and k represents each appliance. P depicts the probability of adoption of a given kind of electricity appliance in a household. W is average watts per hour consumed by the appliance when in active use, while Operationhour is the aggregate yearly working hour of certain appliance. Policyshifter stands for the impact of a certain policy that is constant in the modeling process.

$$(4)\ EC_i = \sum_j \sum_k P_{j,k,occupation} * W_{j,k} * Operationhour_k * Policyshifter_i$$

3.3.2 Single Household Appliance Logistic Model

The core of this model is to correctly estimate the pattern of ownership of a certain appliance. However, before we estimate the ownership pattern, it is important to exhaustively include all the electricity-consuming appliances in Myanmar household's daily life. Table 12 depicts the appliance categories that are included in the model. Airconditioning, cooking, lighting, cooling, entertainment, and communications are considered the main electricity-consuming appliances. Space heating is excluded, considering the high temperature conditions in Myanmar. Washing machines are also excluded due to the data limitations of the household survey.

TABLE 5

APPLIANCE CATEGORIES

End use category	Appliance	Household appliance model
Air conditioning	Air conditioner	Yes
	Central air conditioner	Neglected in Myanmar
Cooking	Cooking stove, rice cooker	Yes
Fans	Fan	Yes
Lighting	Incandescent lamp	Yes
	Bulb	Yes
	LED	No
Freezers	Refrigerator	Yes
Space heating	Boiler	Neglected in Myanmar
	Furnace	Neglected in Myanmar
Communication	Radio	Yes
	TV	Yes
	Computer	Yes
	Mobile	Yes
Washing	Laundry	No
	Washing machine	No

The ownership of appliance of a household has been investigated by scholars for years. Recent research by Rao and Ummel [29] suggests that economic indicators are the predominant drivers in the long run but their impacts are much different across regions and countries. Other noneconomic drivers can help for near-term forecasts. The appliance acquisition decision is based on a complex interaction between household characteristics (economic, noneconomic, behavioral, and cultural) and social and technological factors (geographic, policy, energy supply, and device characteristics). However, it is not possible to include all the factors in one study. We use wealth to describe economic condition of the household; household size, gender of the household head, and age of the household to describe demographic conditions; and state, urban/rural dummy to capture the geographic information of households.

TABLE 6

SUMMARY OF DETERMINATES OF HOUSEHOLD APPLIANCE OWNERSHIP

Categories	Factors
Endogenous factor (household characteristics)	
Economic characteristics	Income, wealth, landholding
Demographic characteristics	Household size, gender, age, household composition, education, labor, information
Behavior and cultural characteristics	Preference, practice, lifestyle, social status
Exogenous factors (social and technology conditions)	
Geographic and environment	Geographic locations, domestic temperature
Policies	Energy policy, subsidies
Energy supply factors	Affordability, availability, accessibility and reliability
Energy device characteristics	Conversion efficiency, cost and payment method, complexity of operation

The ideas of logistics model are explained by Equations 5 and 6. The appliance occupation ratio can be approximated by independent identically distributed trials (observations in the survey). In the equation, i represents the states, l stands for trials, and k depicts the appliances.

$$(5)\ Occupation_{i,l,k} \sim Binary\left(n_{i,l,k}, P_{i,l,k}\right) for\ ..\ l = 1, \ldots, n$$

$$(6)\ Logit\left(E\left[\frac{Occupation_{i,l,k}}{n_{i,l,k}}\right] \middle| \left(D_{i,s,k}, E_{i,w,k}, UR_{i,w,k}\right)\right) = ln\left(\frac{P_{i,l,k,occpuation}}{1 - P_{i,l,k,occupation}}\right) = \Gamma_{i,k}$$

Equation 7 is used for the estimation of impact of each explanatory variable. Here, $\alpha_{i,k}$ is the constant, $D_{i,s,k}$ is demographic variable, $E_{i,w,k}$ is economic variable, and $UR_{i,w,k}$ is the urban/rural dummy, while $\xi_{i,k}$ captures the state's fixed effect and τ is the error term.

$$(7)\ \Gamma_{i,k} = \alpha_{i,k} + \sum_{s} \beta_{i,s,k} * D_{i,s,k} + \sum_{w} \gamma_{i,w,k} * E_{i,w,k} + \rho_{i,k} * UR_{i,w,k} + \xi_{i,k} + \tau$$

3.4 Data

The population and housing census of 2014 is the latest census by the Department of Population. It is also the first population census in more than 30 years. It includes regional population and number of households as well as demographic indicators (percentage of female heads, average age of the heads, and average household size) in each state. The appliances' hourly power consumptions

are drawn from the market survey. However, the appliances' operation hour data are not available in Myanmar, so we use the corresponding data from India as estimated by World Bank [39]. In order to eliminate the difference between Myanmar's households and Indian households, in the next section, the operation hour is calibrated with real electricity consumption data in 2015.

TABLE 7

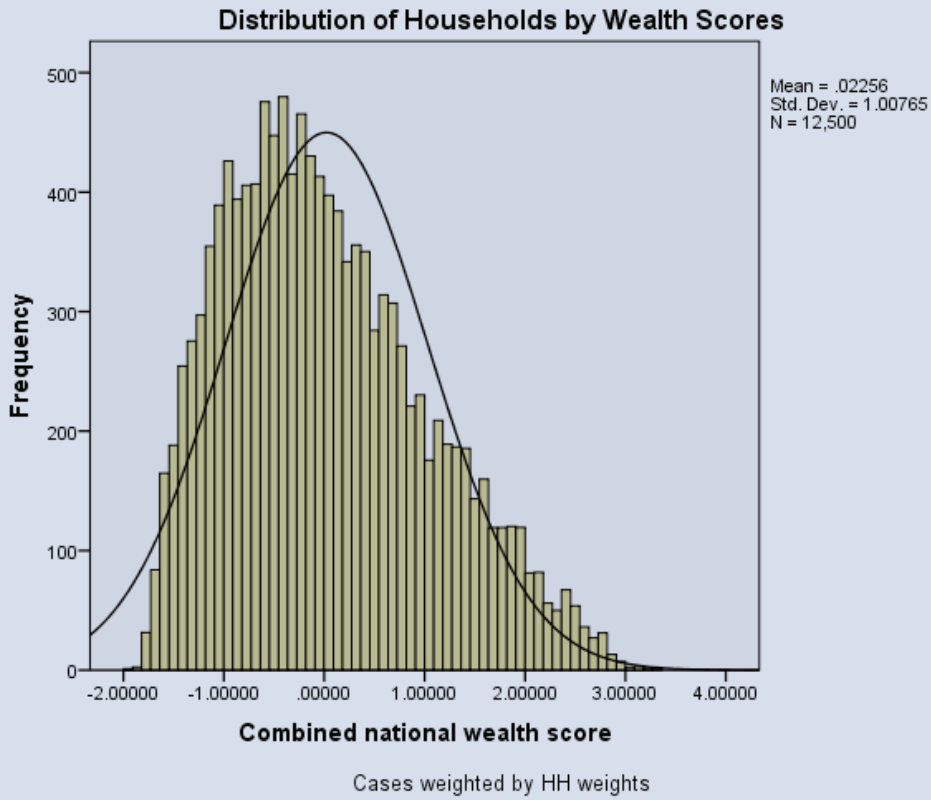
STATISTICAL DESCRIPTION OF WEALTH INDEX IN MDHS

N	Valid	12500
	Missing	0
Mean		0.0225601
Std. error of mean		0.00901268
Median		–0.1213895
Mode		1.93284
Std. deviation		1.00764863
Skewness		0.537
Std. error of skewness		0.022
Kurtosis		–0.344
Std. error of kurtosis		0.044
Minimum		–1.99306
Maximum		3.32630
Percentiles	20	–0.9009567
	40	–0.3765838
	60	0.1605730
	80	0.8972512

In order to get the pattern of household appliance ownership, micro data from National Income and Expenditure Survey by CSO in 2012 is the first choice. However, we were not able to access the micro data. Thus, we used Demographic and Health Survey data (MDHS, 2015–16) for the single household appliance occupation logistic model. The survey was implemented by the Ministry of Health and Sports of the Republic of the Union of Myanmar, funded by the United States Agency for International Development (USAID). The survey included 12,500 household observations all over Myanmar, based on the 2014 census sampling frame. It included questions on whether a household owned a certain electricity appliance, along with the related demographic, geographic information. However, DHS surveys all over the world do not include household income or expenditure data. People usually do not know their incomes or only know it in a broad range or may try to hide it from interviewers in developing countries. To eliminate these impacts, the DHS survey builds a wealth index for each household through principal component analysis, based on the responses to 111 questions in the survey. Households are then ranked, from lowest to highest scores. This list is then separated into five equal pieces or quintiles, each representing 20% of the population. Table 14 describes the statistical information of the wealth index and Figure 45 shows the distribution of the surveyed households by the wealth index.

FIGURE 45

DISTRIBUTION OF HOUSEHOLDS BY WEALTH SCORE



3.5 Results and Calibration

The results from the single household appliance occupation logistic model are presented in Table 15. We dropped the household size from the explanatory variables as it was insignificant in most regressions. Economic condition is explained either by the wealth index or the quintile wealth index. Urban or rural dummy is significant in most regressions, which indicates that the residence area could greatly change the pattern of an appliance's ownership. The gender and age of the household head are also significant means. A state's dummy also allows us to capture the fixed effect of the state, which could be used to calculate the differences in appliances' ownerships in each state.

TABLE 8

ESTIMATION RESULTS FROM THE LOGISTIC REGRESSION

Variables	Radio	TV	Refrigera-tor	Telephone	Mobile	Computer	Air Conditioner	Lighting	Cooking
Wealth						2.258***	4.651***	1.387***	3.212***
Wealth2	0.418***	1.594***	1.167**	1.443***	1.326***				
Wealth3	0.685***	2.892***	1.902***	2.317***	2.558***				

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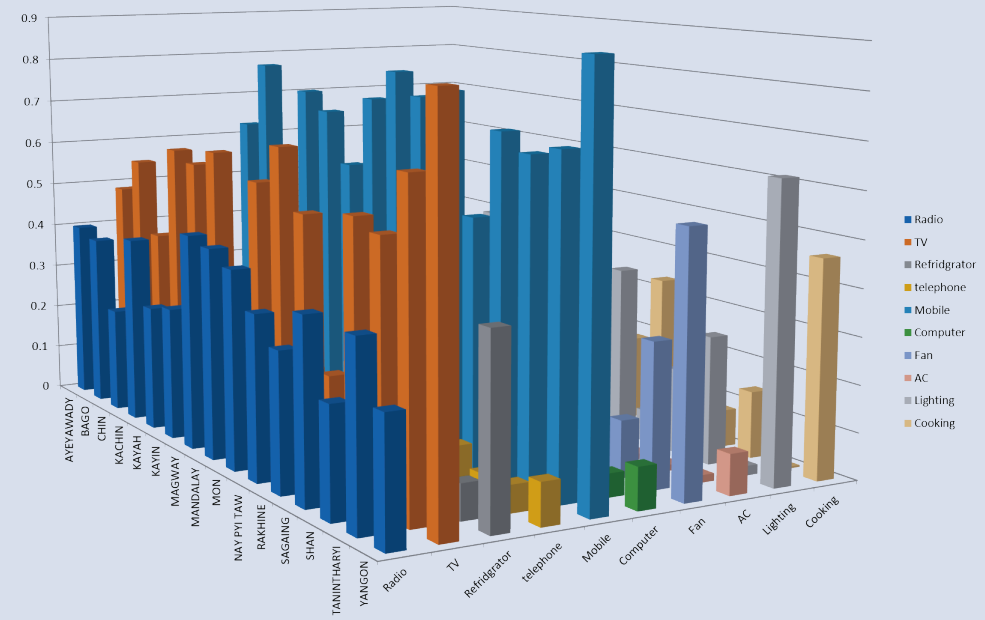
Variables	Radio	TV	Refrigera-tor	Telephone	Mobile	Computer	Air Conditioner	Lighting	Cooking
Wealth4	0.853***	4.422***	3.903***	3.321***	3.850***				
Wealth5	1.142***	6.474***	6.650***	4.875***	6.081***				
UR	-0.301***	0.034***	0.434***	-0.424***	0.388***	0.674***	1.184***	0.541***	0.754***
Sex of head	0.503***	0.235***	0.057	0.197**	0.306***	0.214*	0.199	0.126*	0.115*
Age of head	0.025***	-0.009***	-0.001	0.016***	-0.020***	0.005	0.000	0.011*	0.002
State Dummy	Y	Y	Y	Y	Y	Y	Y	Y	Y
Log likelihood	-7496	-5124	-2466	-2565	-5008	-1411	-928	-3221	-1578
Obs	12500	12500	12500	12500	12500	12500	12500	12500	12500

The marginal effect of each variable can be calculated separately, which allow us to obtain the appliance's ownership probability, based on the ownership pattern and the household characteristics. Figures 46 and 47 show the state-level average ownership of each appliance based on empirical results. These results can be used to develop the pattern of appliance ownership when the condition of a household is set. The ownership pattern can thus be set when the household conditions are set.

FIGURE 46

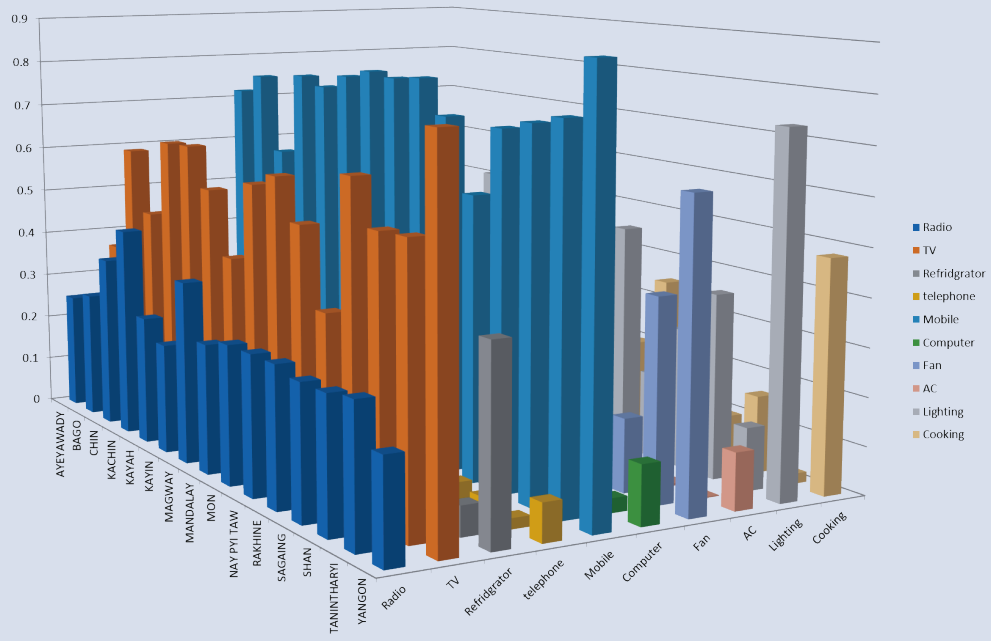
STATE-LEVEL AVERAGE OWNERSHIP OF EACH APPLIANCE (RURAL AREA)



We can easily capture the heterogeneity of appliance ownership by states and appliance categories, and also find the differences between rural and urban areas, which cannot be fully explained by the differences in economic characteristics. Missing these heterogeneities can reduce the accuracy of a prediction. Also, missing the details of a macro or top-down approach can naturally lead to overestimated or underestimated results.

FIGURE 47

STATE-LEVEL AVERAGE OWNERSHIP OF EACH APPLIANCE (URBAN AREA)



As mentioned in the modeling framework, the hourly power consumption is obtained from the market survey. However, it is not possible that Myanmar's household appliance usage could be the same as that of the households in India or in other countries. Thus, the average operation hours of each appliance can be calibrated with the real electricity consumption data when the appliance's hourly power consumption and ownership probability are set. We do not distinguish gird users from off-grid users in the calibration process as there is no data on the electricity consumption of the off-gird users. We thus use the regional residential electricity consumption in 2015 from the ADB energy master plan to adjust the operation hour. The results of the calibration are illustrated in Figure 48. The model is adapted to the Union's consumption data while the distribution in each state suggests high accuracy of the model.

The overall regional electricity consumption data (residential, industrial, and business) in 2015 is provided by Ministry of Electricity and Energy and JICA. We use it to doublecheck our model. The results of the calibration are illustrated in Figure 49. It is easy to find that the share of residential electricity consumption becomes larger in less developed areas.

FIGURE 48

CALIBRATION RESULTS OF THE END-USE MODEL AND THE ADB MASTER PLAN

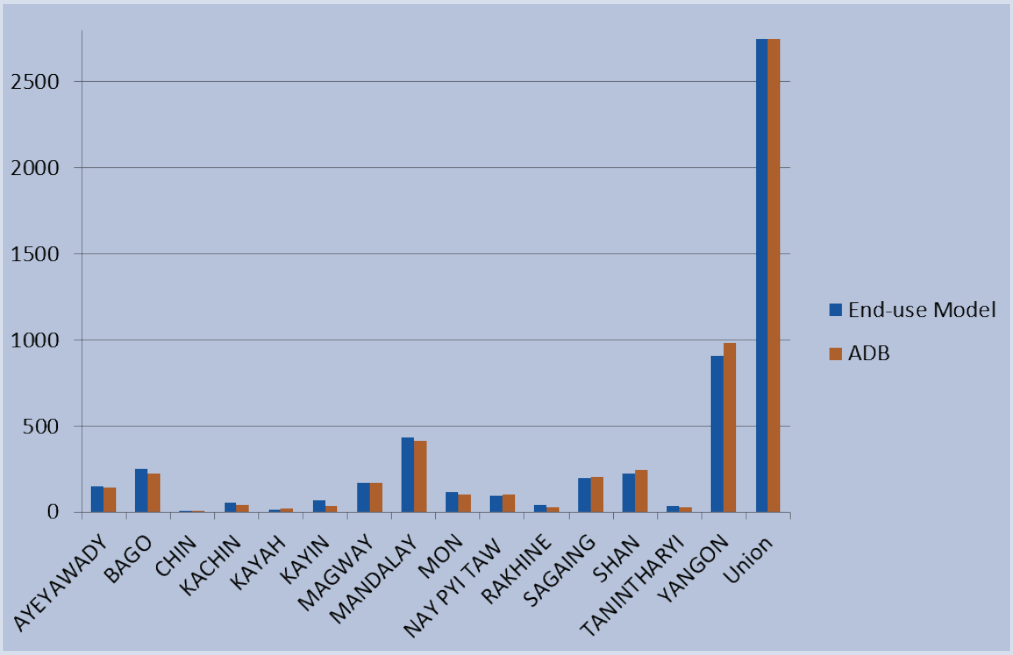
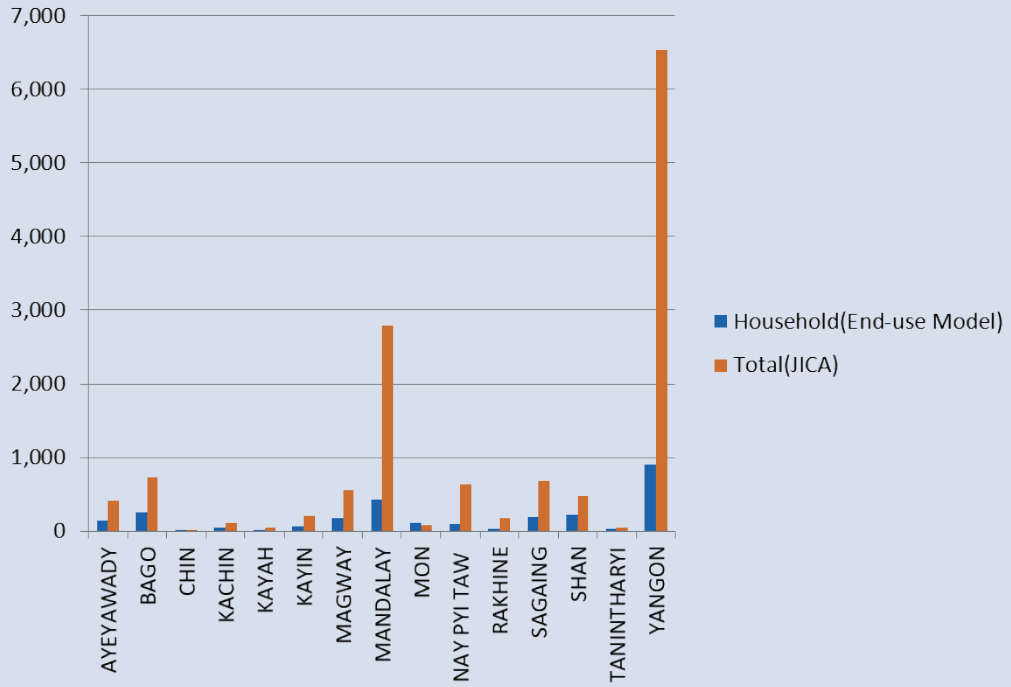


FIGURE 49

COMPARISON OF RESULTS OF THE END-USE MODEL AND TOTAL ELECTRICITY CONSUMPTION



3.6 Residential Electricity Demand Forecast until 2030

The end-use model captures the impact of social transition and economic growth. There are three main driving variables in the model: economic status (wealth), demographic indicators (female or male head of household, and age of the household head), and geographic indicators (urban or rural, residence state).

In order to simulate the impact of urbanization, we build two scenarios. The base scenario uses the population and GDP data of Share Socioeconomic Pathway 2 (SSP2). We assume that the change in demographic structure is small within 15 years, and therefore the demographic structure of each state remains the same with the current situation in Population and Housing Census 2014. We also assume that the wealth accumulation speed is 0.8 times the GDP growth. In the base scenario, urbanization speed is 0.1% per year in each state, which means that annually, 0.1% of total population will migrate to urban areas in each state. In a fast-urbanization scenario, the urbanization speed is 0.5% per year in Yangon and other parameters are similar to those in the base scenario.

The results of two scenarios are illustrated in Figures 50 and 51. The residential electricity consumption will rise from 2,768 GWh in 2015 to 6,736 GWh in 2030. In the fast-urbanization scenario, the residential electricity demand will further rise to 7,449 GWh in 2030. We also find that the Yangon area will continue to become the largest electricity-consuming area of Myanmar and will consume more than one-fourth of the country's residential electricity. If we consider that more people will migrate to Yangon in the coming years, the share can become even larger.

FIGURE 50

REGIONAL RESIDENTIAL ELECTRICITY CONSUMPTION IN THE BASE SCENARIO

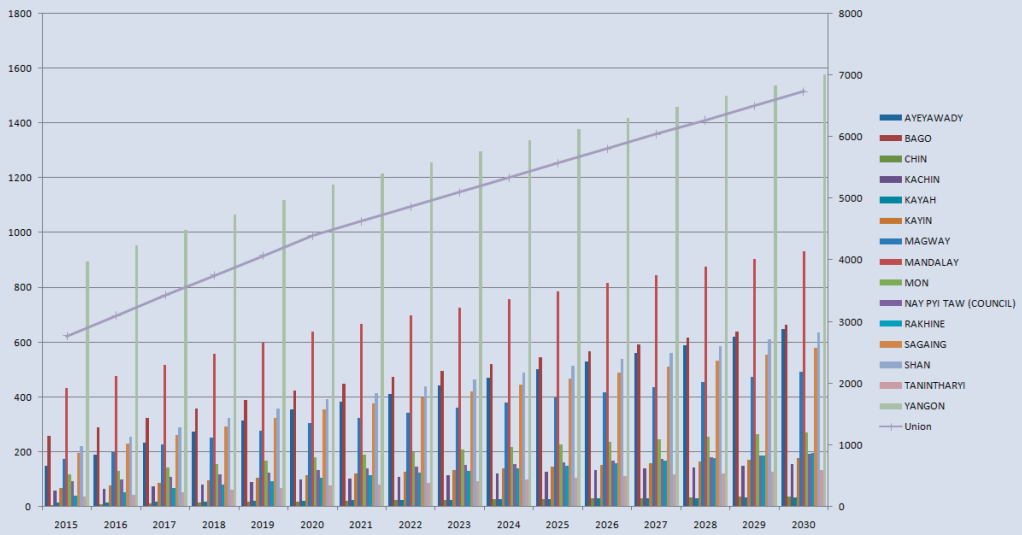


FIGURE 51

REGIONAL RESIDENTIAL ELECTRICITY CONSUMPTION IN THE FAST-URBANIZATION SCENARIO

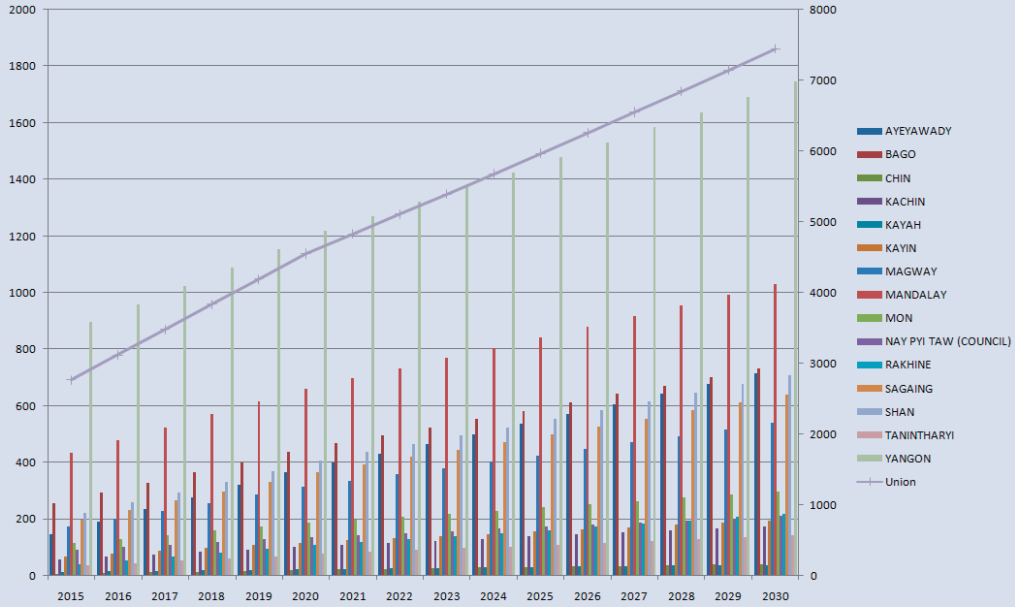


Figure 52 compares the results of base and fast-urbanization scenarios. The results suggest that the changing appliance ownership due to urbanization could increase the electricity consumption

FIGURE 52

COMPARISON OF AGGREGATE RESIDENTIAL ELECTRICITY CONSUMPTIONS IN BASE AND FAST-URBANIZATION SCENARIOS

greatly. 713 GWh of electricity demand could be generated due to fast urbanization. This result urges the government policy to support further investments in power generation.

3.7 Conclusion

The second research, using a bottom-up end-use model, analyzes how the regional residential electricity demand is likely to evolve as a consequence of Myanmar's rapid urbanization. The pattern of ownership of appliances is empirically estimated with a large-scale survey while the appliance operation pattern is calibrated with 2015 residential consumption data. Compared with the traditional top-down model, this model provides high resolution and abundant details on electricity demand.

Myanmar's residential electricity demand could be tripled in 2030 in the fast-urbanization scenario, compared with the demand in 2015. This research provides an alternative approach for estimating residential electricity consumption in developing countries to overcome data limitations. The results provide a better understanding of the household behavior of appliance ownership and electricity consumption. Chapter 3 illustrates the huge potential and high uncertainty of residential electricity demand that needs to be considered in the electrification process and power planning.

4 Myanmar Energy Productivity Analysis based on DNE21+ Model

4.1 Overview of Myanmar's Energy Situation

Before conducting DNE21+ model analysis, we surveyed Myanmar's latest energy supply and demand situation and related socioeconomic conditions through face-to-face interviews with Myanmar's energy experts in Myanmar and Thailand, and also carried out wide-ranging literature reviews.

Table 9 shows the list of interviewees. The interviewers were Junichiro Oda (RITE) and Nan Wang (RITE). The reviewed literature includes the following three reports: JICA National Electricity Master Plan 2014, WB National Electrification Plan 2014, and ADB Myanmar Energy Master Plan 2015. Nippon Koei Co., Ltd., Mitsui & Co., Ltd., and Tokyo Gas Co., Ltd. [24] indicated the ongoing severe natural gas shortage and outlook for the natural gas supply and demand in Myanmar.

TABLE 9

LIST OF INTERVIEWEES ON MYANMAR'S ENERGY SITUATION

Name (Title)	Affiliation, Country
1 Masaki Takahashi (power sector advisor, JICA expert), and U Aung Myo Win	Ministry of Electricity and Energy (MOEE), Myanmar
2 Mamoru Sakai (senior representative), and Kojun Nakashima (representative)	JICA Myanmar Office, Myanmar
3 Masaaki Nishimura (chief representative)	Tokyo Gas Co., Ltd. Thailand Representative Office, Thailand
4 Shobhakar Dhakal (professor)	Asian Institute of Technology (AIT), Thailand
5 Aung Myo Win (deputy director), and Khin Sett Yi (assistant director)	Ministry of Planning and Finance, Myanmar

The study, based on face-to-face interviews and literature reviews, reveals the following conditions in Myanmar:

1. An ongoing natural gas and electricity shortage.

2. Risks derived from energy shortage: Disincentives for investments in not only the energy sector, but also in a wide range of manufacturing industries.

3. Current energy policy led by NLD: All large hydro plant developments are pending; all coal power plant developments are suspended; and natural gas power plant development has a mid-to-low priority.

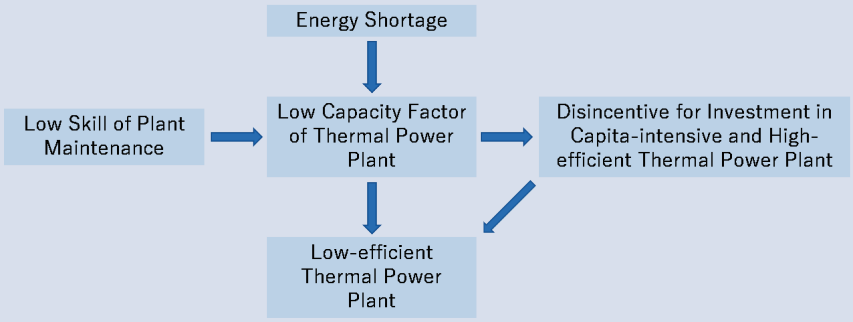
4. Current technical condition of thermal power plants such as low-efficiency, e.g., 20%, and lower capacity, e.g., 30% to 40%.

5. Importance of Myanmar's natural gas export to Thailand and China from the point of view of international relationship and trade balance.

The factors of low efficiency and low capacity for thermal power plants are illustrated in Figure 53, indicating that we should address the energy shortage and low skills of plant maintenance (technical human capacity) toward a fundamental solution.

FIGURE 53

FACTORS OF LOW EFFICIENCY AND LOW CAPACITY FOR THERMAL POWER PLANTS IN MYANMAR



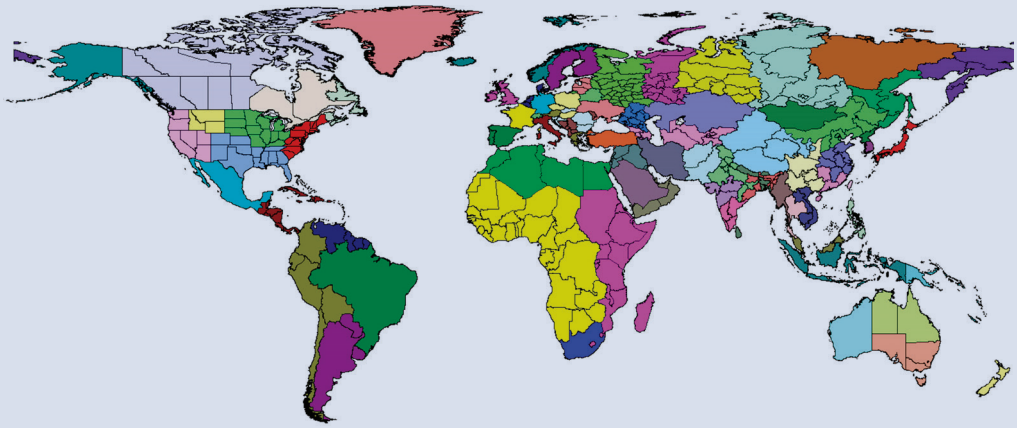
4.2 Methodology of DNE21+ Model

In this report, we use a world energy systems model, DNE21+. The DNE21+ model is a linear programming model for detailed technology assessment under CO2 emission constraints in which the worldwide energy system costs are to be minimized [5, 25].

The model divides the world into 77 regions. The countries of interest are treated as independent regions, and countries with large areas such as the US, Canada, Australia, PR China, India, Brazil, and Russia are further disaggregated into three to eight regions to consider the geographical distribution of natural resources and the transportation costs of energy and CO2 in more detail. Myanmar is treated as an independent region as shown in Figure 54.

FIGURE 54

REGIONAL DIVISION AS PER THE DNE21+ MODEL



When any CO2 emission restriction (an upper limit of emissions, carbon taxes, etc.) is applied, the model specifies the energy systems where costs are minimized, while meeting the following requirements:

1. Production for manufacturing industries such as iron and steel, cement, and paper and pulp.
2. Transportation by automobile, bus, and truck.
3. Residential energy services for TV, lighting, and airconditioning (cooling).

The energy supply sectors are hard-linked with the end-use sectors, including natural gas production and energy exports and imports. The trajectory of technological changes would be practical because the vintages and lifetimes of the facilities are taken into account.

4.3 Scenario Setting for DNE21+ Analysis

Three scenarios are studied as shown in Table 10. The 'current policy scenario' represents the present Myanmar government's policy, which is negative to large hydro and coal power developments. The 'development scenario' has no such development constraints and addresses the energy shortage. The 'two-degree scenario' represents the current two-degree goal, which is noted in the international climate negotiation.

TABLE 10

SCENARIO SETTING FOR DNE21+ ANALYSIS

	Myanmar's power development constraints	Global climate policy
Current policy scenario	Yes	No
Development scenario	No	No
Two-degree scenario	Yes	Yes

Myanmar's power development constraints imply the following:

1. Upper limit for fossil power plant capacity factor (Figure 55).
2. Upper limits for coal power, hydro, and geothermal power plant development (Figure 56).

FIGURE 55

ASSUMED UPPER LIMIT FOR FOSSIL POWER PLANT CAPACITY FACTOR FOR 'CURRENT POLICY' AND 'TWO-DEGREE' SCENARIOS IN MYANMAR

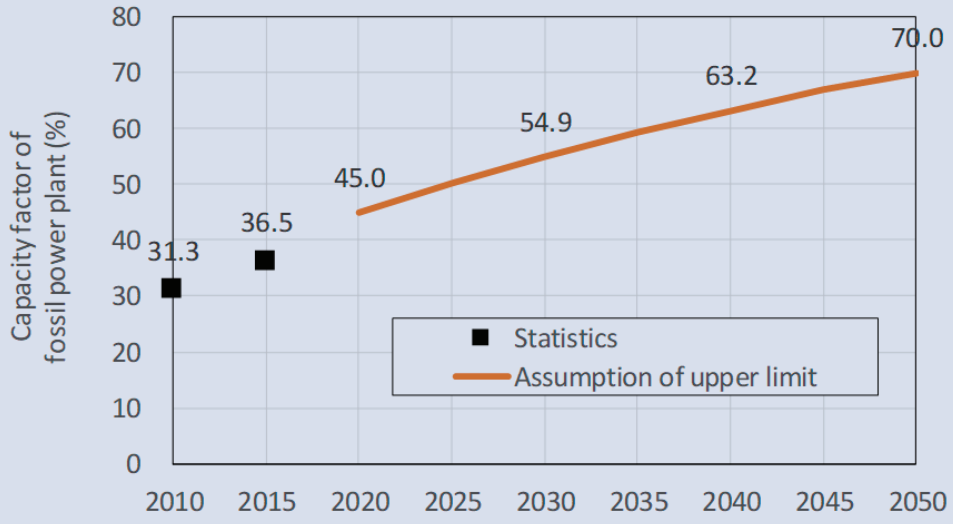
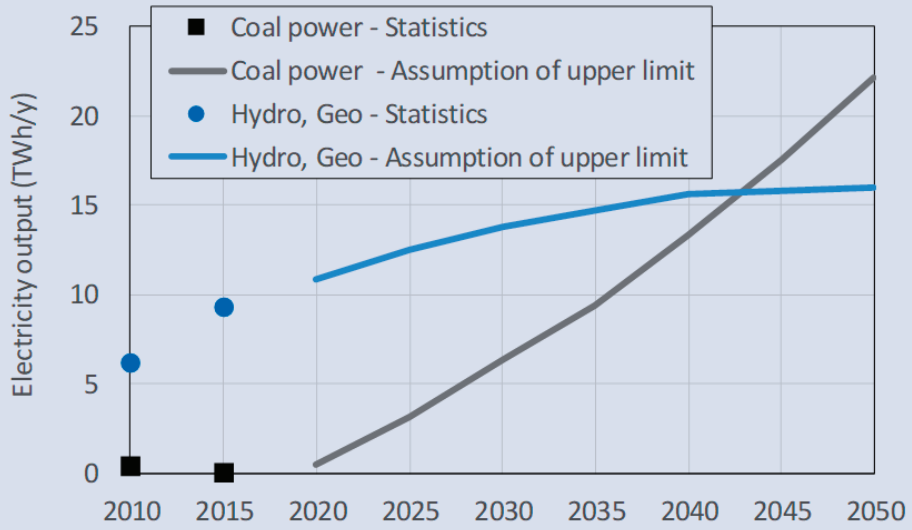


FIGURE 56

ASSUMED UPPER LIMIT FOR ELECTRICITY OUTPUT FOR 'CURRENT POLICY' AND 'TWO-DEGREE' SCENARIOS IN MYANMAR



These constraints are based on the current technical, social, and political situations in Myanmar as denoted in the previous session. The development scenario has no constraints for power development, which means that it follows DNE21+ default assumptions about power development.

Global climate policy represents the global climate mitigation goal, i.e., the two-degree goal. In DNE21+ analysis, we set total global CO2 emissions constraints, which means equalization of marginal abatement costs across all regions and all sectors on a global scale.

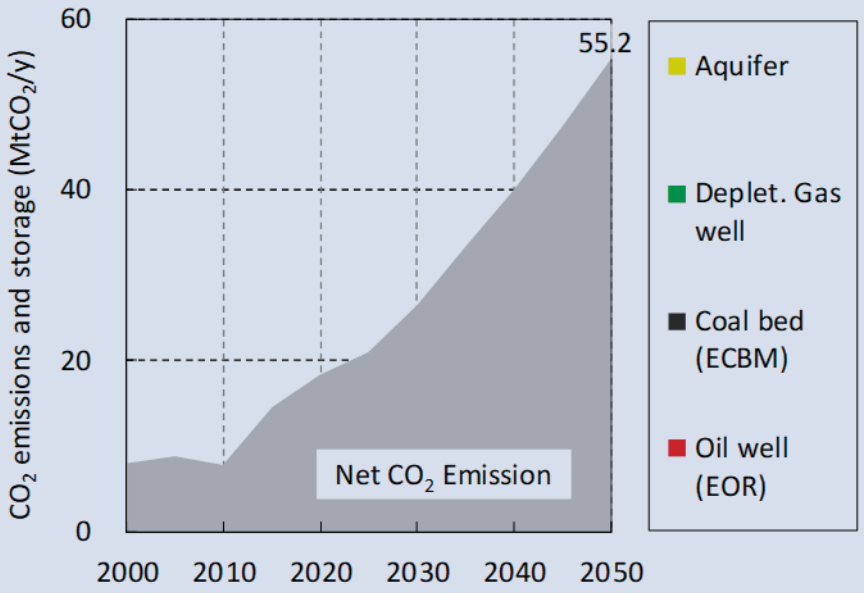
A discount rate of 5% per year is adopted throughout the study in order to calculate cumulative energy system costs up to the year 2050. Interest rates and opportunity costs for investment vary by country, and we consider the regional difference in depreciation rate for DNE21+ analysis based on per-capita GDP. For example, Myanmar's interest rates are higher than those of Japan.

4.4 Results of DNE21+ Model

Figure 57 shows DNE21+ results of energy-related CO2 emissions in Myanmar. Net CO2 emissions in the two-degree scenario are almost half of other scenarios, and the marginal abatement cost will reach 183 US2000$/tCO2 in 2050. The two-degree scenario is based on international climate negotiation. However, it is a normative goal for Myanmar's current socioeconomic condition because additional energy system costs are significant, as shown in Table 11.

FIGURE 57-1

DNE21+ RESULTS: ENERGY-RELATED CO2 EMISSIONS IN MYANMAR



Current policy scenario

FIGURE 57-2

DNE21+ RESULTS: ENERGY-RELATED CO2 EMISSIONS IN MYANMAR

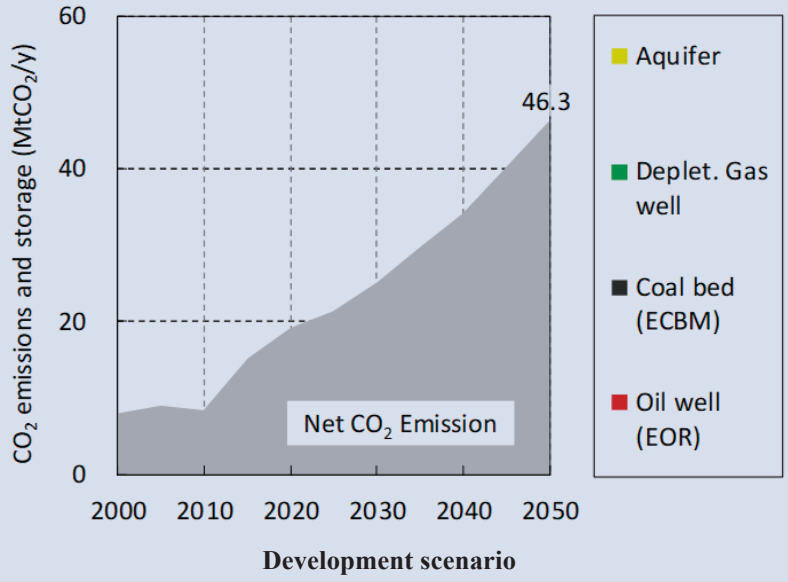


FIGURE 57-3

DNE21+ RESULTS: ENERGY-RELATED CO2 EMISSIONS IN MYANMAR

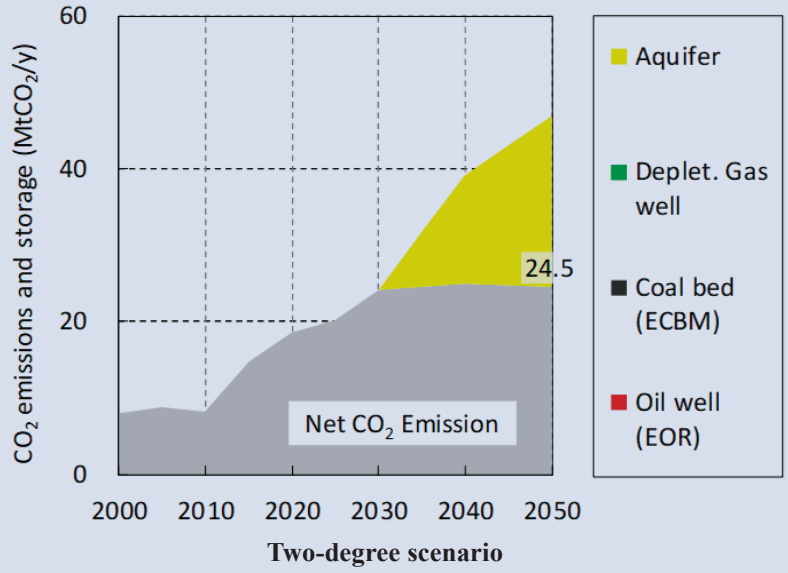


TABLE 11

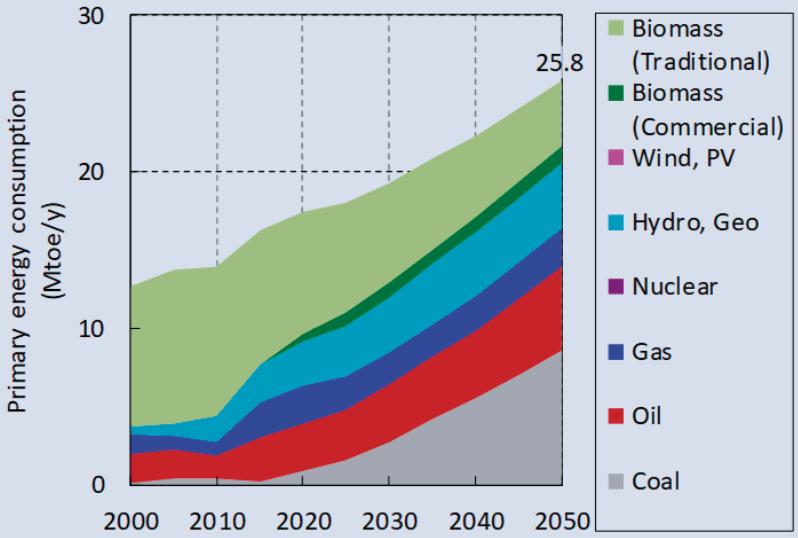
DNE21+ RESULTS: ADDITIONAL ENERGY SYSTEMS COSTS PER GDP IN TWO-DEGREE SCENARIO IN MYANMAR

	2030	2040	2050
Two-degree scenario	2.1%	2.3%	0.9%

CO2 emissions in current policy scenario are higher than those in development scenario. This is because, in the current policy scenario, the efficiency of a thermal power plant is very low and total primary energy supply is large (see Figure 58).

FIGURE 58-1

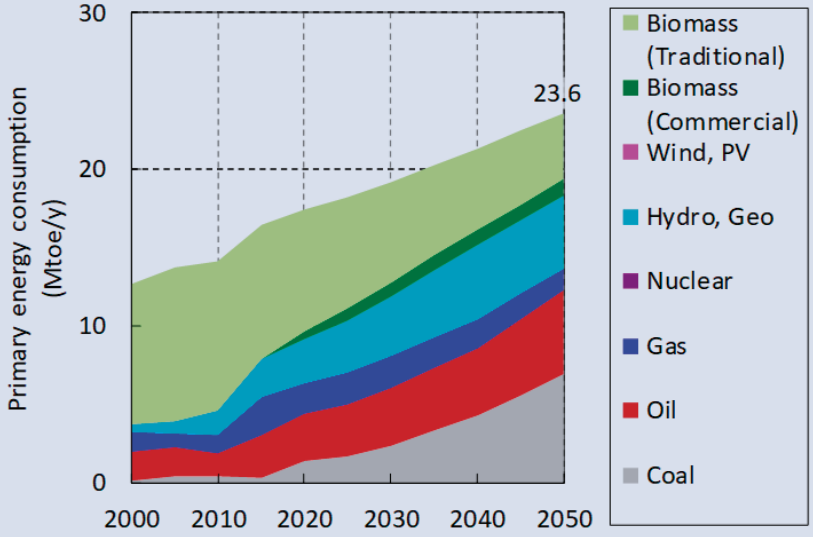
DNE21+ RESULTS: PRIMARY ENERGY SUPPLY IN MYANMAR



Current policy scenario

FIGURE 58-2

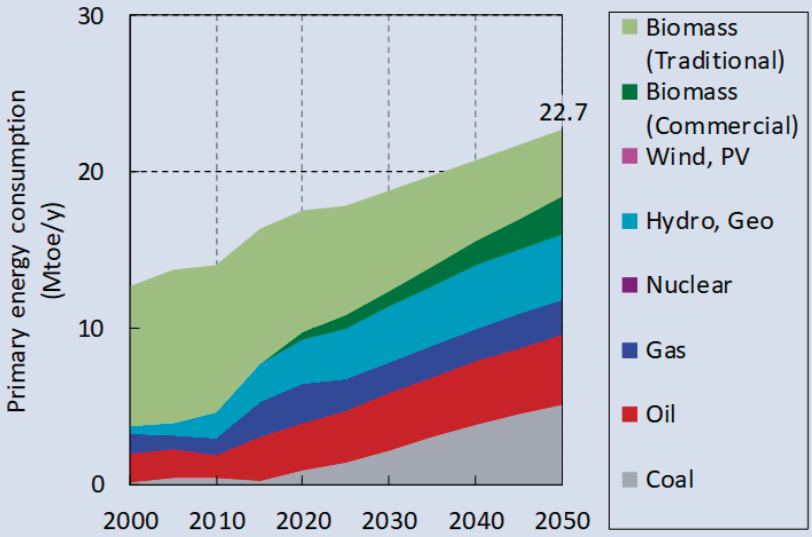
DNE21+ RESULTS: PRIMARY ENERGY SUPPLY IN MYANMAR



Development scenario

FIGURE 58-3

DNE21+ RESULTS: PRIMARY ENERGY SUPPLY IN MYANMAR

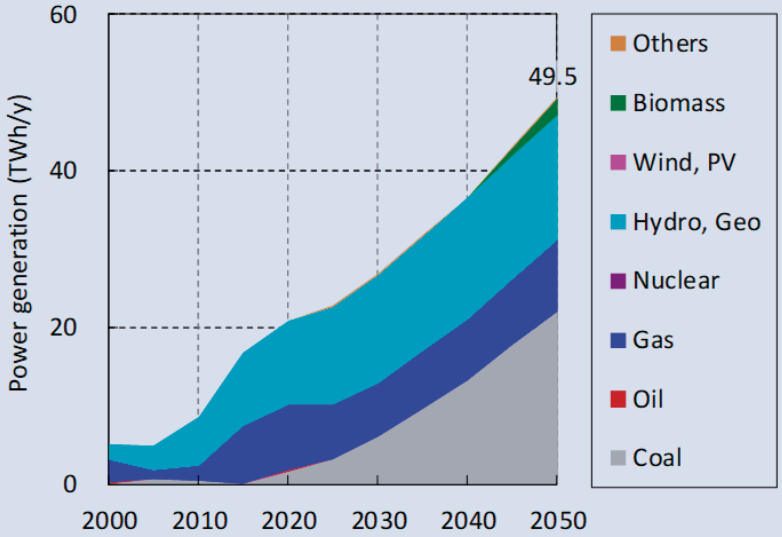


Two-degree scenario

Figure 59 shows DNE21+ results of power generation in Myanmar. In two-degree scenario, almost all thermal power plants and biomass power plants would have carbon capture and storage (CCS) facilities by 2050. However, we must note that the large diffusion of CCS is too optimistic, keeping Myanmar's current socioeconomic condition in view. In current policy scenario, total power output is slightly lower than that in the development scenario due to the higher cost of power generation and price elasticity effect. Moreover, fossil fuel consumption is high due to low-efficiency fossil power plants.

FIGURE 59-1

DNE21+ RESULTS: POWER GENERATION GROSS OUTPUT IN MYANMAR



Current policy scenario

FIGURE 59-2

DNE21+ RESULTS: POWER GENERATION GROSS OUTPUT IN MYANMAR

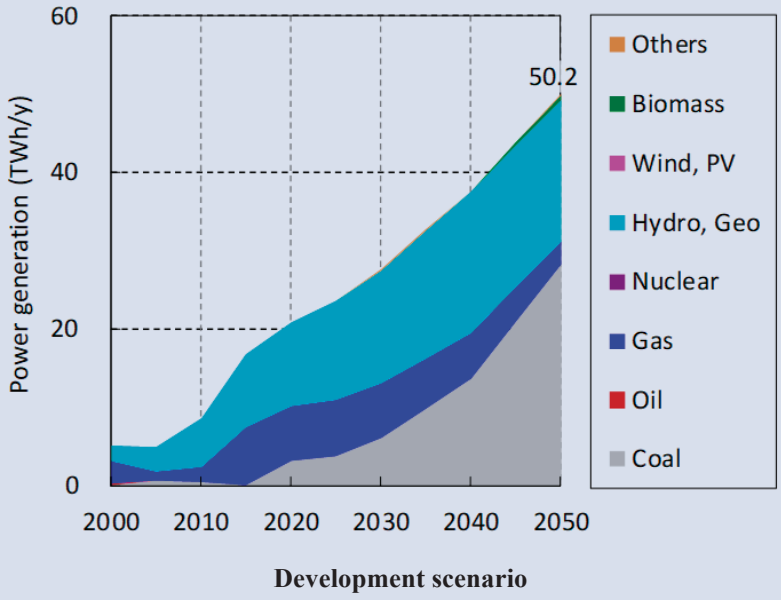


FIGURE 59-3

DNE21+ RESULTS: POWER GENERATION GROSS OUTPUT IN MYANMAR

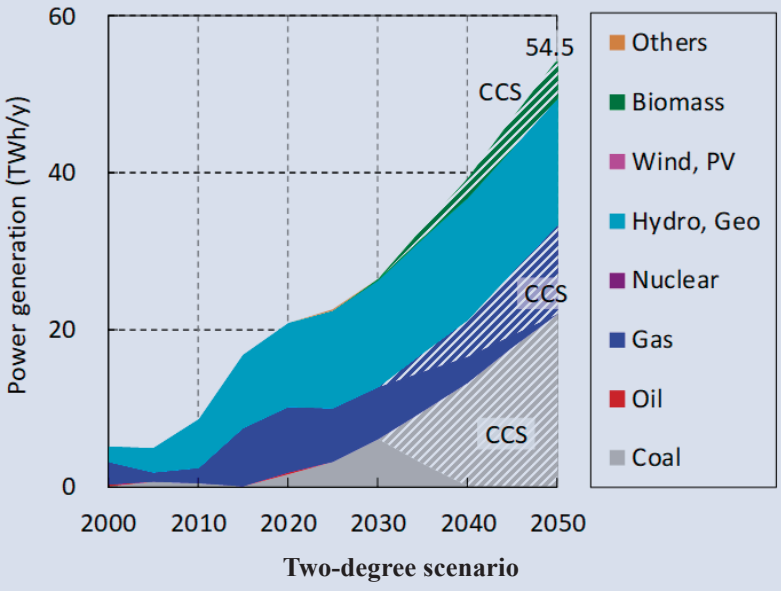


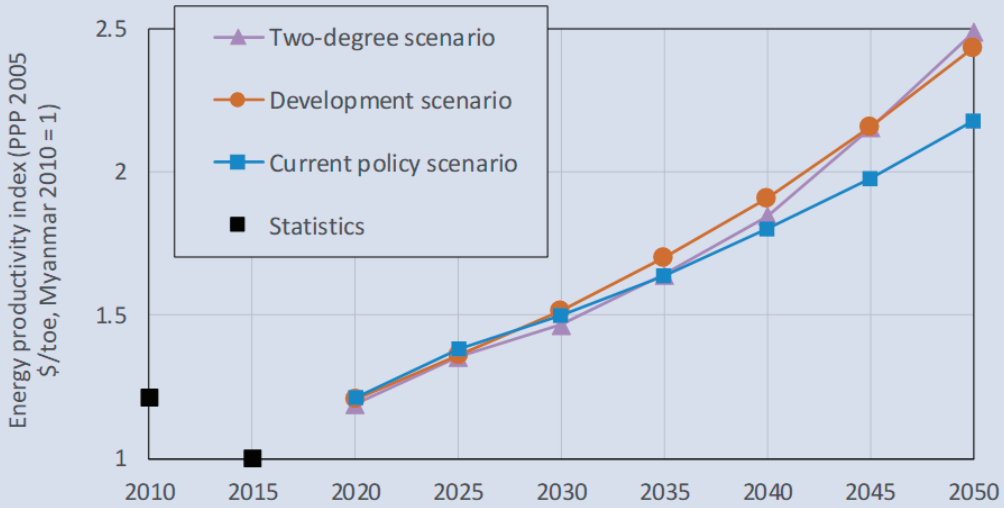
Figure 59 indicated that Myanmar's power output in a two-degree scenario would be higher than others. This is because the electricity increase, derived from own use of carbon capture and storage (CCS) and substitution from non-electric energy to electricity, compensated the overall electricity saving effect.

Energy productivity by scenario is shown in Figure 60, which refers to GDP (PPP 2005 $) of Myanmar's all sectors and total primary energy supply without traditional biomass (Figure 58). Energy productivity can be improved until 2050, based on DNE21+ results, though it is noted that the DNE21+ model assumes more of an agriculture-based economy and less of a manufacturing economy throughout the period.

Energy productivity in current policy scenario is lower than that in the development scenario. This is because, in current policy scenario, efficiency of thermal power plant is very low and total primary energy supply is large (Figure 58). In two-degree scenario, we refer to transient GDP loss derived from additional energy system costs (Table 11), which means that we don't refer to cumulative GDP loss.

FIGURE 60

DNE21+ RESULTS: ENERGY PRODUCTIVITY BY SCENARIO IN MYANMAR



Note: GDP (PPP 2005) and Primary energy supply without traditional biomass is referred.

4.5 Summary of Energy Productivity Analysis based on DNE21+ Model

In this section, we surveyed Myanmar's latest energy supply-and-demand situation and related socioeconomic conditions based on face-to-face interviews with Myanmar experts in Myanmar and Thailand. We also conducted wide-ranging literature reviews. The survey reveals the following conditions in Myanmar:

1. Ongoing energy shortage in natural gas and electricity,

2. Current energy policy led by NLD: All large hydro plant developments are pending; all coal power plant developments are suspended; and natural gas power plant development has a mid-to-low priority.

3. Current technical conditions of power plants include low efficiency, e.g., 20% to 30%, and lower capacity factor, e.g., 30% to 40%.

4. Importance of Myanmar's natural gas export to Thailand and PR China.

Based on the survey, we conducted Myanmar's energy supply-and-demand analysis using a world energy systems model, DNE21+. Three scenarios, namely, current policy, development, and two-degree, were studied. In current policy scenario, low-efficiency fossil power plants would remain operational up to 2050, which would require large fuel input as compared to the development scenario. As a result, energy productivity of current policy scenario is inferior to that of the development scenario.

The two-degree scenario is a normative and optimistic scenario in view of the global warming mitigation. The marginal abatement cost will reach 183 US2000$/tCO2 in 2050. The results indicate that Myanmar's total primary energy supply in the two-degree scenario would be at almost the same level as the base case. This is because energy increase derived from carbon capture and storage (CCS) would compensate the overall energy saving effect. As a result, energy productivity of the two-degree scenario is at almost the same level as the development scenario.

Based on the above survey and DNE21+ analysis, we conclude the following policy implications:

1. Myanmar should address the ongoing energy shortage.

    a) Predictable return on investment in a power plant, through stable supply of fossil fuel and capacity factor, is required for stimulating further investments in high-efficiency and capital-intensive power plants.

    b) Not only natural gas but also coal has a role in addressing energy shortages in the current socioeconomic conditions.

2. Myanmar should explore wide-ranging technology options that accelerate capacity building including human resources development.

    a) Capacity building is important for improving efficiencies of thermal power plants.

    b) Capacity building is also important for long-term energy productivity and CO2 emission reductions. Foreign countries should support Myanmar's capacity building from both hardware and software dimensions.

REFERENCES

[1] ADB, Myanmar Energy Sector Initial Assessment, Manila: Asian Development Bank; 2012.

[2] ADB, Myanmar Energy Master Plan, Manila: Asian Development Bank; 2015.

[3] ADB, Asian Development Outlook 2017. Asia's Potential Growth, Manila: Asian Development Bank; 2017.

[4] APO, APO Productivity Databook 2016, Tokyo: Asian Productivity Organization; 2016.

[5] Akimoto K., Takashi H., Fuminori S., et al. Assessment of the Emission Reduction Target of Halving CO2 Emissions by 2050: Macro-factors analysis and model analysis under newly developed socio-economic scenarios. Energy Strategy Rev 2014; 2(3–4), pp. 246–256.

[6] Bhattacharyya S.C. Influence of India's Transformation on Residential Energy Demand. Applied Energy 2015; 142, pp. 228–237.

[7] Central Statistical Organization. The Government of the Republic of the Union of Myanmar, Ministry of National Planning and Economic Development. Myanmar Statistical Yearbook 2015.

[8] Central Statistical Organization. The Government of the Republic of the Union of Myanmar, Ministry of National Planning and Economic Development. Selected Monthly Indicators 2015.

[9] CIA. The CIA World Factbook 2016, Washington D.C.: Central Intelligence Agency.

[10] CRED. The Emergency Events Database 2016, Brussels: Centre for Research on the Epidemiology of Disasters; 2016.

[11] Dapice D., Valley T., Wilkinson B., et al. Revitalizing Agriculture in Myanmar: Breaking Down Barriers, Building a Framework for Growth. Cambridge: Harvard ASH Center, Harvard Kennedy School; 2010.

[12] Dapice D., Valley T. Creating a Future: Using Natural Resources for New Federalism and Unity. Cambridge: Harvard ASH Center, Harvard Kennedy School; 2014.

[13] Ebashi M. Gunjiseikenka ni okeru Myanmar no Shijoukeizaika to Kongo no Seisakukadai (Market-oriented Economic Reform and Future Policy Issue under Military Regime in Myanmar) (in Japanese). The Ritsumeikan Business Review: the Bimonthly Journal of Ritsumeikan University, Osaka: Ritsumeikan Keieigakkai, pp. 129–172.

[14] FAO. FAOSTAT 2016, Rome: Food and Agriculture Organization of the United Nations; 2016.

[15] Gertler P.J., Shelef O., Wolfram C., et al. The Demand for Energy-Using Assets Among the World's Rising Middle Classes. America Economic Review 2016; 106, pp. 1,366–1,401.

[16] Global Witness. Lords of Jade. London: Global Witness; 2015.

[17] Global Witness. Jade: Myanmar's "Big State Secret." London: Global Witness; 2015.

[18] IDE. Asian International Input-Output Table 2005: Technical Note, Chiba: Institute of Developing Economies, Japan External Trade Organization; 2013.

[19] IMF. Myanmar: Staff Report for 2011 Article IV Consultation, Washington D.C.: International Monetary Fund; 2011.

[20] JICA. Myanmar Koku Denryoku Kaihatsu Keikaku Program Keisei Jumbi Chousa: Final Report (Preparatory Survey for Program of Electricity Development Plan in Myanmar: Final Report) (in Japanese). Tokyo: Japan International Cooperation Agency; 2014.

[21] Kellenberg D., Levinson A. Misreporting Trade: Tariff Evasion, Corruption, and Auditing Standards. NBER Working Paper Series, No. 22593, National Bureau of Economic Research; 2016.

[22] Toshihiko K. The Impact of United States Sanctions on the Myanmar Garment Industry. IDE Discussion Paper Series No. 42, Institute of Developing Economies, JETRO; 2005.

[23] Toshihiko K., ed. Myanmar Keizai no Jitsuzou: Naze Gunsei wa Ikinokoretanoka (Real Image of Myanmar Economy) (in Japanese). Chiba: Institute of Developing Economies, Japan External Trade Organization; 2008.

[24] Nippon Koei Co. Ltd., Mitsui & Co. Ltd., and Tokyo Gas Co. Ltd. Survey of Natural Gas Utilization in the Republic of the Union of Myanmar (in Japanese); 2016.

[25] Junichiro O., Akimoto K., Sano F., et al. Diffusion of Energy Efficient Technologies and CO2 Emission Reductions in Iron and Steel Sector. Energy Economics 2007; 29(4), pp. 868–888.

[26] Okamoto I. Myanmar no Shokuryoumondai: Taiseiiji to Beikokuseisaku (Food Problem in Myanmar) (in Japanese). In: Kudo K. ed., op. cit.; 2008; pp. 89–116.

[27] Pala International. Burma Gem Sales and Statistics. http://www.palagems.com/gem-news-burma-stats/. 2016.

[28] Perry P.J. Myanmar (Burma) since 1962: The Failure of Development. Hampshire: Ashgate Publishing Limited; 2007.

[29] Rao N.D., Ummel K. White Goods for White People? Drives of Electric Appliance Growth in Emerging Economies. Energy Research & Social Science 2017; 27, pp.106–116.

[30] Ruijven Bas J. van, et al. Model Projections for Household Energy Use in India. Energy Policy 2011; 64, pp. 7747–7761.

[31] Shimada H. Infra no Genjo to Myanmar Seihu no Taiou: Douro to Denryoku wo Raishotoshite (Current Infrastructure and Efforts by Myanmar Government: for Road and Electricity) (in Japanese). In: Kudo K. ed., op. cit.; 2008; pp. 67–87.

[32] Shor R. As Jadeite Prices Soar, so Does Supply Uncertainty. http://www.gia.edu/gia-news-research-jadeite-prices-supply-shor. 2013.

[33] Swan G.L., Ugursal V.I. Modeling of End-Use Energy Consumption in the Residential Sector: A Review of Modeling Techniques. Renewable and Sustainable Energy Reviews 2009; 13, pp. 1819–1835.

[34] The Economist Intelligence Unit. Country Report: Myanmar, January 2010. http://www.eiu.com/.

[35] UNSD. 2015 International Trade Statistics Yearbook, New York: United Nations Statistics Division. 2016.

[36] US Department of Agriculture Grain: World Markets and Trade. Washington D.C.: The Global Commodity Analysis Division, Office of Global Analysis, Foreign Agricultural Service, USDA; 2016.

[37] US Geological Survey. Minerals Yearbook: Burma [Advance Release]. Virginia: United States Geological Survey; 2013.

[38] Wolfram C., Shelef O., Gertler P.J. How Will Energy Demand Develop in the Developing World? Journal of Economic Perspective 2012; 26, pp. 119-138

[39] World Bank. Residential Consumption of Electricity in India. Washington D.C.: World Bank; 2008.

[40] WTO. International Trade Statistics 2015. Geneva: World Trade Organization; 2015.

TABLE 12

VALUE ADDED AT CURRENT PRICES BY INDUSTRY

	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.		4.1	
	Agriculture	Livestock and fishery	Forestry	Energy and mining	Manufactu-ring	Electricity	Construction	Transporta-tion and communica-tions	Financial institu-tions	Social and Administra-tive Service	Rental and other services	Wholesale and retail	GDP without jade trade	Jade	GDP with jade trade
1990	73,305	14,408	3,349	1,054	12,811	386	2,763	5,988	270	6,024	4,052	40,504	164,913	27	164,940
1991	94,272	16,947	3,865	1,177	14,215	318	3,863	6,908	318	6,413	5,178	48,812	202,285	44	202,329
1992	132,604	22,159	4,856	1,332	18,945	463	4,507	7,998	367	6,692	5,823	66,151	271,895	59	271,954
1993	203,172	29,811	6,835	1,743	27,204	653	5,211	10,423	521	8,702	6,943	91,658	392,876	137	393,013
1994	282,164	36,456	5,208	2,704	33,013	1,218	7,739	18,180	768	9,906	8,607	119,313	525,277	107	525,384
1995	347,210	41,572	5,973	3,382	45,603	1,872	13,057	24,605	1,041	10,782	11,335	160,596	667,029	565	667,594
1996	446,741	56,975	7,553	5,074	62,516	2,202	19,058	35,199	1,279	11,482	13,992	199,409	861,481	810	862,292
1997	615,078	80,594	9,039	6,466	89,282	1,933	26,494	66,368	1,475	13,293	19,911	280,787	1,210,719	2,029	1,212,747
1998	908,519	127,212	12,571	8,137	138,100	991	37,035	98,480	1,945	14,622	26,315	394,212	1,768,138	3,756	1,771,894
1999	1,125,133	181,671	17,294	11,755	167,940	2,558	40,425	125,106	2,215	16,505	32,174	519,262	2,242,037	27,549	2,269,586
2000	1,236,865	204,791	19,446	50,206	229,057	3,444	46,044	175,655	2,641	39,354	35,114	599,871	2,642,489	88,043	2,730,531
2001	1,626,353	252,189	37,593	178,442	336,186	3,202	77,115	205,446	3,299	44,685	50,064	822,171	3,636,746	123,172	3,759,918
2002	2,552,951	298,546	45,561	265,233	484,146	4,654	185,611	320,849	4,799	50,724	85,965	1,207,703	5,506,741	274,271	5,781,012
2003	3,029,534	346,163	72,696	277,988	567,472	5,992	303,497	615,363	5,297	64,742	119,782	1,455,581	6,864,106	557,019	7,421,125
2004	2,697,712	491,596	98,092	606,256	617,939	20,023	356,771	632,192	6,748	103,890	151,644	1,454,672	7,237,534	1,018,610	8,256,144
2005	3,379,863	668,559	191,629	775,661	821,449	27,652	461,656	917,550	10,237	112,599	196,534	1,818,008	9,381,398	1,941,927	11,323,325
2006	4,118,806	907,894	244,062	1,567,791	1,067,439	110,010	651,973	1,174,094	14,399	340,892	283,133	2,165,846	12,646,339	1,284,232	13,930,571
2007	5,697,632	1,235,032	299,215	2,137,639	1,316,423	189,790	893,654	1,505,154	16,948	371,290	378,504	2,766,518	16,807,799	1,620,163	18,427,962
2008	5,764,500	1,611,915	251,065	1,835,653	1,560,123	218,690	1,236,066	1,733,328	19,936	399,679	506,375	3,002,225	18,139,555	3,944,119	22,083,674
2009	6,284,683	1,812,867	307,268	2,056,187	1,644,346	337,675	1,518,309	1,939,887	27,392	551,654	609,840	3,022,929	20,133,037	3,038,258	23,151,295
2010	6,393,831	2,139,815	325,395	1,758,771	1,934,028	421,883	1,839,335	2,152,710	37,715	915,720	738,484	3,154,016	21,811,704	13,843,701	35,655,405
2011	5,887,547	2,255,544	176,617	2,710,693	2,044,690	481,449	2,165,836	2,418,269	65,318	989,006	883,291	3,440,004	23,518,264	1,919,191	42,709,455
2012	6,012,879	2,485,132	189,474	3,164,151	2,305,897	614,930	2,515,898	2,479,916	85,346	1,326,077	1,095,646	3,743,241	26,018,587	4,834,606	30,853,193
2013	6,524,901	2,779,615	184,930	3,467,620	2,586,735	695,855	3,056,830	2,761,187	114,385	1,683,301	1,323,898	4,163,097	29,342,354	21,039,400	50,381,753
2014	6,819,856	3,143,754	138,380	4,795,229	2,920,369	924,959	3,777,091	3,085,360	135,791	2,025,534	1,537,312	4,513,996	33,817,631	30,375,925	64,193,556

(**Unit:** Million Kyat)

TABLE 13

VALUE ADDED AT 2010 CONSTANT PRICES BY INDUSTRY

	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.		4.1	
	Agriculture	Livestock and fishery	Forestry	Energy and mining	Manufacturing	Electricity	Construction	Transportation and communications	Financial institutions	Social and administrative service	Rental and other services	Wholesale and Retail	GDP without jade trade	Jade	GDP with jade trade
1990	3,487,848	426,686	287,379	130,444	532,099	41,399	85,057	715,333	396	182,071	117,887	1,750,109	8,450,394	70,582	10,997,860
1991	3,351,294	451,142	282,558	144,719	510,641	44,190	99,636	714,651	466	189,931	120,888	1,706,412	8,307,554	85,657	10,812,396
1992	3,766,950	471,650	273,282	173,709	565,901	57,953	110,777	804,065	537	195,485	125,237	1,856,706	9,138,773	93,190	11,894,210
1993	3,942,508	494,321	275,998	192,752	619,096	72,106	123,792	861,285	743	209,600	129,622	1,960,663	9,637,621	90,070	12,543,151
1994	4,206,650	524,203	236,604	221,419	671,719	75,556	143,166	916,486	1,094	223,805	134,793	2,088,152	10,269,254	106,632	13,365,600
1995	4,436,202	539,841	225,894	258,327	722,440	80,505	182,065	957,437	1,475	237,601	143,256	2,145,937	10,794,813	574,627	14,061,368
1996	4,603,316	603,835	230,685	283,816	755,671	90,843	226,851	1,003,182	1,798	250,914	151,760	2,189,593	11,278,369	475,610	14,688,187
1997	4,743,542	646,766	237,184	355,866	793,487	106,971	249,079	1,044,450	2,057	266,692	160,938	2,249,020	11,708,635	637,047	15,253,610
1998	4,901,063	707,239	244,782	401,721	842,680	101,180	264,872	1,092,713	2,407	284,028	171,535	2,293,218	12,165,120	371,590	15,830,903
1999	5,021,732	804,760	256,011	663,692	921,689	115,541	276,542	1,169,444	2,709	303,925	181,422	2,382,606	12,747,876	1,550,552	16,737,601
2000	5,534,482	857,122	264,402	897,786	1,085,002	133,229	287,491	1,364,817	3,150	317,136	192,044	2,684,025	14,205,475	3,281,558	18,922,922
2001	5,551,558	914,352	284,755	924,799	1,336,636	122,874	372,148	1,511,620	3,935	360,103	227,763	2,910,638	15,088,223	2,417,398	19,849,952
2002	5,996,011	975,857	302,450	986,281	1,434,259	150,012	597,165	1,589,433	5,724	408,762	273,346	3,056,153	16,351,702	3,217,381	21,688,148
2003	6,091,105	1,111,019	321,826	1,190,625	1,451,659	172,562	715,083	1,657,355	6,318	452,691	311,955	3,174,592	17,113,269	3,180,414	22,622,326
2004	5,609,664	1,227,224	302,803	1,513,384	1,438,531	185,195	811,496	1,652,828	8,049	520,007	357,005	3,087,007	16,947,106	4,432,291	23,171,366
2005	6,037,663	1,358,191	314,976	1,852,104	1,527,408	220,730	900,796	1,831,553	12,211	563,598	399,845	3,276,373	18,495,387	5,916,326	26,048,173
2006	6,041,609	1,548,046	341,206	1,836,793	1,618,074	243,178	1,037,864	1,892,117	14,371	614,231	456,880	3,308,574	19,108,372	6,050,298	26,874,099
2007	6,650,024	1,661,201	342,319	1,987,221	1,679,117	254,919	1,216,358	2,017,384	16,943	669,018	518,842	3,405,856	20,588,204	5,993,515	28,737,122
2008	6,315,995	1,829,973	333,405	1,826,977	1,720,836	284,257	1,436,612	1,983,410	19,931	720,197	588,999	3,224,541	20,356,666	9,737,022	30,289,444
2009	6,614,226	2,012,150	324,178	1,676,885	1,785,974	333,433	1,634,271	2,075,562	27,379	772,429	656,692	3,198,057	21,122,447	7,628,971	30,095,541
2010	6,393,831	2,139,815	325,395	1,758,771	1,934,028	421,883	1,839,335	2,152,710	37,715	915,720	738,484	3,154,016	21,811,704	13,843,701	35,655,405
2011	6,187,653	2,297,330	349,347	1,948,856	2,143,116	443,981	2,004,847	2,263,276	77,956	989,006	851,621	3,217,408	22,801,134	12,771,635	35,367,471
2012	6,173,033	2,460,788	372,388	1,965,325	2,321,517	484,041	2,191,896	2,342,289	110,139	1,129,436	988,907	3,341,346	23,895,513	5,642,765	28,943,680
2013	6,307,992	2,660,557	347,556	2,005,630	2,543,181	551,844	2,550,899	2,501,591	147,614	1,271,001	1,145,558	3,443,677	25,502,728	4,454,472	28,429,373
2014	6,446,174	2,851,251	259,638	2,392,549	2,790,523	632,724	2,955,950	2,720,369	175,238	1,421,442	1,269,456	3,580,121	27,765,537	4,934,166	31,188,610

(**Unit:** Million Kyat as of 2010)

TABLE 14

GROWTH RATE OF VALUE ADDED AT CONSTANT PRICES BY INDUSTRY

	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.		4.1	
	Agriculture	Livestock and fishery	Forestry	Energy and mining	Manufacturing	Electricity	Construction	Transportation and communications	Financial institutions	Social and administrative service	Rental and other services	Wholesale and retail	GDP without jade trade	Jade	GDP with jade trade
1991	-4.0	5.6	-1.7	10.4	-4.1	6.5	15.8	-0.1	16.4	4.2	2.5	-2.5	-1.7	19.4	-1.7
1992	11.7	4.4	-3.3	18.3	10.3	27.1	10.6	11.8	14.0	2.9	3.5	8.4	9.5	8.4	9.5
1993	4.6	4.7	1.0	10.4	9.0	21.9	11.1	6.9	32.5	7.0	3.4	5.4	5.3	-3.4	5.3
1994	6.5	5.9	-15.4	13.9	8.2	4.7	14.5	6.2	38.7	6.6	3.9	6.3	6.3	16.9	6.4
1995	5.3	2.9	-4.6	15.4	7.3	6.3	24.0	4.4	29.9	6.0	6.1	2.7	5.0	168.4	5.1
1996	3.7	11.2	2.1	9.4	4.5	12.1	22.0	4.7	19.8	5.5	5.8	2.0	4.4	-18.9	4.4
1997	3.0	6.9	2.8	22.6	4.9	16.3	9.3	4.0	13.5	6.1	5.9	2.7	3.7	29.2	3.8
1998	3.3	8.9	3.2	12.1	6.0	-5.6	6.1	4.5	15.7	6.3	6.4	1.9	3.8	-53.9	3.7
1999	2.4	12.9	4.5	50.2	9.0	13.3	4.3	6.8	11.8	6.8	5.6	3.8	4.7	142.9	5.6
2000	9.7	6.3	3.2	30.2	16.3	14.2	3.9	15.4	15.1	4.3	5.7	11.9	10.8	75.0	12.3
2001	0.3	6.5	7.4	3.0	20.9	-8.1	25.8	10.2	22.2	12.7	17.1	8.1	6.0	-30.6	4.8
2002	7.7	6.5	6.0	6.4	7.0	20.0	47.3	5.0	37.5	12.7	18.2	4.9	8.0	28.6	8.9
2003	1.6	13.0	6.2	18.8	1.2	14.0	18.0	4.2	9.9	10.2	13.2	3.8	4.6	-1.2	4.2
2004	-8.2	9.9	-6.1	24.0	-0.9	7.1	12.6	-0.3	24.2	13.9	13.5	-2.8	-1.0	33.2	2.4
2005	7.4	10.1	3.9	20.2	6.0	17.6	10.4	10.3	41.7	8.0	11.3	6.0	8.7	28.9	11.7
2006	0.1	13.1	8.0	-0.8	5.8	9.7	14.2	3.3	16.3	8.6	13.3	1.0	3.3	2.2	3.1
2007	9.6	7.1	0.3	7.9	3.7	4.7	15.9	6.4	16.5	8.5	12.7	2.9	7.5	-0.9	6.7
2008	-5.2	9.7	-2.6	-8.4	2.5	10.9	16.6	-1.7	16.2	7.4	12.7	-5.5	-1.1	48.5	5.3
2009	4.6	9.5	-2.8	-8.6	3.7	16.0	12.9	4.5	31.8	7.0	10.9	-0.8	3.7	-24.4	-0.6
2010	-3.4	6.2	0.4	4.8	8.0	23.5	11.8	3.6	32.0	17.0	11.7	-1.4	3.2	59.6	17.0
2011	-3.3	7.1	7.1	10.3	10.3	5.1	8.6	5.0	72.6	7.7	14.3	2.0	4.4	-8.1	-0.8
2012	-0.2	6.9	6.4	0.8	8.0	8.6	8.9	3.4	34.6	13.3	14.9	3.8	4.7	-81.7	-20.0
2013	2.2	7.8	-6.9	2.0	9.1	13.1	15.2	6.6	29.3	11.8	14.7	3.0	6.5	-23.6	-1.8
2014	2.2	6.9	-29.2	17.6	9.3	13.7	14.7	8.4	17.2	11.2	10.3	3.9	8.5	10.2	9.3

(**Unit:** Percentage. Note: The GDP growths are measured in translog index.)

TABLE 15

GROSS OUTPUT AT CURRENT PRICES BY INDUSTRY

	1. Agriculture	2. Livestock and fishery	3. Forestry	4. Energy and mining	5. Manufacturing	6. Electricity	7. Construc-tion	8. Transportati-on and communica-tions	9. Financial institu-tions	10. Social and administra-tive service	11. Rental and other services	12. Wholesale and retail	Total gross output	4.1 Jade	Total gross output with jade
1990	86,314	21,802	4,979	1,801	76,025	788	9,062	8,333	1,702	12,596	5,156	57,162	285,718	27	285,746
1991	111,129	25,446	5,775	2,044	83,896	815	12,670	9,312	2,006	14,138	6,681	69,306	343,218	44	343,262
1992	154,955	33,986	7,355	2,319	112,898	1,005	14,779	10,722	2,312	14,742	7,542	94,164	456,779	59	456,838
1993	237,886	45,793	10,331	3,059	167,819	1,098	17,433	14,152	3,356	19,198	9,047	132,194	661,365	137	661,503
1994	331,027	56,085	8,004	4,734	205,001	2,064	26,126	25,035	4,585	21,915	11,178	172,095	867,850	107	867,957
1995	402,801	64,354	9,256	5,916	282,897	2,923	44,489	34,293	5,893	24,200	14,700	231,874	1,123,595	565	1,124,160
1996	517,091	88,089	11,908	8,963	386,874	3,234	63,254	49,122	8,176	26,969	18,154	288,078	1,469,912	810	1,470,722
1997	707,956	124,159	14,066	11,496	550,603	3,746	82,794	92,618	9,431	33,154	25,835	400,121	2,055,979	2,029	2,058,007
1998	1,037,743	195,663	19,996	14,563	844,717	4,294	112,116	137,432	12,682	36,804	33,942	560,434	3,010,385	3,756	3,014,141
1999	1,286,797	279,604	27,666	20,916	1,019,329	15,312	117,713	174,206	14,687	40,890	42,140	736,487	3,775,746	27,549	3,803,295
2000	1,485,994	315,359	31,446	89,326	1,379,654	18,488	129,150	243,836	17,623	98,235	45,715	848,832	4,703,658	88,043	4,791,701
2001	1,975,057	406,079	59,039	319,287	2,009,552	16,847	208,636	286,668	21,679	111,501	65,667	1,160,683	6,640,695	123,172	6,763,867
2002	3,096,088	480,453	71,834	475,400	28,72,193	24,628	484,990	457,471	34,024	127,141	113,609	1,700,990	9,938,821	274,271	10,213,092
2003	3,633,691	563,305	111,840	499,119	3,341,364	32,326	748,298	864,898	37,760	157,010	159,506	2,050,115	12,199,230	557,019	12,756,249
2004	3,211,673	787,433	156,100	1,056,349	3,611,530	36,380	871,803	874,477	47,547	244,031	203,483	2,025,937	13,126,742	1,018,610	14,145,352
2005	4,047,458	1,088,888	304,247	1,312,731	4,765,588	48,663	1,118,125	1,247,263	67,238	256,425	258,716	2,533,527	17,048,869	1,941,927	18,990,796
2006	4,952,039	1,434,399	394,553	2,739,716	6,138,771	241,204	1,565,231	1,604,692	94,502	753,361	373,264	3,019,663	23,311,394	1,284,232	24,595,626
2007	6,916,643	2,006,063	489,359	3,674,023	7,539,224	487,859	2,144,040	2,069,162	111,891	777,974	497,923	3,897,039	30,611,200	1,620,163	32,231,363
2008	7,040,472	2,625,659	412,489	3,156,672	8,931,653	559,993	2,958,776	2,402,017	138,576	796,160	669,458	4,291,552	33,983,478	3,944,119	37,927,597
2009	7,644,832	2,962,026	503,586	3,596,378	9,690,413	688,096	3,643,777	2,679,997	182,824	1,047,250	806,613	4,283,745	37,729,537	3,038,258	40,767,795
2010	7,801,242	3,526,495	533,739	3,040,187	11,314,085	870,805	4,397,598	2,970,989	250,759	1,660,353	978,060	4,501,848	41,846,159	13,843,701	55,689,860
2011	7,164,252	3,717,701	305,267	4,155,749	11,942,423	967,244	5,197,613	3,319,331	437,672	1,795,898	1,174,850	4,915,254	45,093,255	19,191,191	64,284,445
2012	7,354,367	4,096,460	324,691	4,834,095	13,198,370	1,230,779	6,066,981	3,419,822	572,302	2,364,544	1,461,302	5,338,821	50,262,535	4,834,606	55,097,141
2013	7,899,536	4,580,596	313,156	5,315,782	14,726,700	1,400,413	7,421,771	3,772,181	766,887	2,984,616	1,765,696	5,938,515	56,885,849	21,039,400	77,925,248
2014	8,285,026	5,209,608	238,697	7,369,059	16,568,302	1,805,852	9,167,263	4,232,576	912,858	3,576,016	2,052,486	6,440,150	65,857,893	30,375,925	96,233,818

(**Unit:** Million Kyat)

TABLE 16

GROSS OUTPUT AT 2010 CONSTANT PRICES BY INDUSTRY

	1. Agriculture	2. Livestock and fishery	3. Forestry	4. Energy and mining	5. Manufacturing	6. Electricity	7. Construction	8. Transportation and communications	9. Financial institutions	10. Social and administrative service	11. Rental and other services	12. Wholesale and rretail	Total gross output	4.1 Jade	Total gross output with jade
1990	4,106,790	645,667	427,247	222,906	3,157,683	84,469	278,968	995,541	2,493	380,724	150,017	2,469,851	13,840,194	70,582	16,143,852
1991	3,950,578	677,382	422,211	251,402	3,013,767	113,433	326,789	963,390	2,938	418,726	155,978	2,422,862	13,664,937	85,657	15,939,793
1992	4,401,887	723,380	413,951	302,474	3,372,350	125,767	363,292	1,077,959	3,380	430,664	162,211	2,642,989	15,042,698	93,190	17,546,888
1993	4,616,120	759,329	417,132	338,221	3,819,220	121,300	414,136	1,169,492	4,783	462,400	168,898	2,827,779	16,227,114	90,070	18,928,121
1994	4,935,121	806,456	363,634	387,635	4,171,131	127,994	483,339	1,262,095	6,531	495,103	175,057	3,011,903	17,443,012	106,632	20,346,734
1995	5,146,470	835,666	350,041	451,883	4,481,643	125,717	620,349	1,334,396	8,349	533,292	185,786	3,098,384	18,438,990	574,627	21,519,376
1996	5,328,220	933,593	363,730	501,331	4,676,363	133,406	752,912	1,399,969	11,492	589,333	196,901	3,163,214	19,364,524	475,610	22,596,686
1997	5,459,824	996,376	369,081	632,727	4,893,458	207,354	778,374	1,457,561	13,154	665,151	208,823	3,204,850	20,071,069	637,047	23,425,779
1998	5,598,168	1,087,789	389,352	718,977	5,154,440	438,635	801,858	1,524,912	15,692	714,887	221,253	3,260,171	20,881,042	371,590	24,355,290
1999	5,743,276	1,238,582	409,569	1,180,897	5,594,287	691,672	805,258	1,628,409	17,965	752,962	237,617	3,379,328	22,093,978	1,550,552	25,905,862
2000	6,649,238	1,319,884	427,558	1,597,324	6,535,187	715,113	806,388	1,894,578	21,020	791,638	250,023	3,797,958	25,206,931	3,281,558	29,796,312
2001	6,741,861	1,472,302	447,197	1,654,752	7,989,748	646,470	1,006,855	2,109,227	25,858	898,544	298,749	4,109,032	27,936,319	2,417,398	32,759,547
2002	7,271,654	1,570,460	476,854	1,767,794	8,508,731	793,833	1,560,354	2,266,238	40,583	1,024,581	361,247	4,304,440	30,374,164	3,217,381	35,779,052
2003	7,305,808	1,807,941	495,115	2,137,732	8,547,596	931,012	1,763,103	2,329,425	45,039	1,097,858	415,411	4,471,256	31,494,951	3,180,414	37,039,542
2004	6,678,403	1,965,753	481,871	2,636,942	8,407,459	336,476	1,982,967	2,286,269	56,712	1,221,462	479,048	4,299,306	31,170,021	4,432,291	37,388,674
2005	7,230,230	2,212,097	500,084	3,134,508	8,861,168	388,445	2,181,717	2,489,704	80,199	1,283,500	526,354	4,565,864	33,784,676	5,916,326	41,263,968
2006	7,263,824	2,445,788	551,596	3,209,797	9,305,433	533,185	2,491,662	2,586,049	94,317	1,357,430	602,321	4,612,876	35,294,999	6,050,298	43,039,321
2007	8,072,799	2,698,289	559,853	3,415,495	9,616,394	655,276	2,918,265	2,773,334	111,859	1,401,814	682,538	4,797,639	37,943,338	5,993,515	46,075,316
2008	7,714,040	2,980,854	547,769	3,141,753	9,851,732	727,887	3,438,825	2,748,577	138,536	1,434,633	778,693	4,609,343	38,205,408	9,737,022	48,092,833
2009	8,045,695	3,287,632	531,300	2,932,959	10,525,052	679,452	3,922,073	2,867,436	182,740	1,466,366	868,583	4,531,916	39,862,456	7,628,971	48,917,592
2010	7,801,242	3,526,495	533,739	3,040,187	11,314,085	870,805	4,397,598	2,970,989	250,759	1,660,353	978,060	4,501,848	41,846,159	13,843,701	55,689,860
2011	7,529,436	3,786,574	603,814	2,987,781	12,517,298	891,969	4,811,269	3,106,587	522,354	1,795,898	1,132,726	4,597,198	44,214,039	12,771,635	56,695,357
2012	7,550,251	4,056,330	638,142	3,002,564	13,287,774	968,806	5,285,663	3,230,034	738,555	2,013,911	1,318,940	4,765,616	46,718,332	5,642,765	51,259,622
2013	7,636,930	4,384,398	588,542	3,074,585	14,478,736	1,110,590	6,193,406	3,417,536	989,665	2,253,578	1,527,842	4,912,287	50,405,557	4,454,472	52,458,821
2014	7,831,063	4,724,893	447,859	3,676,745	15,831,639	1,235,304	7,174,295	3,731,872	1,178,042	2,509,510	1,694,868	5,107,784	55,309,352	4,934,166	57,719,269

(**Unit:** Million Kyat as of 2010)

TABLE 17

GROWTH RATE OF VALUE ADDED AT CONSTANT PRICES BY INDUSTRY

	1. Agriculture	2. Livestock and fishery	3. Forestry	4. Energy and mining	5. Manufactu-ring	6. Electricity	7. Construction	8. Transporta-tion and communica-tions	9. Financial institutions	10. Social and admini-strative service	11. Rental and other services	12. Wholesale and retail	Total gross output	4.1 Jade	Total gross output with jade
1991	-3.9	4.8	-1.2	12.0	-4.7	29.5	15.8	-3.3	16.4	9.5	3.9	-1.9	-	19.4	-
1992	10.8	6.6	-2.0	18.5	11.2	10.3	10.6	11.2	14.0	2.8	3.9	8.7	-	8.4	-
1993	4.8	4.8	0.8	11.2	12.4	-3.6	13.1	8.2	34.7	7.1	4.0	6.8	-	-3.4	-
1994	6.7	6.0	-13.7	13.6	8.8	5.4	15.5	7.6	31.2	6.8	3.6	6.3	-	16.9	-
1995	4.2	3.6	-3.8	15.3	7.2	-1.8	25.0	5.6	24.5	7.4	5.9	2.8	-	168.4	-
1996	3.5	11.1	3.8	10.4	4.3	5.9	19.4	4.8	32.0	10.0	5.8	2.1	-	-18.9	-
1997	2.4	6.5	1.5	23.3	4.5	44.1	3.3	4.0	13.5	12.1	5.9	1.3	-	29.2	-
1998	2.5	8.8	5.3	12.8	5.2	74.9	3.0	4.5	17.6	7.2	5.8	1.7	-	-53.9	-
1999	2.6	13.0	5.1	49.6	8.2	45.5	0.4	6.6	13.5	5.2	7.1	3.6	-	142.9	-
2000	14.6	6.4	4.3	30.2	15.5	3.3	0.1	15.1	15.7	5.0	5.1	11.7	-	75.0	-
2001	1.4	10.9	4.5	3.5	20.1	-10.1	22.2	10.7	20.7	12.7	17.8	7.9	-	-30.6	-
2002	7.6	6.5	6.4	6.6	6.3	20.5	43.8	7.2	45.1	13.1	19.0	4.6	-	28.6	-
2003	0.5	14.1	3.8	19.0	0.5	15.9	12.2	2.8	10.4	6.9	14.0	3.8	-	-1.2	-
2004	-9.0	8.4	-2.7	21.0	-1.7	-101.8	11.8	-1.9	23.0	10.7	14.3	-3.9	-	33.2	-
2005	7.9	11.8	3.7	17.3	5.3	14.4	9.6	8.5	34.7	5.0	9.4	6.0	-	28.9	-
2006	0.5	10.0	9.8	2.4	4.9	31.7	13.3	3.8	16.2	5.6	13.5	1.0	-	2.2	-
2007	10.6	9.8	1.5	6.2	3.3	20.6	15.8	7.0	17.1	3.2	12.5	3.9	-	-0.9	-
2008	-4.5	10.0	-2.2	-8.4	2.4	10.5	16.4	-0.9	21.4	2.3	13.2	-4.0	-	48.5	-
2009	4.2	9.8	-3.1	-6.9	6.6	-6.9	13.1	4.2	27.7	2.2	10.9	-1.7	-	-24.4	-
2010	-3.1	7.0	0.5	3.6	7.2	24.8	11.4	3.5	31.6	12.4	11.9	-0.7	-	59.6	-
2011	-3.5	7.1	12.3	-1.7	10.1	2.4	9.0	4.5	73.4	7.8	14.7	2.1	-	-8.1	-
2012	0.3	6.9	5.5	0.5	6.0	8.3	9.4	3.9	34.6	11.5	15.2	3.6	-	-81.7	-
2013	1.1	7.8	-8.1	2.4	8.6	13.7	15.8	5.6	29.3	11.2	14.7	3.0	-	-23.6	-
2014	2.5	7.5	-27.3	17.9	8.9	10.6	14.7	8.8	17.4	10.8	10.4	3.9	-	10.2	-

(**Unit:** Percentage. Note: The GDP growths are measured in translog index.)

TABLE 18

FINAL DEMAND AT CURRENT PRICES

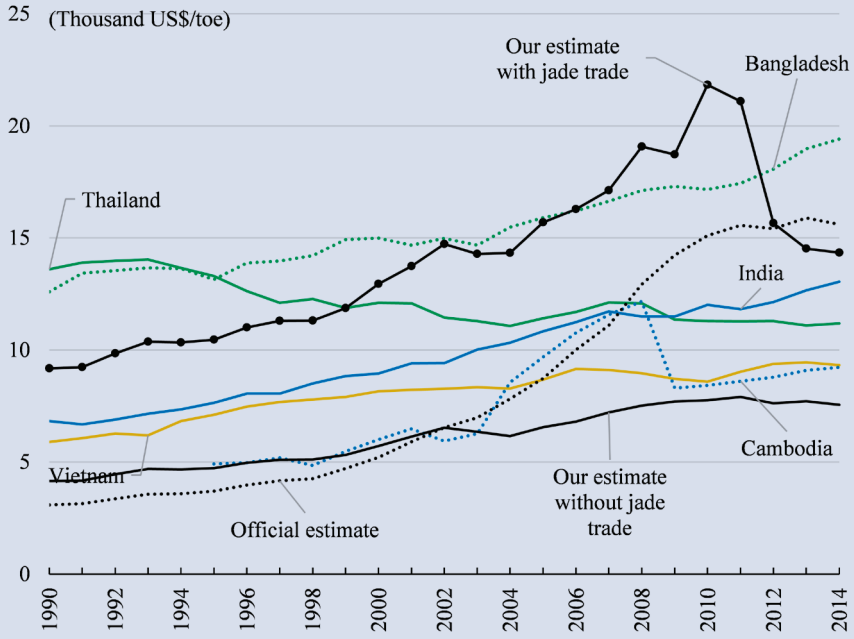
	Household consumption expenditure	Government consumption expenditure	Gross fixed capital formation	Change in inventory	Export	Import	GDP without jade trade	Export of jade	GDP with jade trade
1990	150,064	12,596	15,504	(1,995)	16,378	(27,633)	164,913	27	164,940
1991	182,354	14,138	18,157	1,032	18,295	(31,692)	202,285	44	202,329
1992	242,532	14,742	21,240	2,601	29,241	(38,461)	271,895	59	271,954
1993	358,439	19,198	34,762	7,360	51,846	(78,729)	392,876	137	393,013
1994	472,211	21,915	50,392	3,875	78,055	(101,171)	525,277	107	525,384
1995	628,114	24,200	74,466	3,540	97,280	(160,571)	667,029	565	667,594
1996	833,683	26,969	110,305	(21,262)	127,530	(215,745)	861,481	810	862,292
1997	1,165,369	33,154	168,535	(10,276)	190,733	(336,796)	1,210,719	2,029	1,212,747
1998	1,775,090	36,804	327,265	(7,605)	458,234	(821,650)	1,768,138	3,756	1,771,894
1999	2,264,634	40,890	313,441	38,859	542,125	(957,912)	2,242,037	27,549	2,269,586
2000	2,323,647	98,235	283,204	16,709	845,832	(925,138)	2,642,489	88,043	2,730,531
2001	3,151,128	111,501	494,968	(2,610)	1,313,804	(1,432,045)	3,636,746	123,172	3,759,918
2002	4,227,764	127,141	703,566	19,095	1,813,125	(1,383,949)	5,506,741	274,271	5,781,012
2003	6,016,285	157,010	1,203,388	418	1,930,630	(2,443,625)	6,864,106	557,019	7,421,125
2004	5,904,911	244,031	1,414,393	39,689	2,670,237	(3,035,727)	7,237,534	1,018,610	8,256,144
2005	7,311,648	256,425	1,660,677	57,041	3,769,336	(3,673,729)	9,381,398	1,941,927	11,323,325
2006	8,009,222	753,361	2,219,096	23,996	6,436,582	(4,795,917)	12,646,339	1,284,232	13,930,571
2007	11,417,901	777,974	3,557,885	43,470	8,135,708	(7,125,140)	16,807,799	1,620,163	18,427,962
2008	13,381,565	796,160	4,592,304	(29,231)	7,033,265	(7,634,508)	18,139,555	3,944,119	22,083,674
2009	13,921,433	1,047,250	4,770,521	(41,587)	7,414,254	(6,998,833)	20,113,037	3,038,258	23,151,295
2010	15,286,689	1,660,353	5,808,122	106,059	8,090,512	(9,140,031)	21,811,704	13,843,701	35,655,405
2011	17,532,096	1,795,898	6,976,959	27,084	7,625,839	(10,439,611)	23,518,264	19,191,191	42,709,455
2012	20,063,058	2,364,544	8,563,841	532,457	8,437,201	(13,942,515)	26,018,587	4,834,606	30,853,193
2013	23,002,853	2,984,616	11,078,712	253,895	11,225,753	(19,203,475)	29,342,354	21,039,400	50,381,753
2014	26,015,266	3,576,016	13,540,088	138,565	14,509,821	(23,962,125)	33,817,631	30,375,925	64,193,556

(**Unit:** Million Kyat)

APPENDIX 2: ENERGY PRODUCTIVITY

FIGURE 61

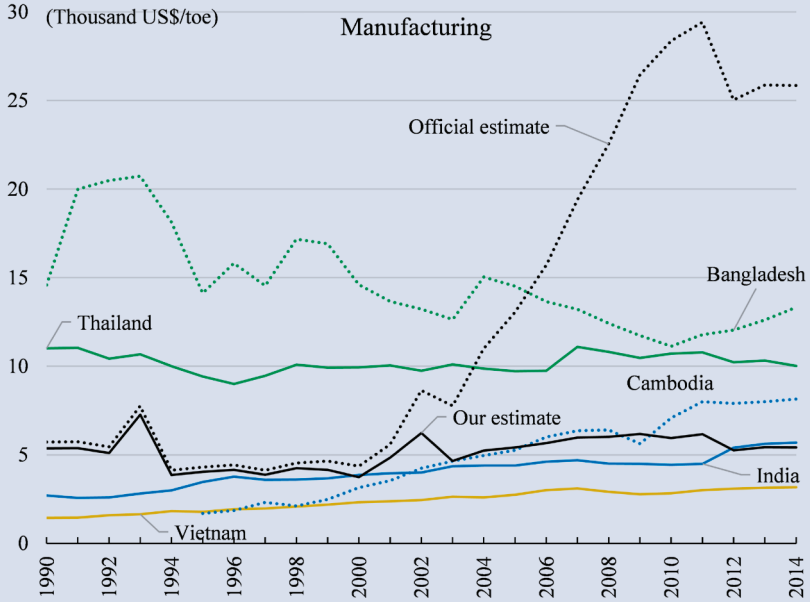
COUNTRY-WISE COMPARISON OF ENERGY PRODUCTIVITY



Note: GDP at constant market prices per person, using 2011 PPP, reference year 2014.

FIGURE 62

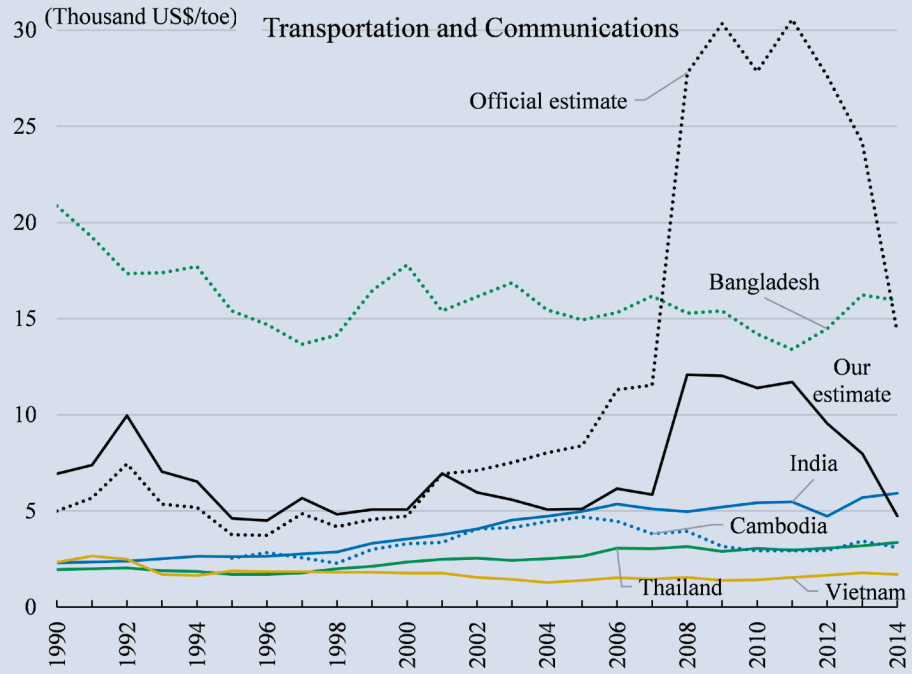
COUNTRY-WISE COMPARISON OF ENERGY PRODUCTIVITY IN MANUFACTURING



Note: GDP at constant market prices per person, using 2011 PPP, reference year 2014.

FIGURE 63

COUNTRY-WISE COMPARISON OF ENERGY PRODUCTIVITY IN TRANSPORTATION AND COMMUNICATION



Note: GDP at constant market prices per person, using 2011 PPP, reference year 2014.

FIGURE 64-1

COMPOSITION OF ENERGY CONSUMPTION

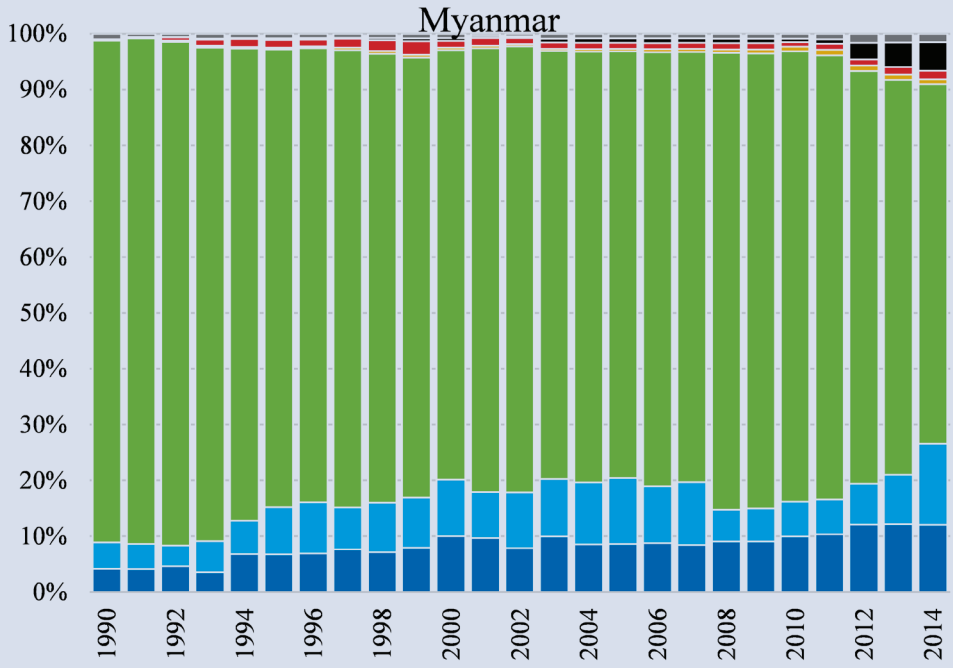


FIGURE 64-2

COMPOSITION OF ENERGY CONSUMPTION

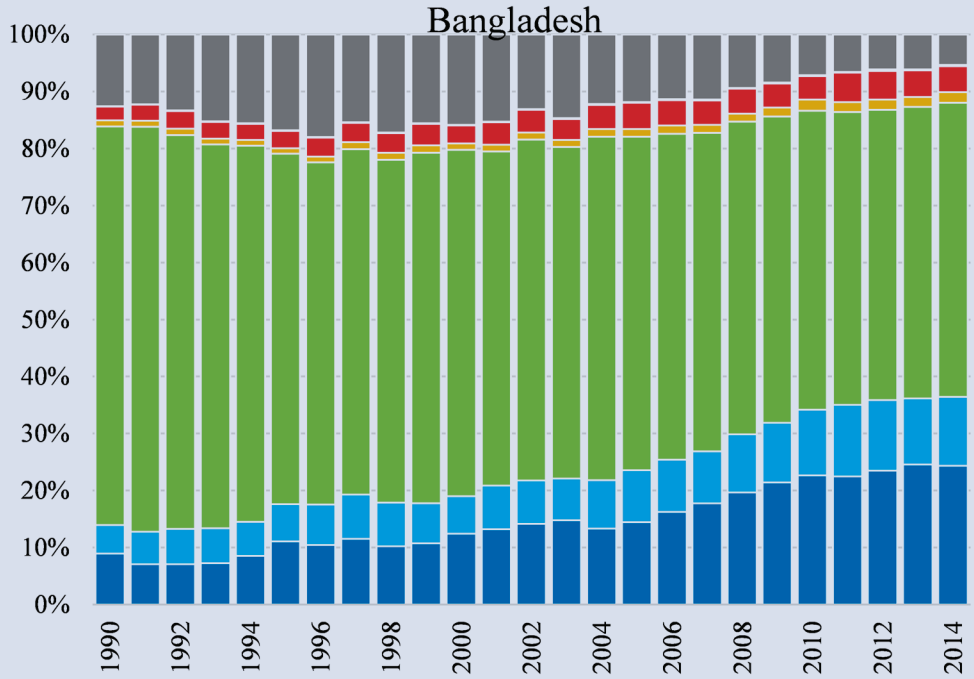


FIGURE 64-3

COMPOSITION OF ENERGY CONSUMPTION

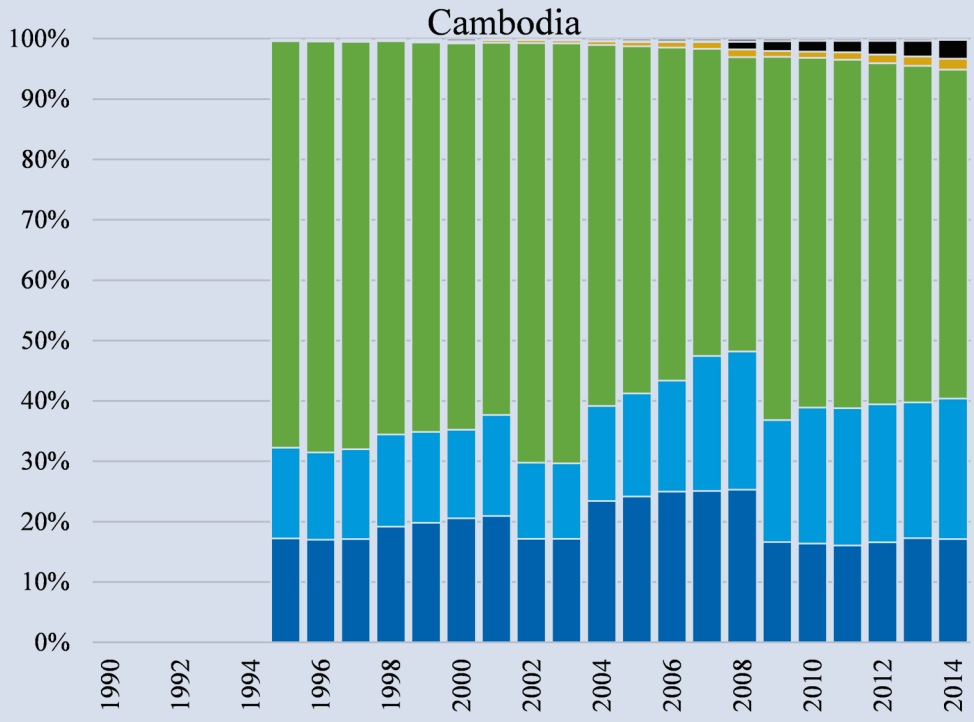


FIGURE 64-4

COMPOSITION OF ENERGY CONSUMPTION

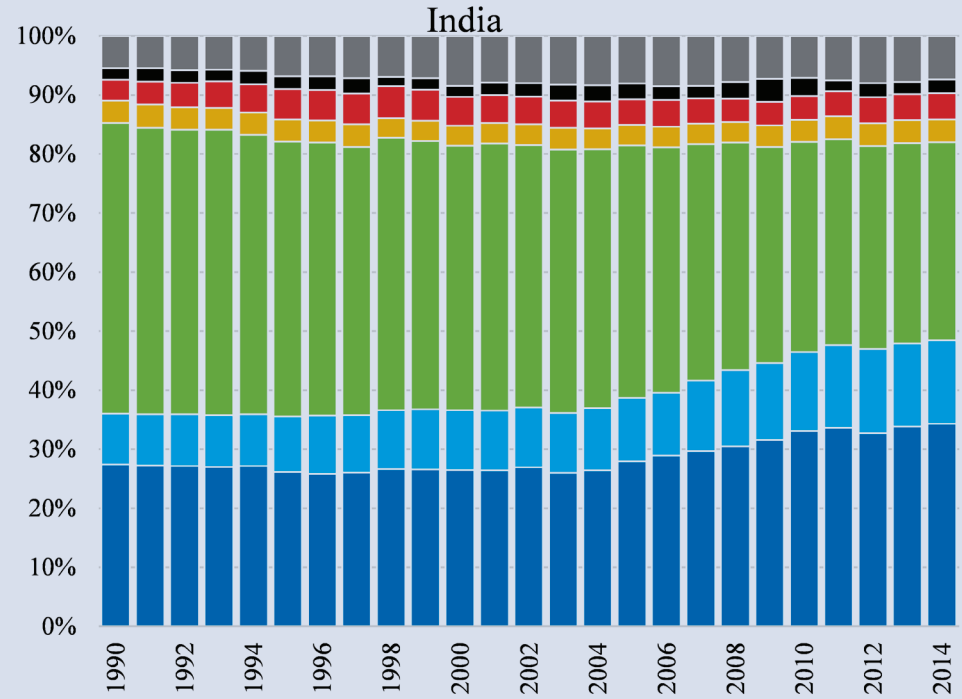


FIGURE 64-5

COMPOSITION OF ENERGY CONSUMPTION

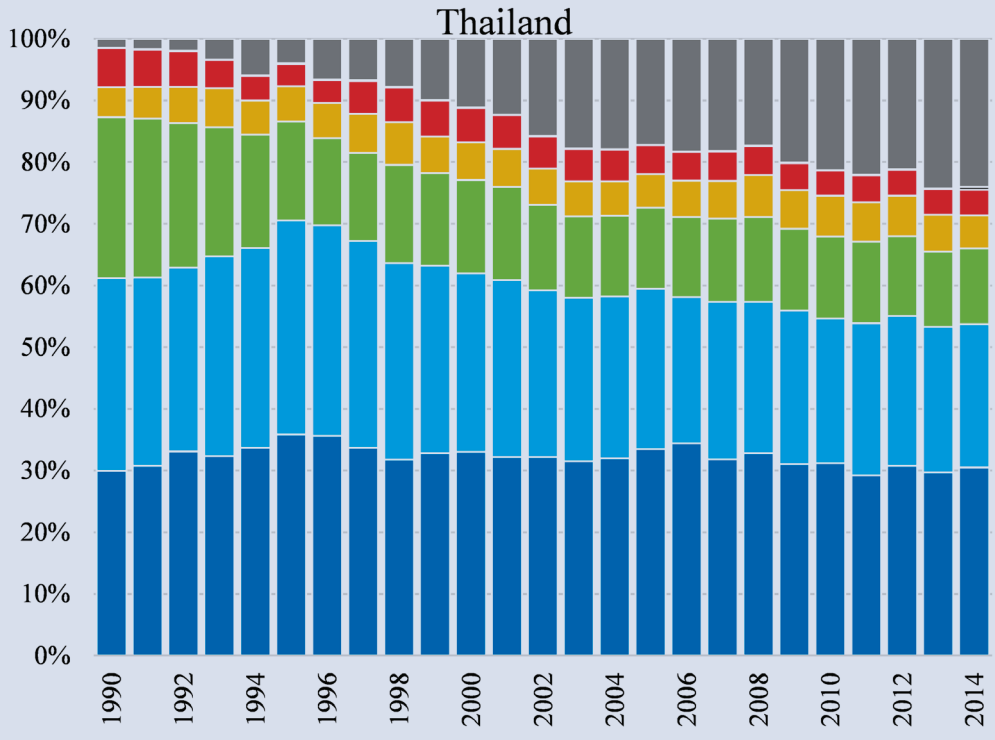
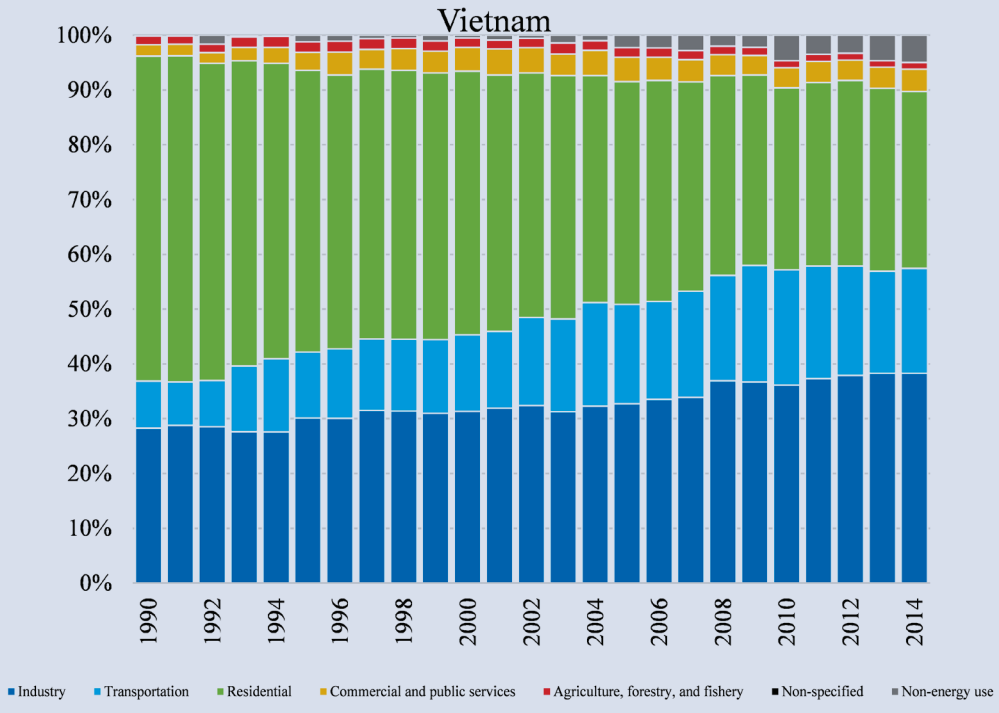


FIGURE 64-6

COMPOSITION OF ENERGY CONSUMPTION



APPENDIX 3: EXAMINATION OF EXPORTS

MYANMAR'S EXPORT VS COUNTERPARTS' IMPORT FROM MYANMAR

FIGURE 65-1

MYANMAR'S EXPORT VS COUNTERPARTS' IMPORT FROM MYANMAR

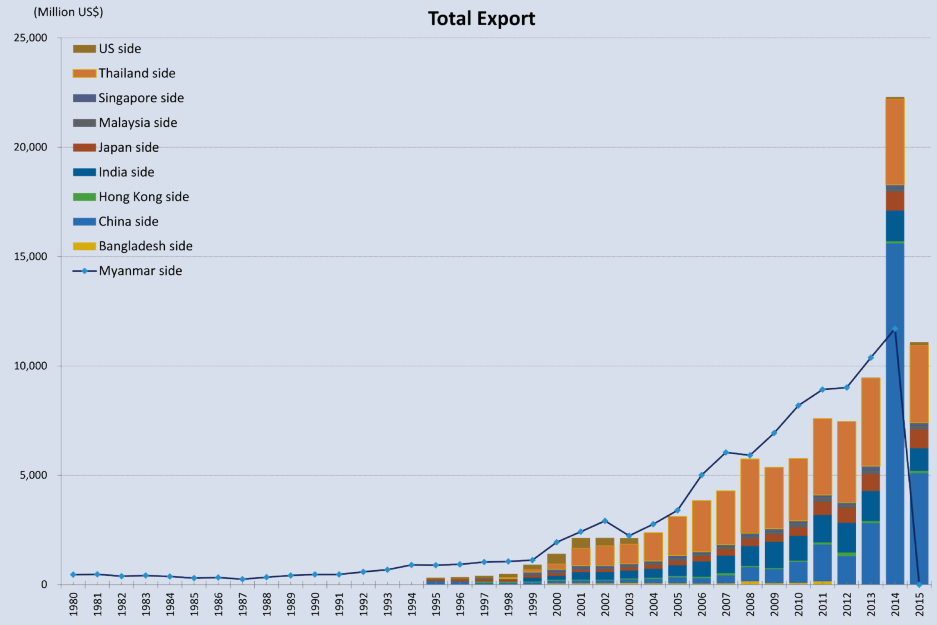


FIGURE 65-2

MYANMAR'S EXPORT VS COUNTERPARTS' IMPORT FROM MYANMAR

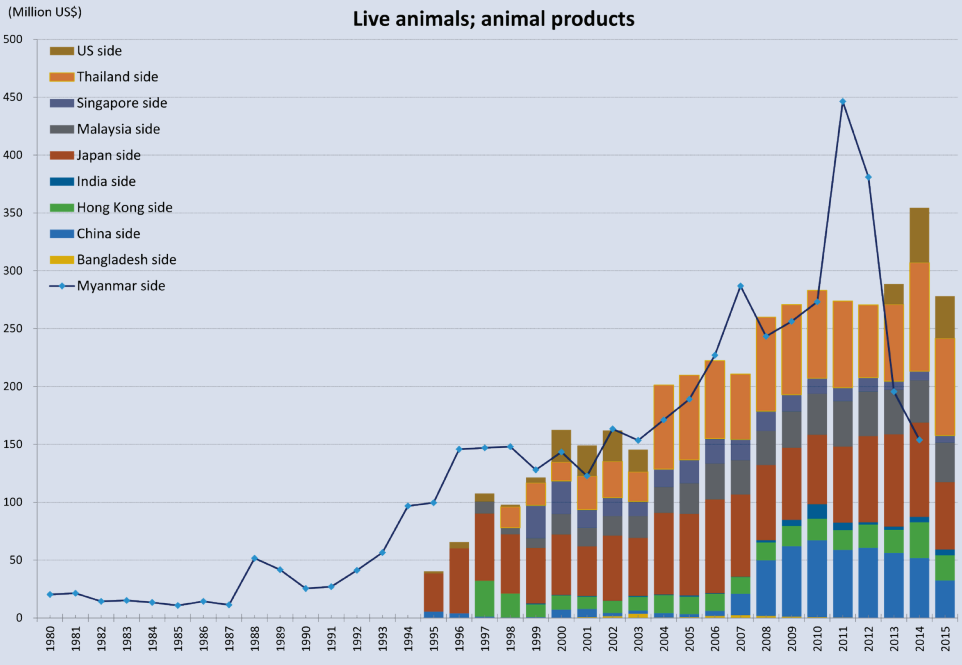


FIGURE 65-3

MYANMAR'S EXPORT VS COUNTERPARTS' IMPORT FROM MYANMAR

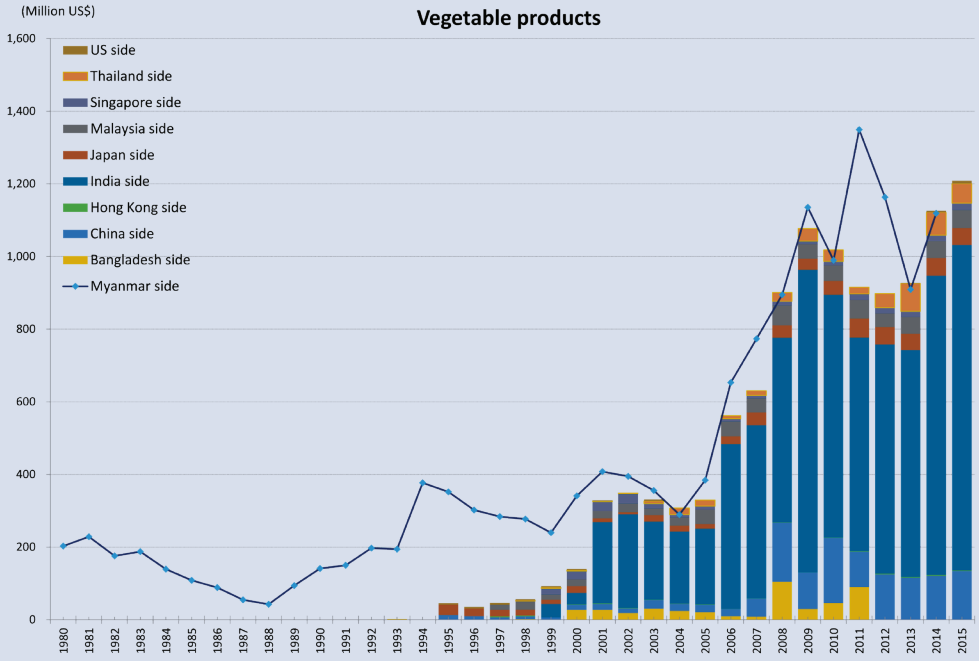


FIGURE 65-4

MYANMAR'S EXPORT VS COUNTERPARTS' IMPORT FROM MYANMAR

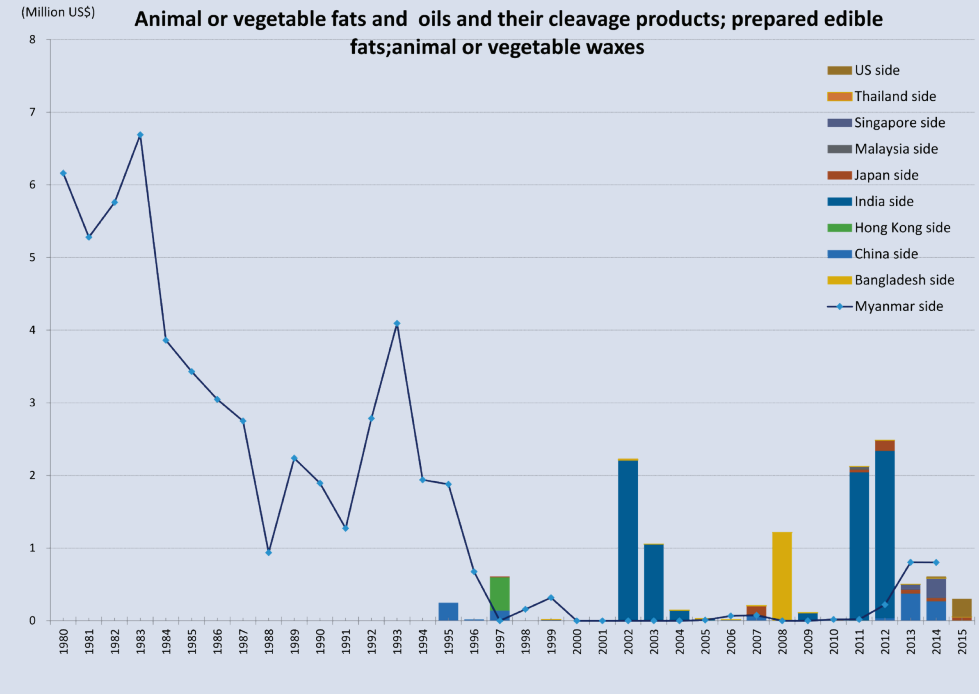


FIGURE 65-5

MYANMAR'S EXPORT VS COUNTERPARTS' IMPORT FROM MYANMAR

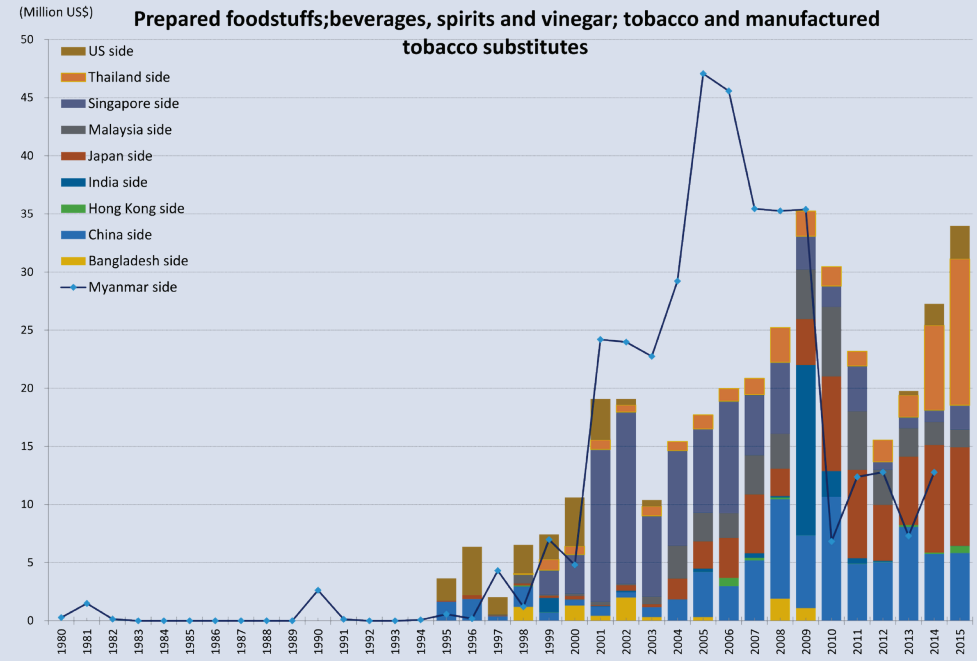


FIGURE 65-6

MYANMAR'S EXPORT VS COUNTERPARTS' IMPORT FROM MYANMAR

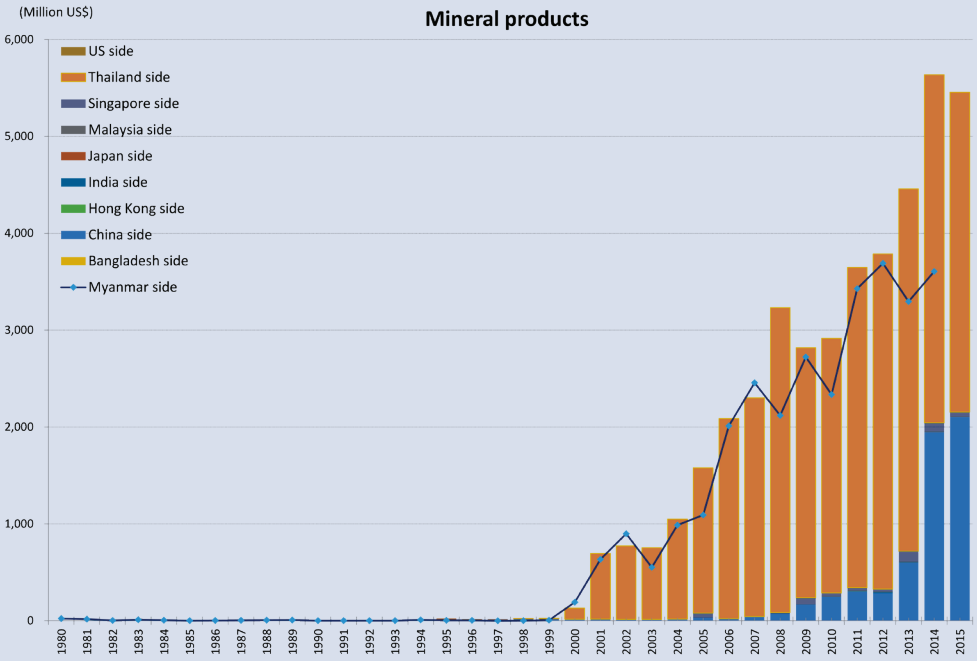


FIGURE 65-7

MYANMAR'S EXPORT VS COUNTERPARTS' IMPORT FROM MYANMAR

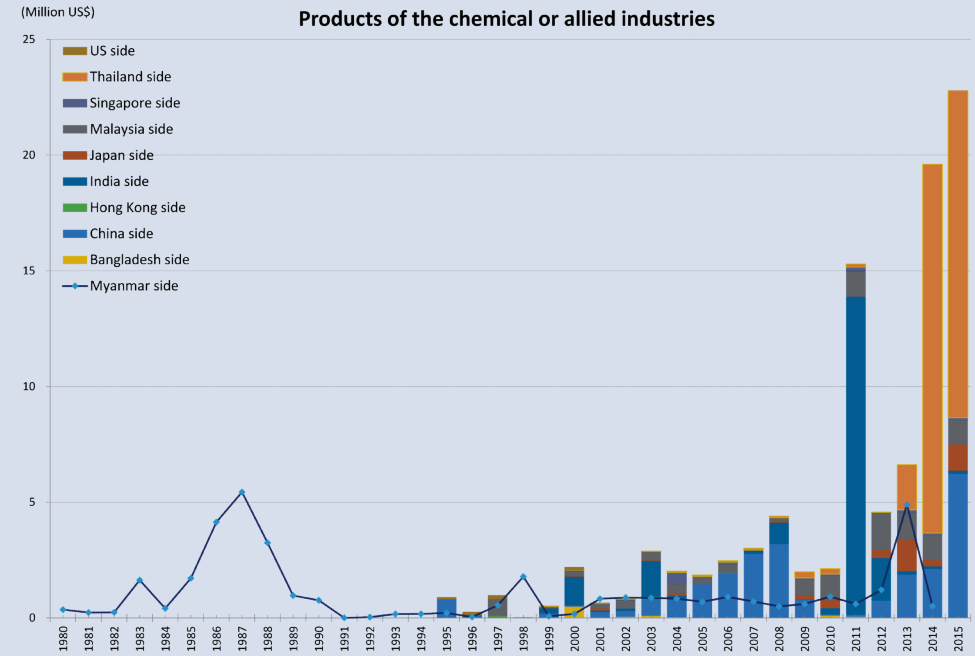


FIGURE 65-8

MYANMAR'S EXPORT VS COUNTERPARTS' IMPORT FROM MYANMAR

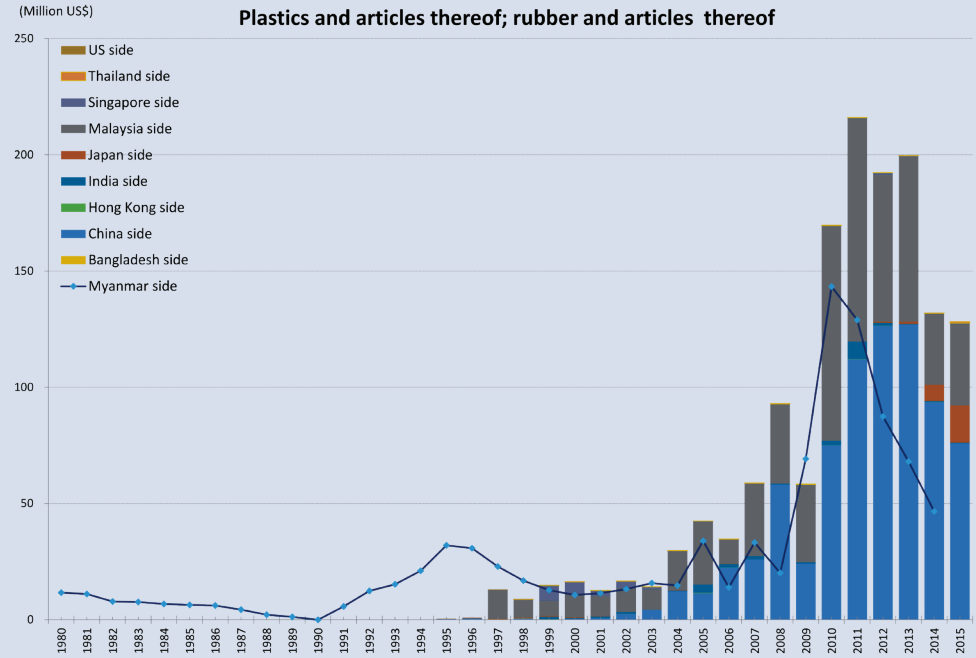


FIGURE 65-9

MYANMAR'S EXPORT VS COUNTERPARTS' IMPORT FROM MYANMAR

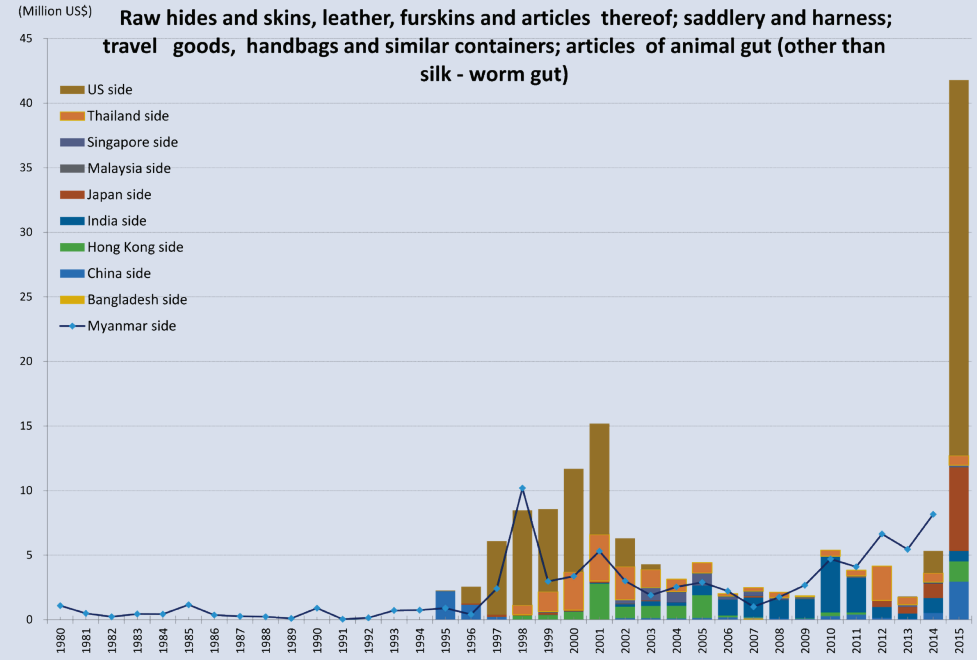


FIGURE 65-10

MYANMAR'S EXPORT VS COUNTERPARTS' IMPORT FROM MYANMAR

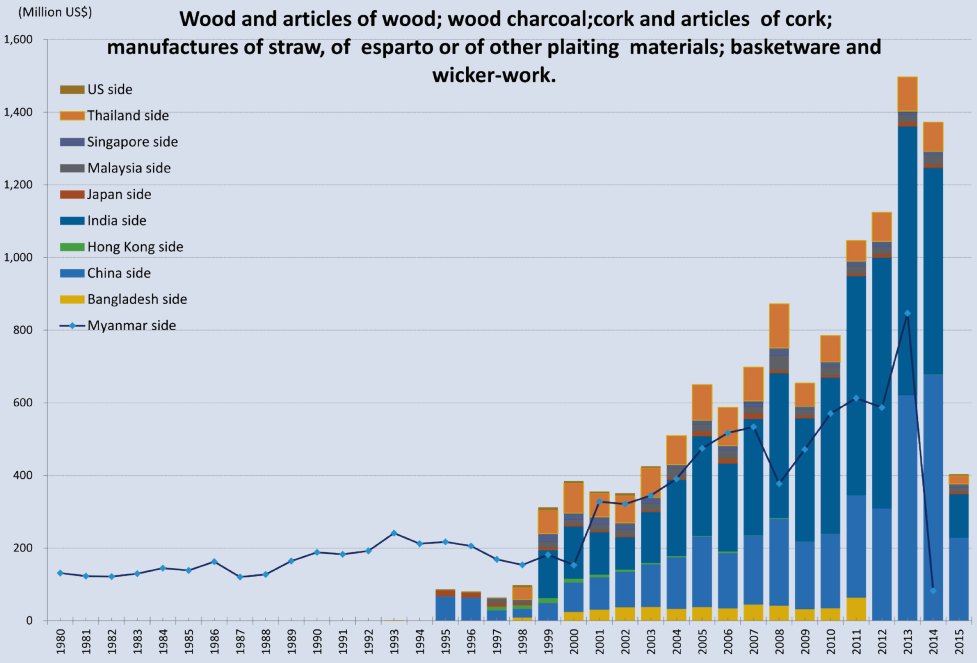


FIGURE 65-11

MYANMAR'S EXPORT VS COUNTERPARTS' IMPORT FROM MYANMAR

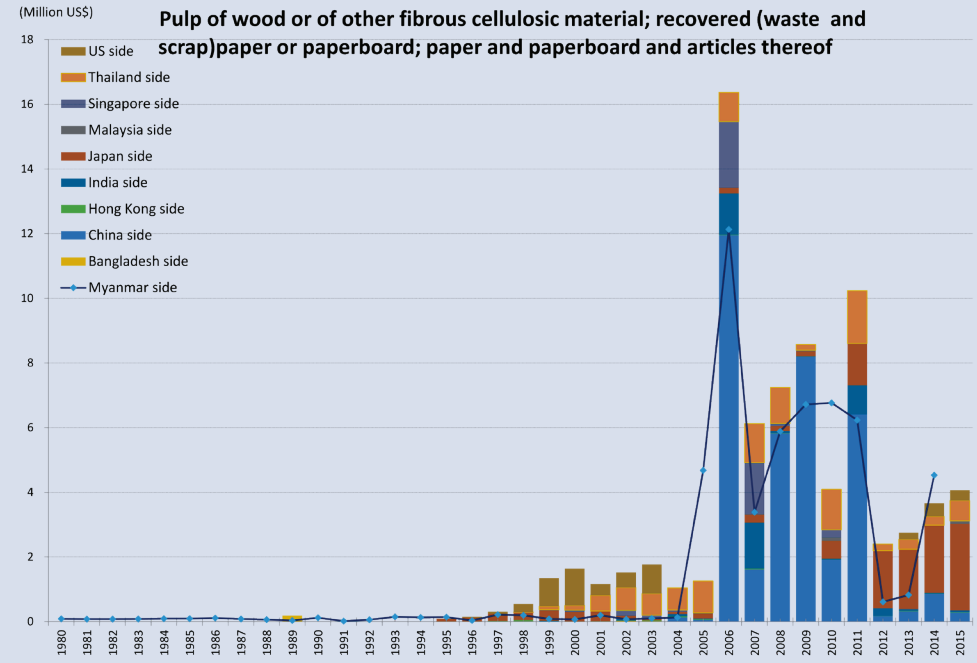


FIGURE 65-12

MYANMAR'S EXPORT VS COUNTERPARTS' IMPORT FROM MYANMAR

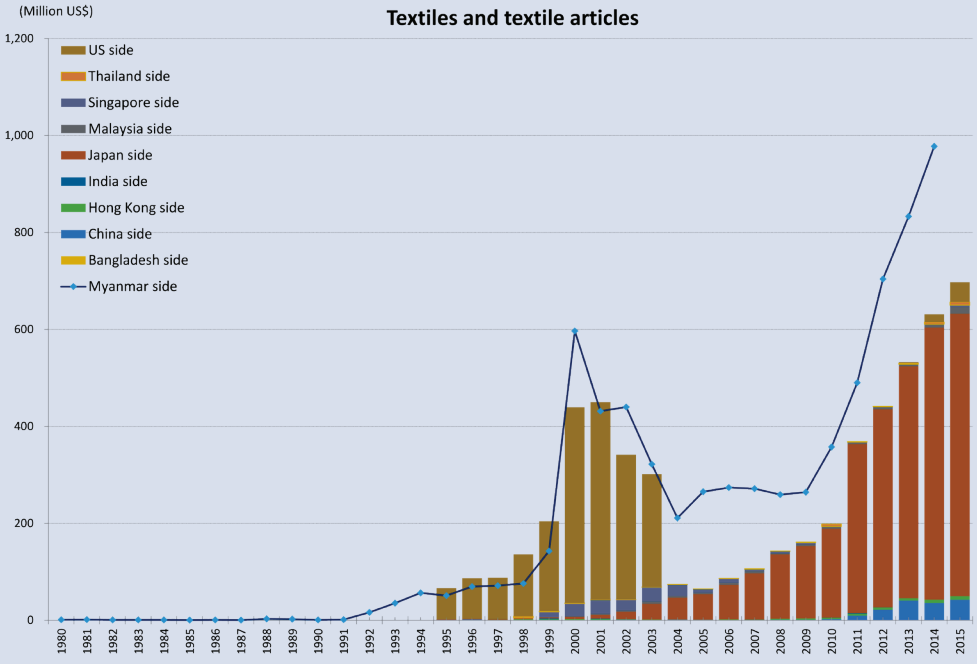


FIGURE 65-13

MYANMAR'S EXPORT VS COUNTERPARTS' IMPORT FROM MYANMAR

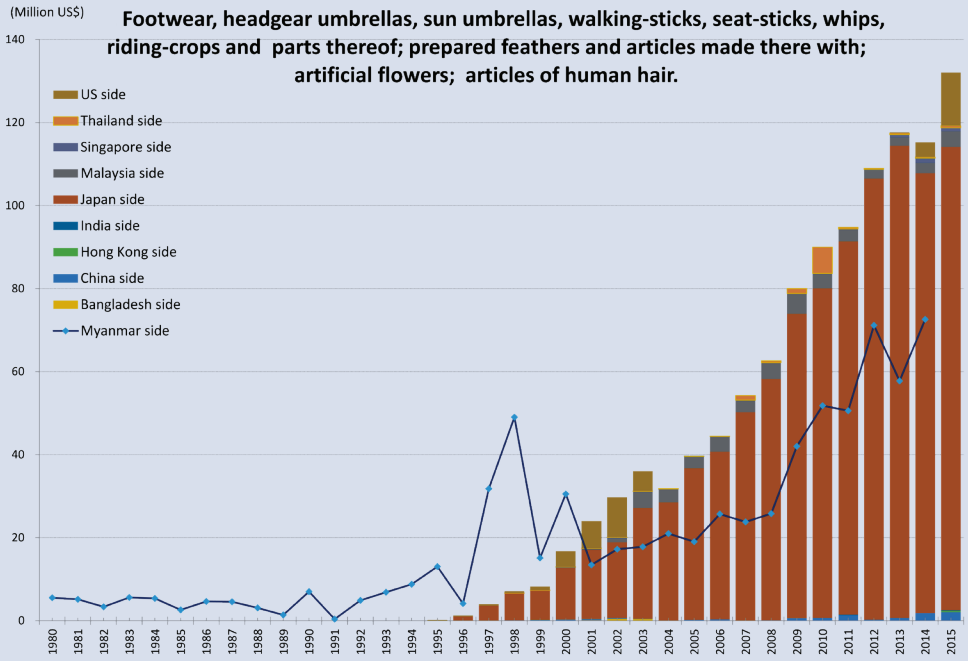


FIGURE 65-14

MYANMAR'S EXPORT VS COUNTERPARTS' IMPORT FROM MYANMAR

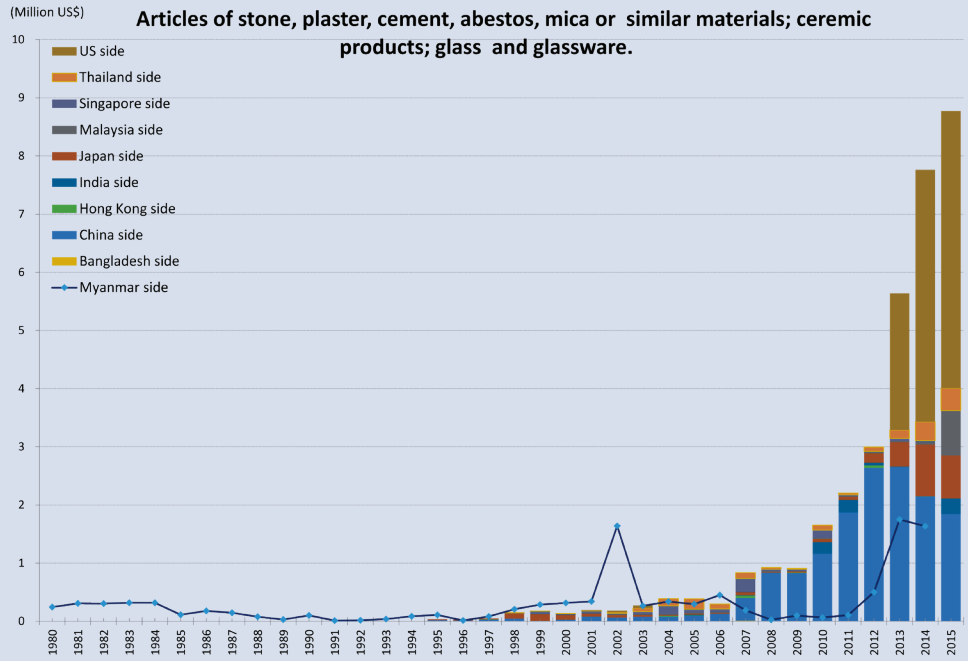


FIGURE 65-15

MYANMAR'S EXPORT VS COUNTERPARTS' IMPORT FROM MYANMAR

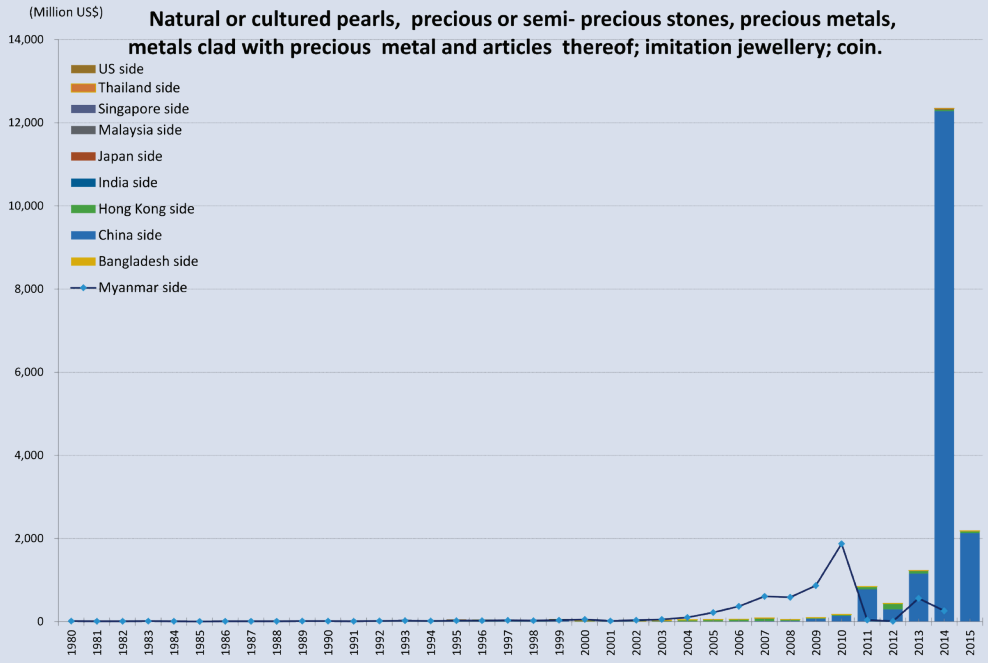


FIGURE 65-16

MYANMAR'S EXPORT VS COUNTERPARTS' IMPORT FROM MYANMAR

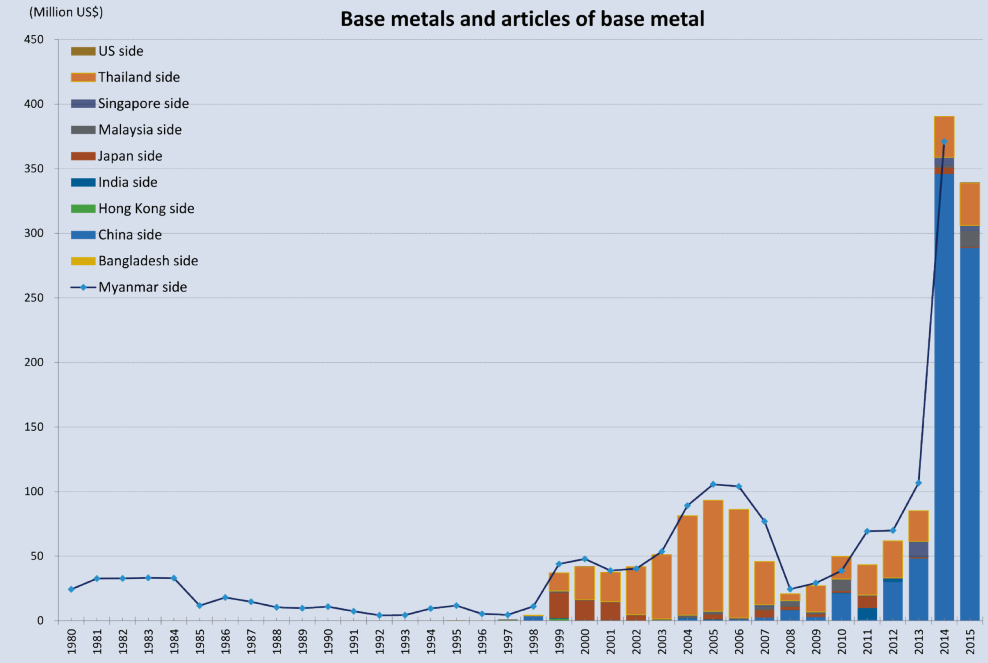


FIGURE 65-17

MYANMAR'S EXPORT VS COUNTERPARTS' IMPORT FROM MYANMAR

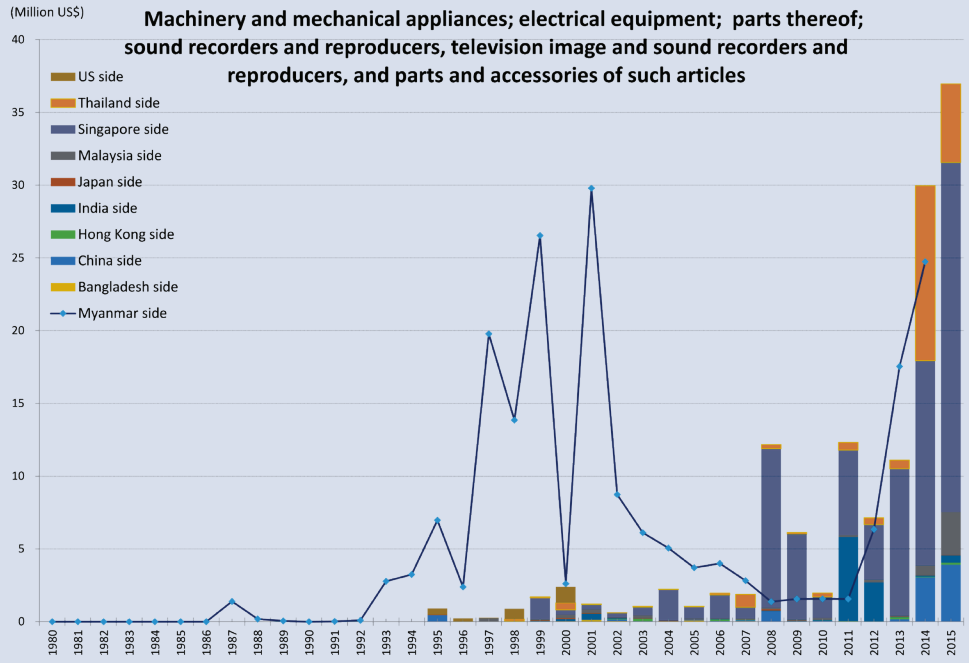


FIGURE 65-18

MYANMAR'S EXPORT VS COUNTERPARTS' IMPORT FROM MYANMAR

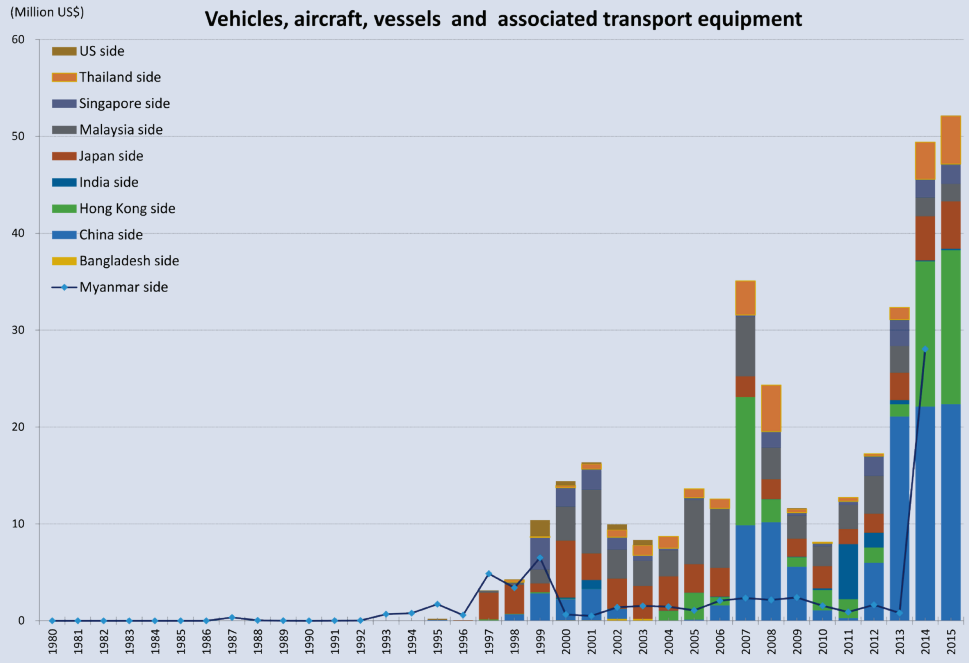


FIGURE 65-19

MYANMAR'S EXPORT VS COUNTERPARTS' IMPORT FROM MYANMAR

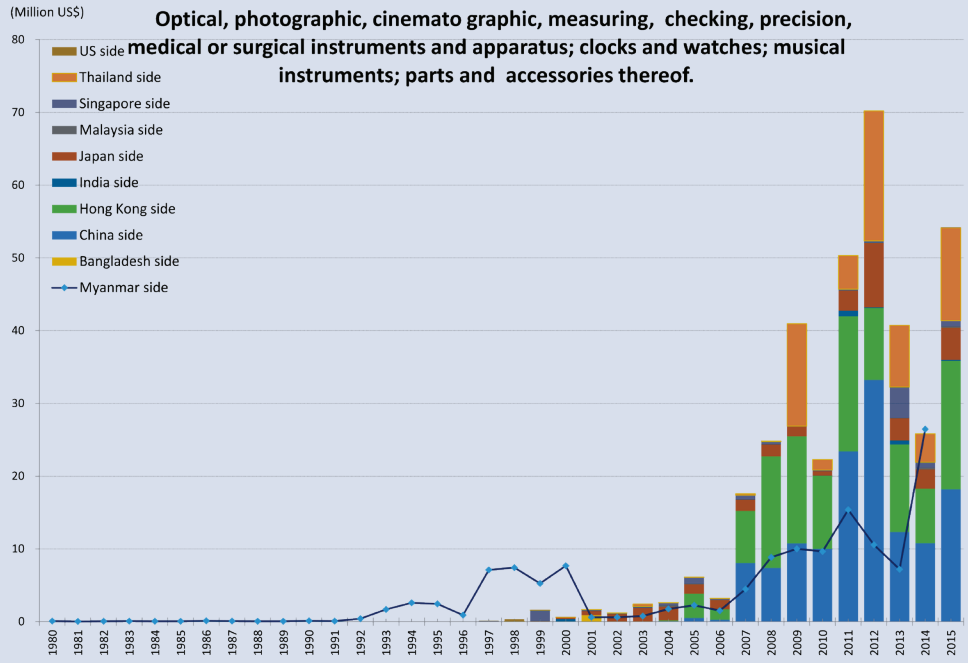


FIGURE 65-20

MYANMAR'S EXPORT VS COUNTERPARTS' IMPORT FROM MYANMAR

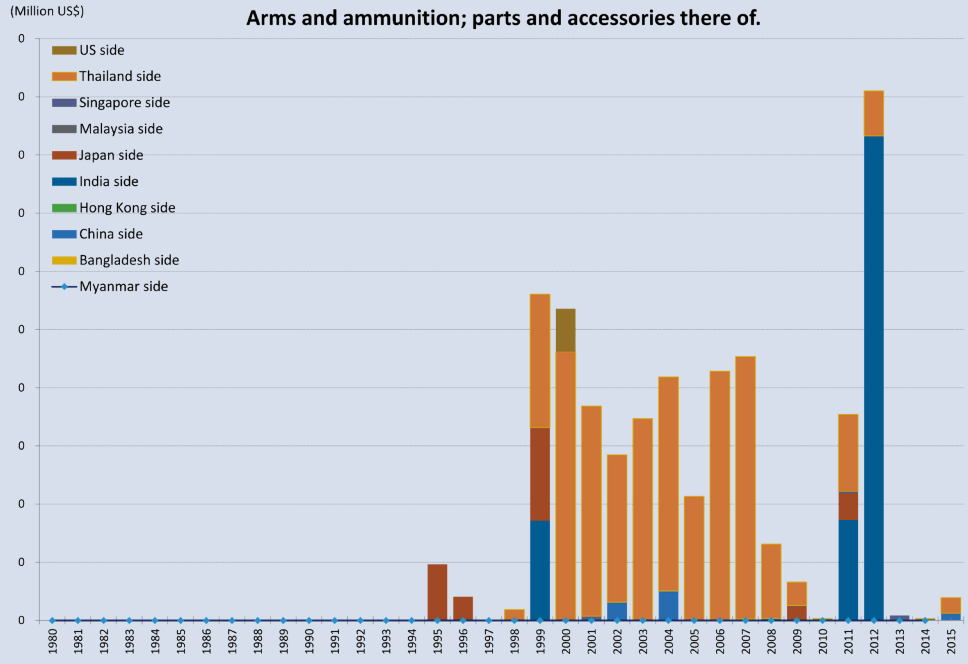
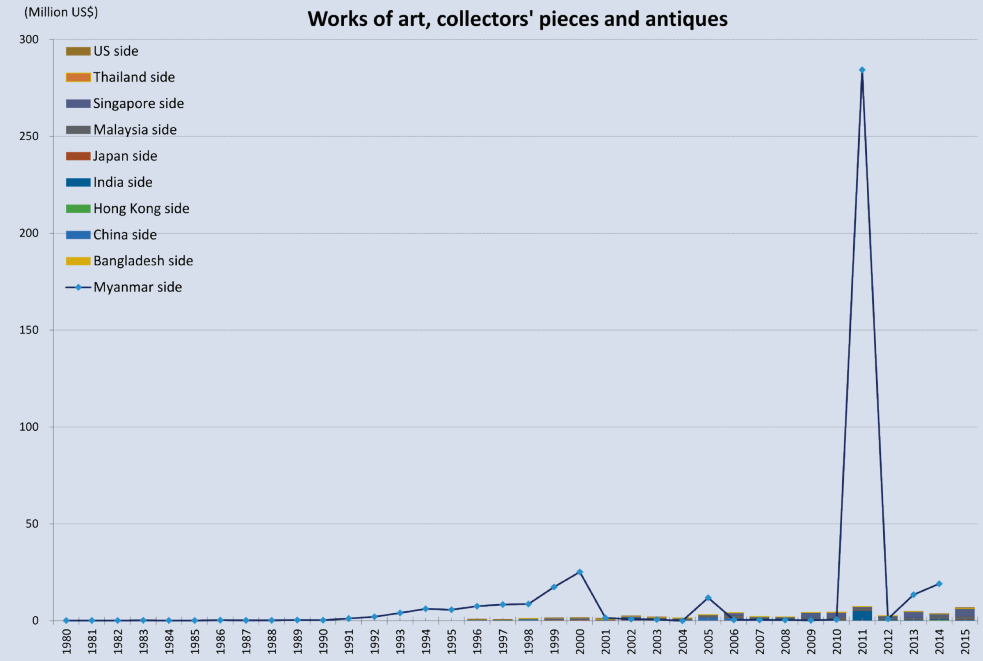


FIGURE 65-21

MYANMAR'S EXPORT VS COUNTERPARTS' IMPORT FROM MYANMAR

FIGURE 65-22

MYANMAR'S EXPORT VS COUNTERPARTS' IMPORT FROM MYANMAR



APPENDIX 4: EXAMINATION OF IMPORTS

MYANMAR'S IMPORT VS COUNTERPARTS' EXPORT TO MYANMAR

FIGURE 66-1

MYANMAR'S IMPORT VS COUNTERPARTS' EXPORT TO MYANMAR

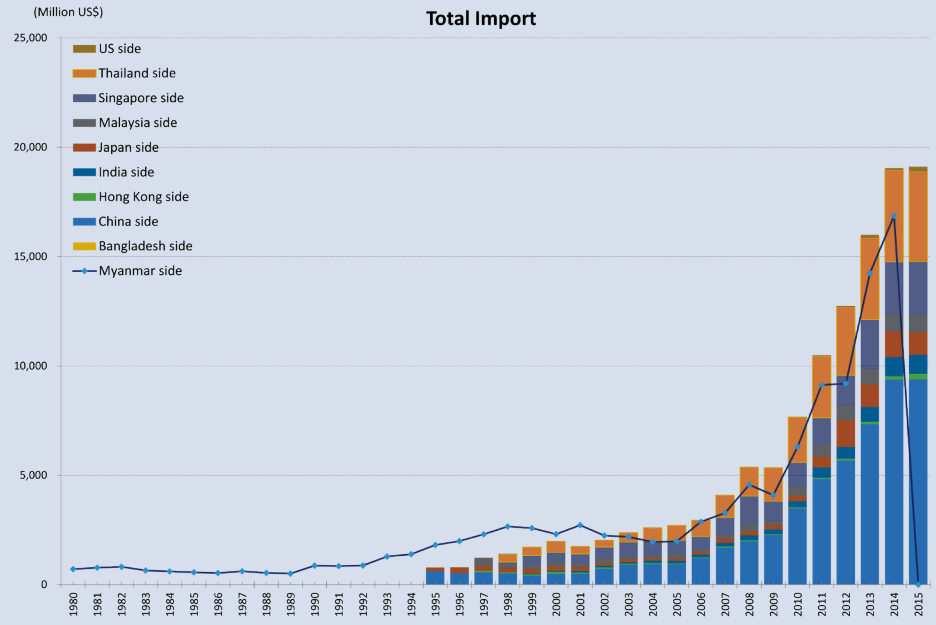


FIGURE 66-2

MYANMAR'S IMPORT VS COUNTERPARTS' EXPORT TO MYANMAR

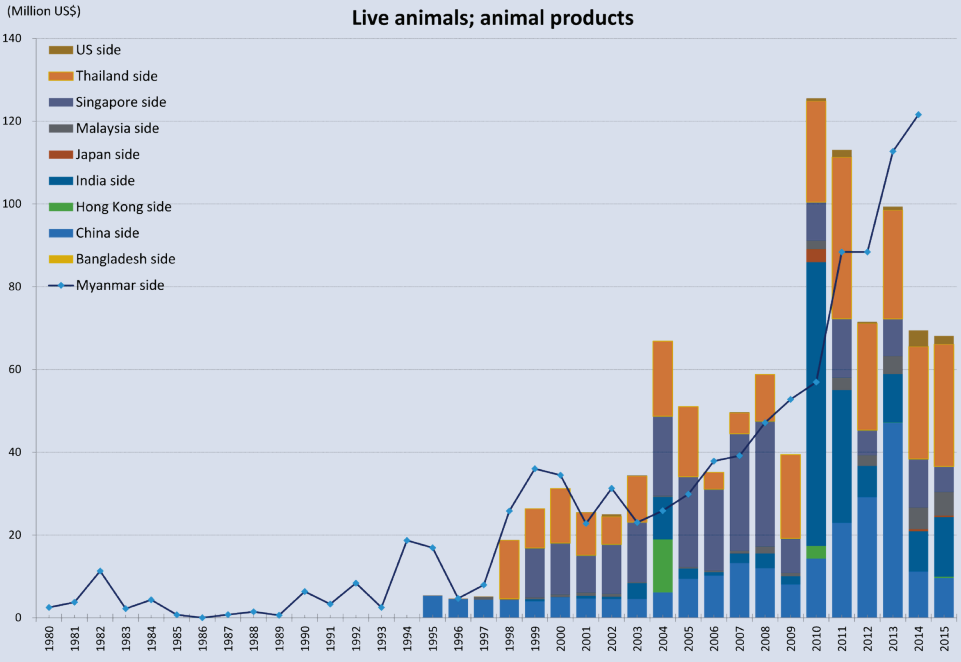


FIGURE 66-3

MYANMAR'S IMPORT VS COUNTERPARTS' EXPORT TO MYANMAR

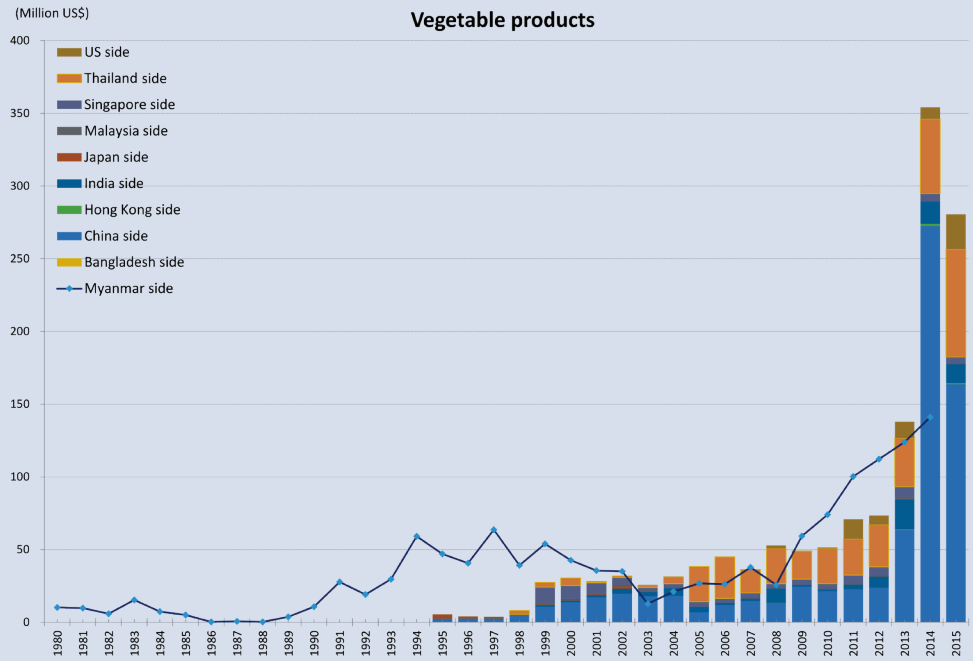


FIGURE 66-4

MYANMAR'S IMPORT VS COUNTERPARTS' EXPORT TO MYANMAR

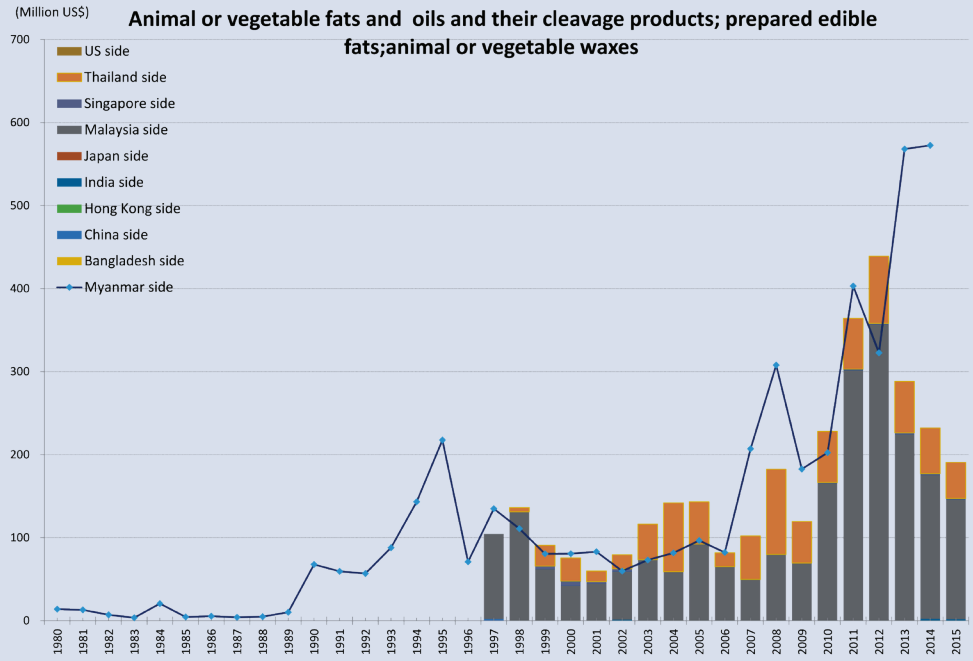


FIGURE 66-5

MYANMAR'S IMPORT VS COUNTERPARTS' EXPORT TO MYANMAR

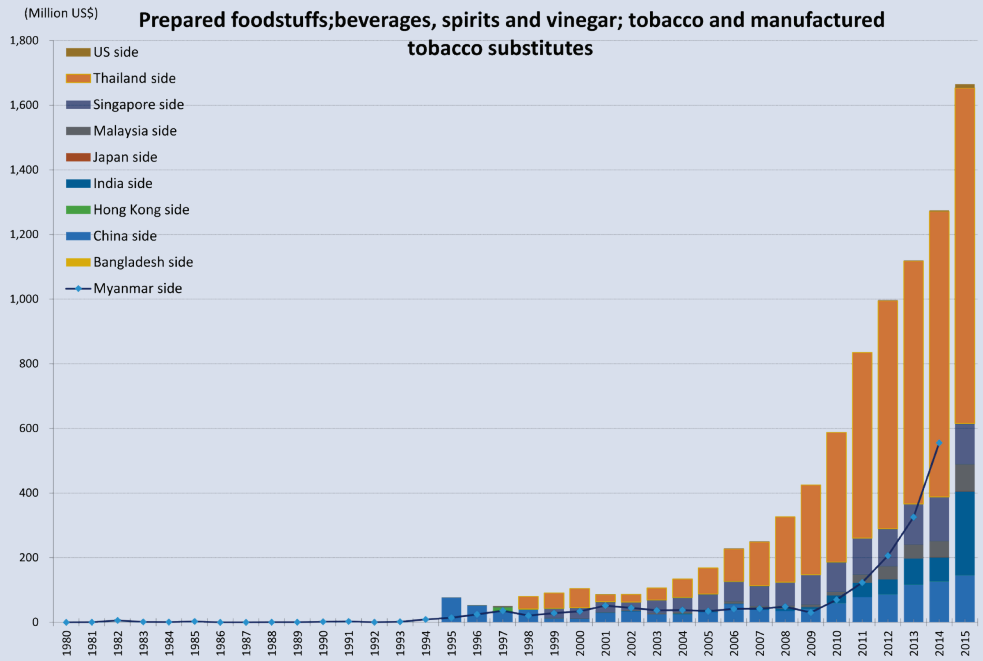


FIGURE 66-6

MYANMAR'S IMPORT VS COUNTERPARTS' EXPORT TO MYANMAR

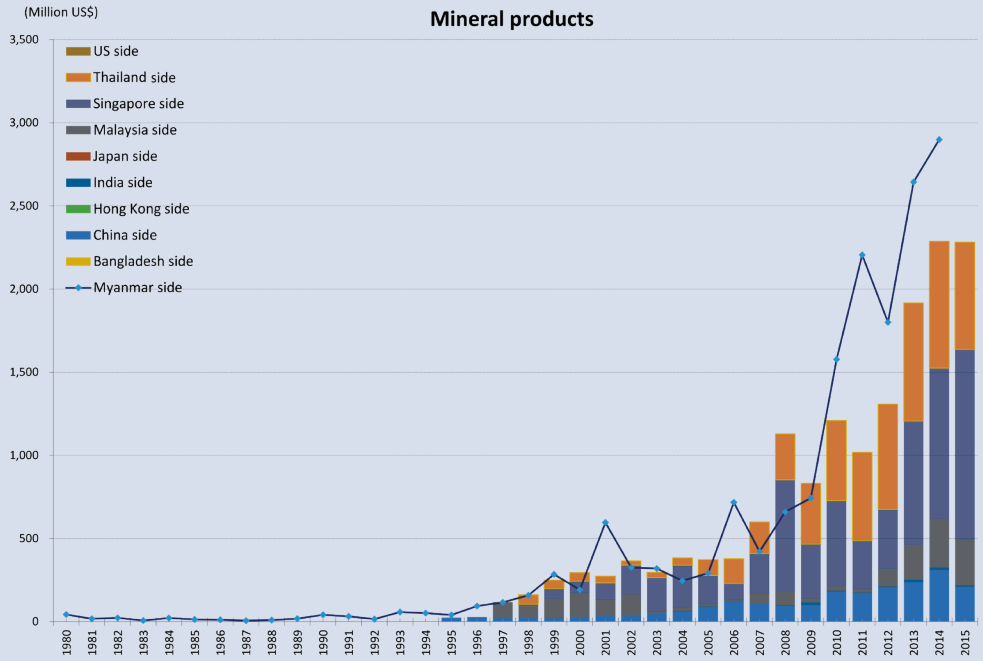


FIGURE 66-7

MYANMAR'S IMPORT VS COUNTERPARTS' EXPORT TO MYANMAR

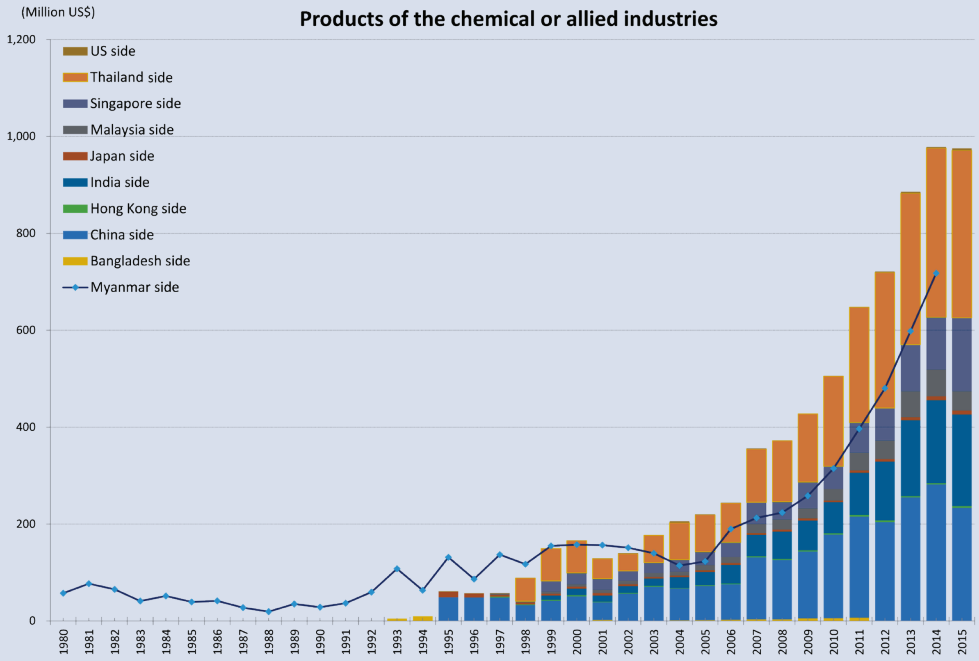


FIGURE 66-8

MYANMAR'S IMPORT VS COUNTERPARTS' EXPORT TO MYANMAR

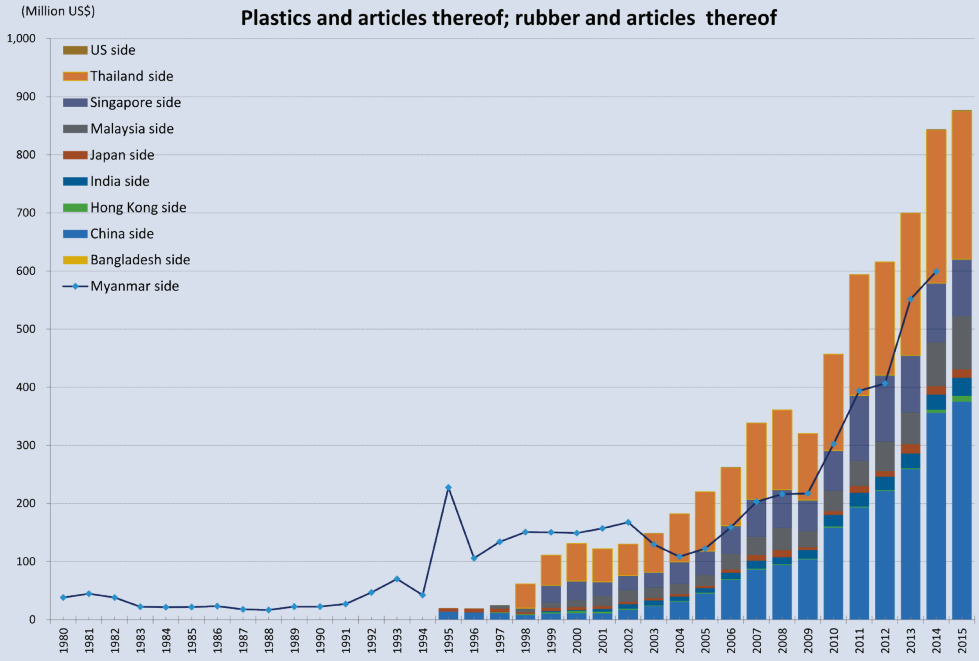


FIGURE 66-9

MYANMAR'S IMPORT VS COUNTERPARTS' EXPORT TO MYANMAR

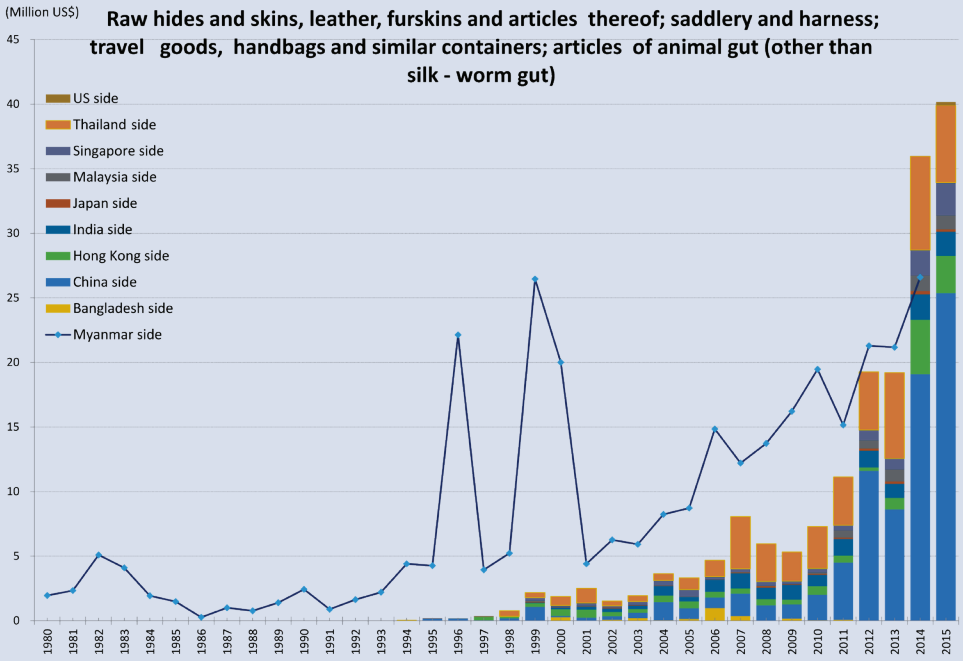


FIGURE 66-10

MYANMAR'S IMPORT VS COUNTERPARTS' EXPORT TO MYANMAR

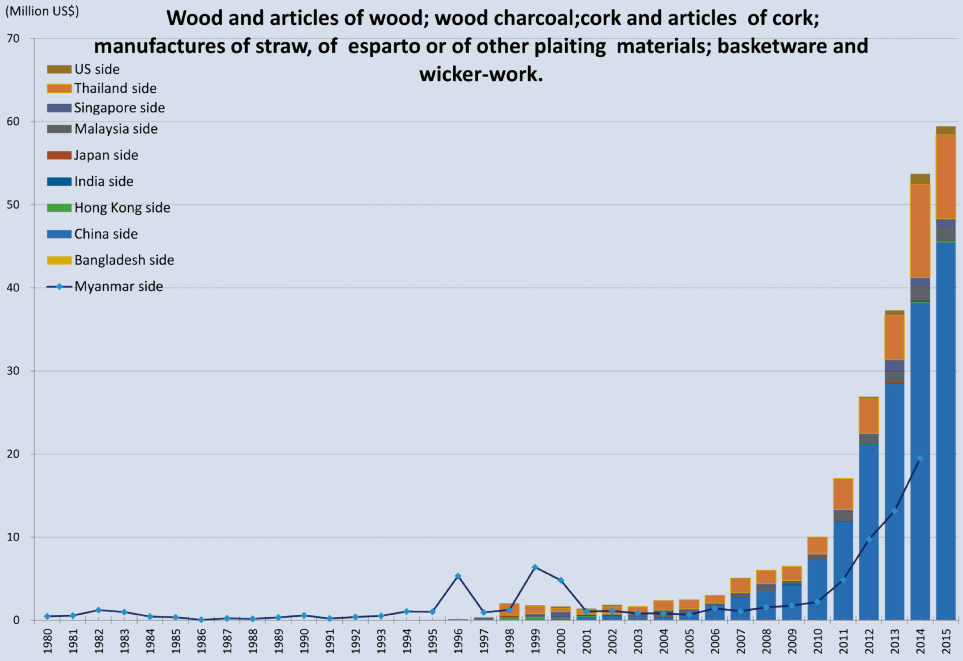


FIGURE 66-11

MYANMAR'S IMPORT VS COUNTERPARTS' EXPORT TO MYANMAR

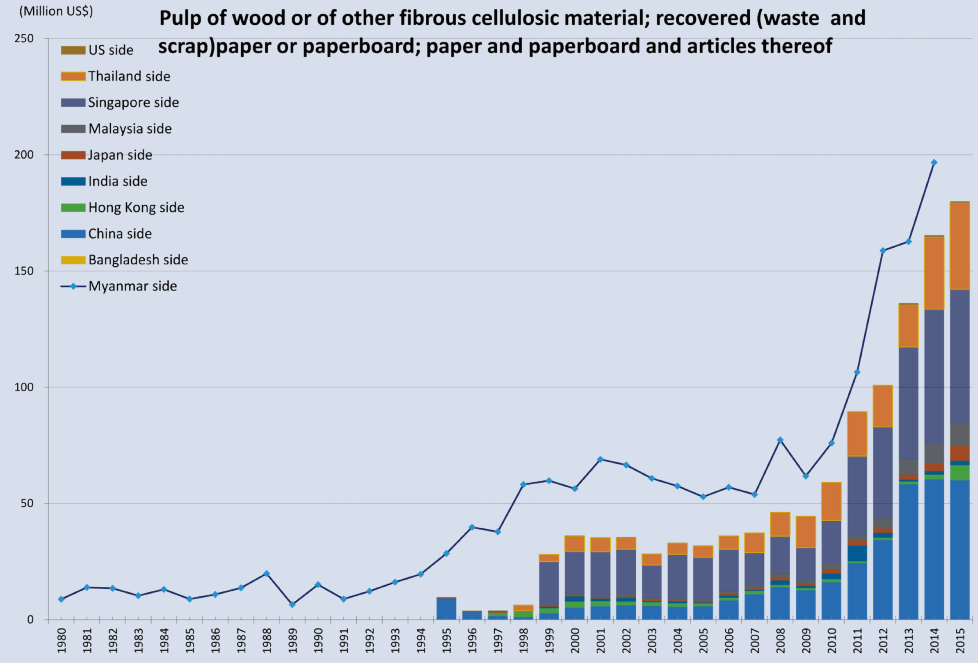


FIGURE 66-12

MYANMAR'S IMPORT VS COUNTERPARTS' EXPORT TO MYANMAR

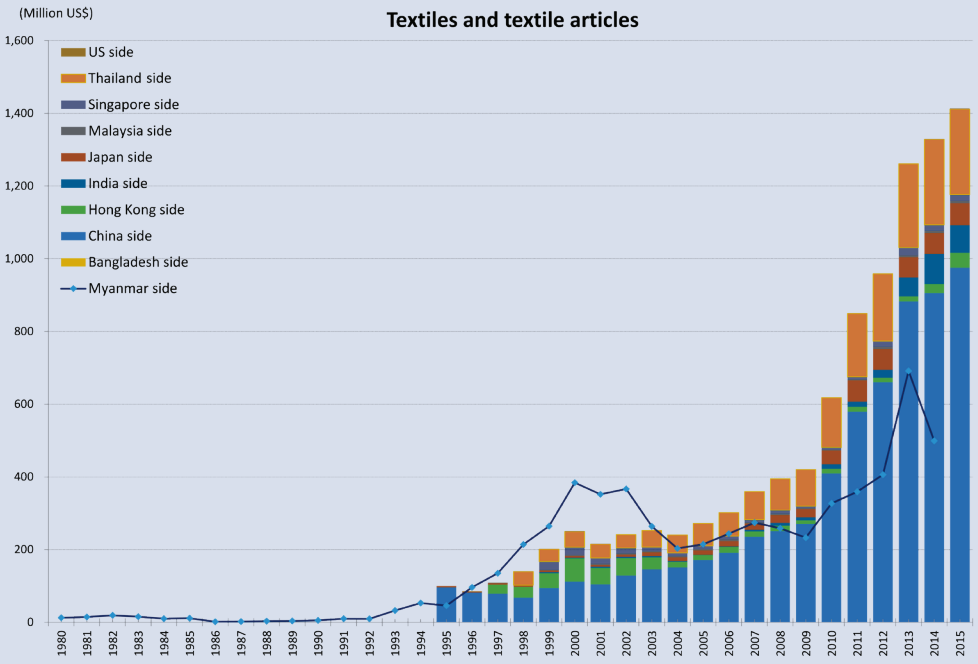


FIGURE 66-13

MYANMAR'S IMPORT VS COUNTERPARTS' EXPORT TO MYANMAR

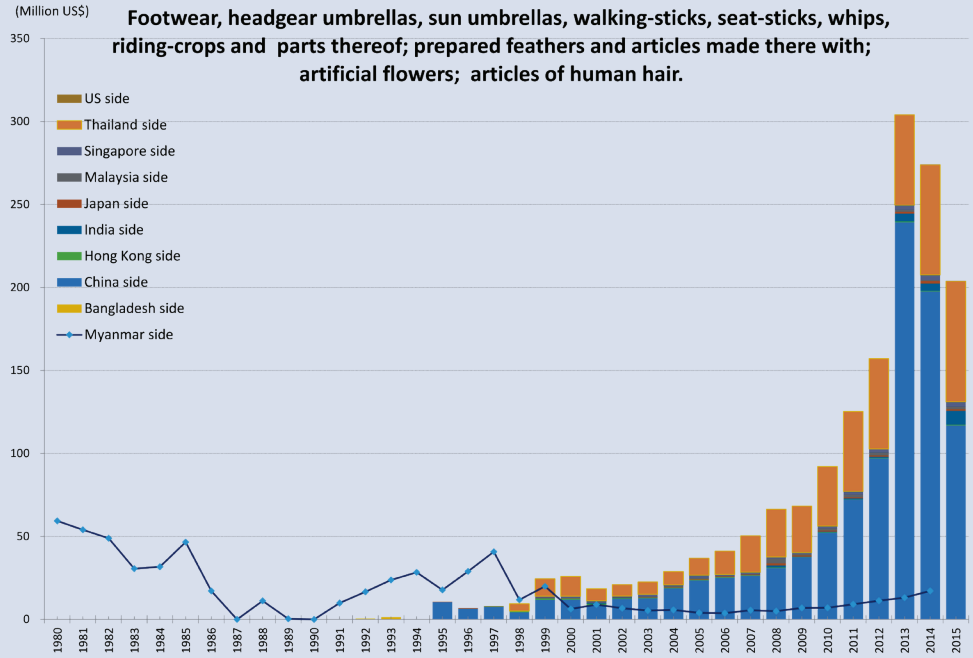


FIGURE 66-14

MYANMAR'S IMPORT VS COUNTERPARTS' EXPORT TO MYANMAR

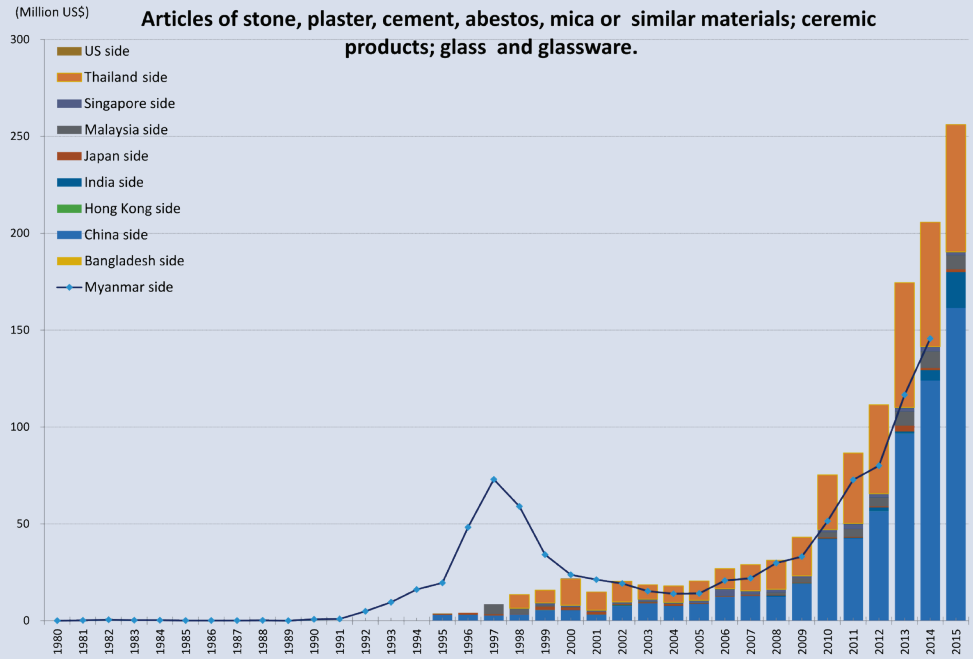


FIGURE 66-15

MYANMAR'S IMPORT VS COUNTERPARTS' EXPORT TO MYANMAR

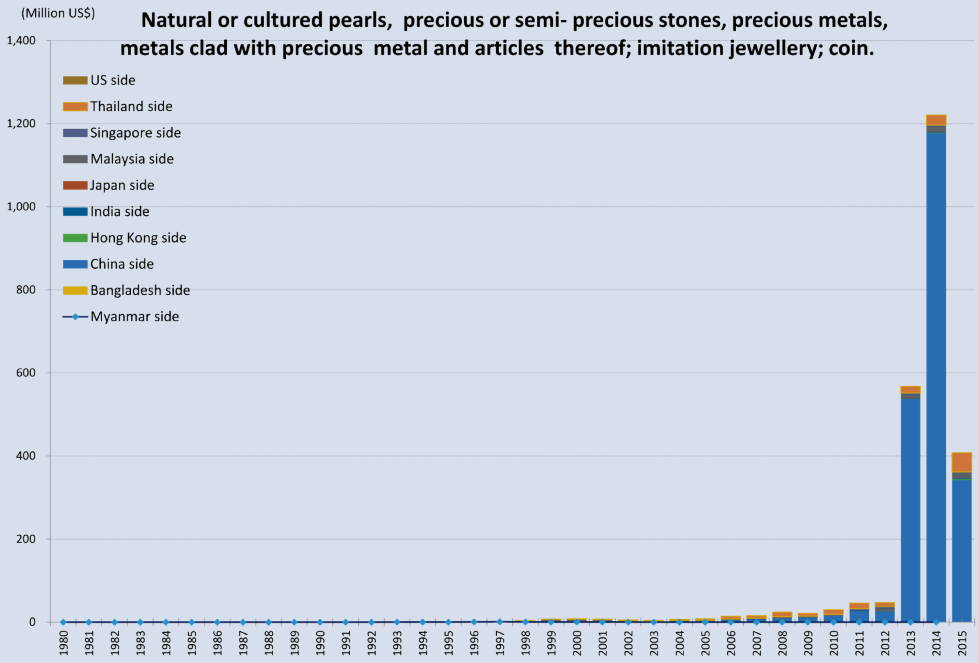


FIGURE 66-16

MYANMAR'S IMPORT VS COUNTERPARTS' EXPORT TO MYANMAR

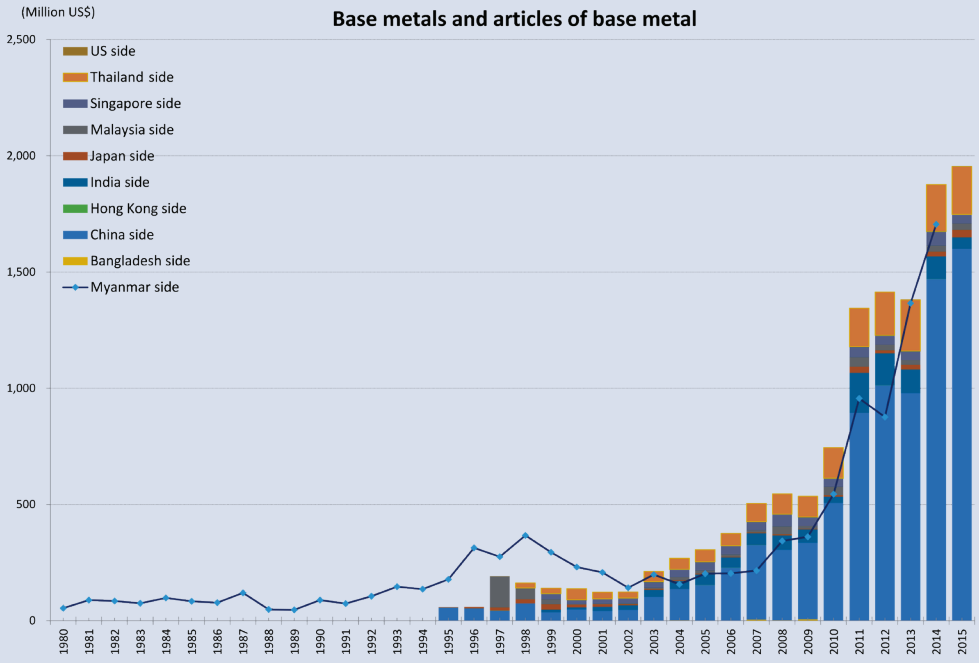


FIGURE 66-17

MYANMAR'S IMPORT VS COUNTERPARTS' EXPORT TO MYANMAR

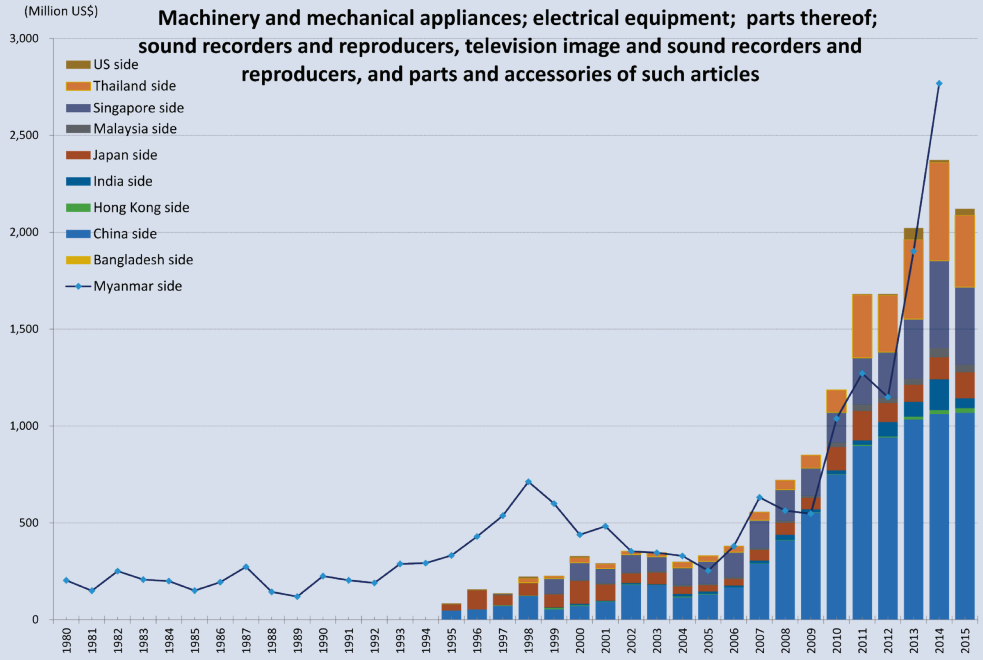


FIGURE 66-18

MYANMAR'S IMPORT VS COUNTERPARTS' EXPORT TO MYANMAR

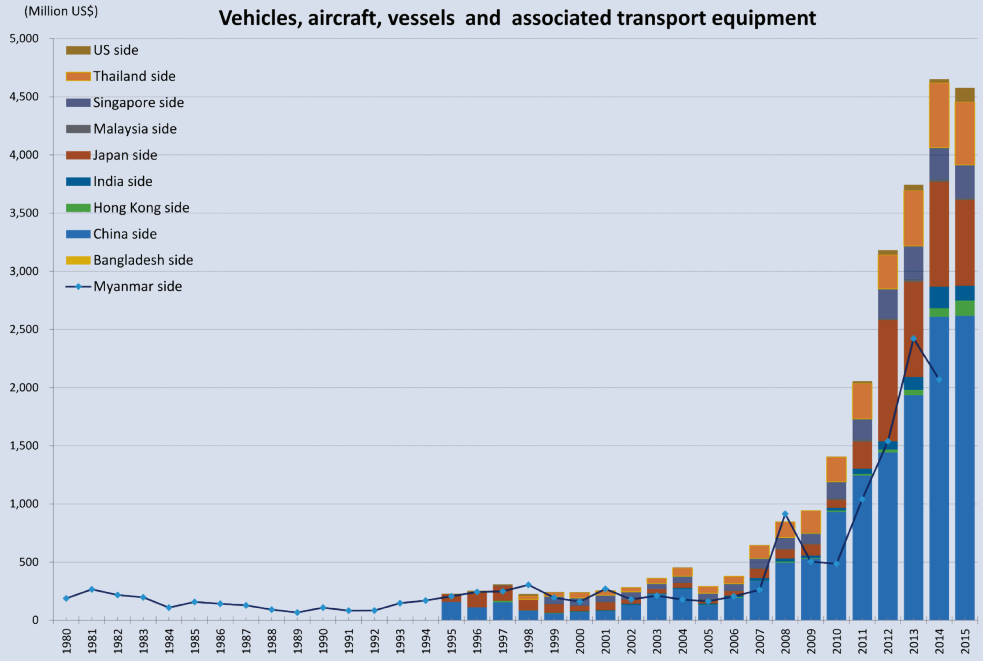


FIGURE 66-19

MYANMAR'S IMPORT VS COUNTERPARTS' EXPORT TO MYANMAR

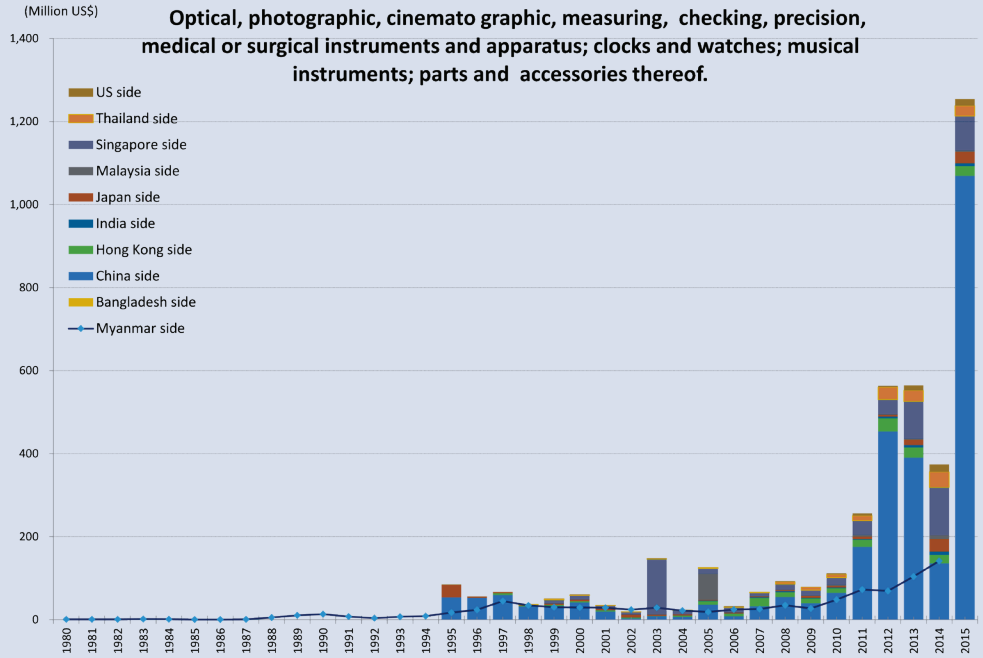


FIGURE 66-20

MYANMAR'S IMPORT VS COUNTERPARTS' EXPORT TO MYANMAR

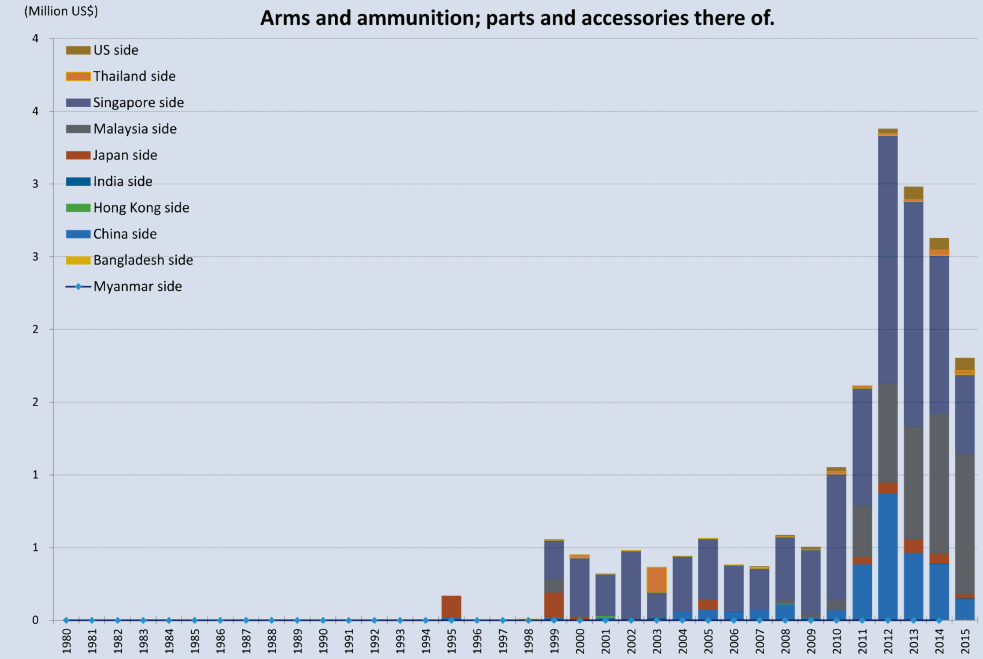


FIGURE 66-21

MYANMAR'S IMPORT VS COUNTERPARTS' EXPORT TO MYANMAR

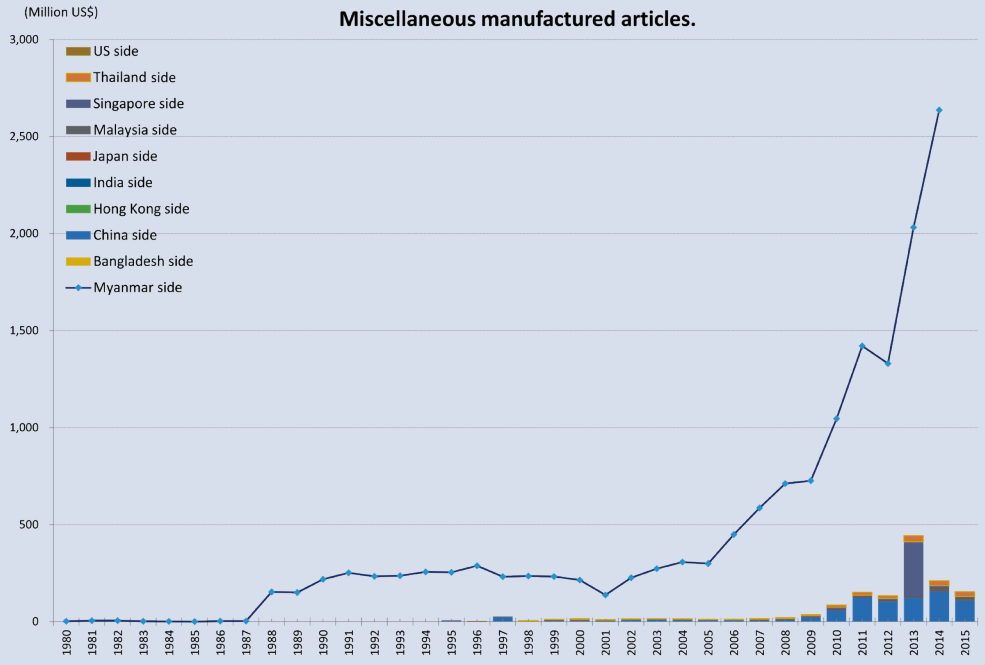
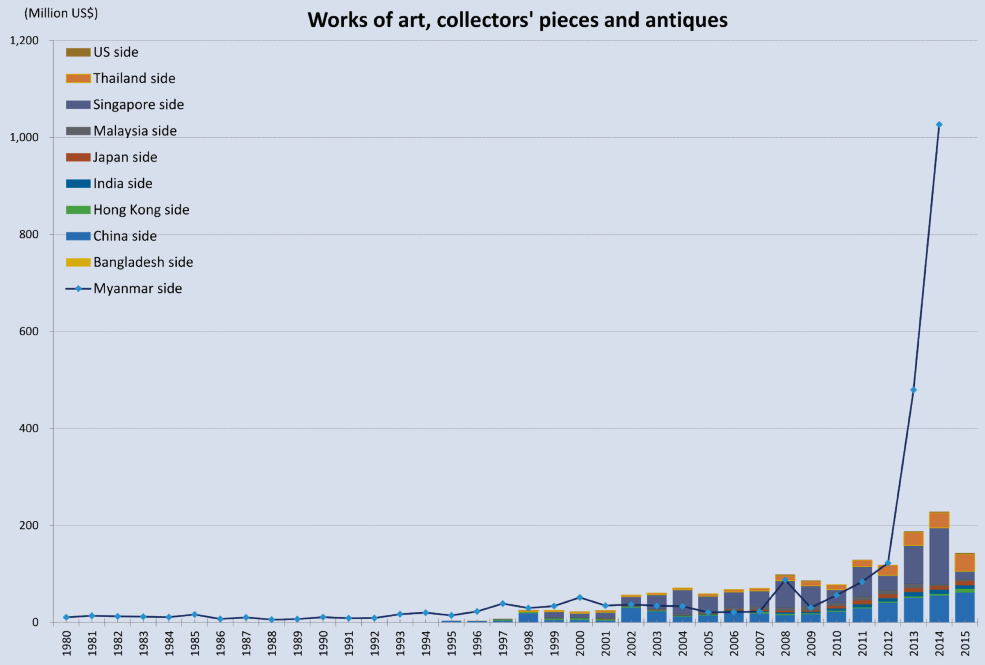


FIGURE 66-22

MYANMAR'S IMPORT VS COUNTERPARTS' EXPORT TO MYANMAR



SUSTAINABLE PRODUCTIVITY

THE NEW FRONTIER FOR PRODUCTIVITY

Bangladesh
Cambodia
Republic of China
Fiji
Hong Kong
India
Indonesia
Islamic Republic of Iran
Japan
Republic of Korea
Lao PDR
Malaysia
Mongolia
Nepal
Pakistan
Philippines
Singapore
Sri Lanka
Thailand
Vietnam

GREEN PRODUCTIVITY AND PRODUCTIVITY MEASUREMENT PROGRAM FOR MYANMAR