American Journal of Climate Change, 2017, 6, 99-115
http://www.scirp.org/journal/ajcc
ISSN Online: 2167-9509
ISSN Print: 2167-9495

Economic Growth and CO_2-Emissions: What If Vietnam Followed China's Development Path?

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How to cite this paper: Oberheitmann, A. (2017) Economic Growth and CO_2-Emissions: What If Vietnam Followed China's Development Path? *American Journal of Climate Change*, **6**, 99-115.
https://doi.org/10.4236/ajcc.2017.61006

Received: October 24, 2016
Accepted: March 10, 2017
Published: March 13, 2017

Abstract

Vietnam and China both are quickly emerging market economies in Asia. China has had an unprecedented economic growth in Asia for the past 30 years. Also, Vietnam's GDP is increasing, but more slowly. However, Vietnam is starting to catch up. Against this background, this article assesses the question what the economic and environmental impacts in Vietnam would be, if the country followed China's development path. Based on econometric analysis, it is shown that currently, Vietnam is lagging behind China in terms of economic growth for 11 years. Although Vietnam and China have a similar primary energy mix in the early 1980s, China is still massively relying on coal, whereas Vietnam starts to develop hydro power in the late 1980s on large scale. Due to a quick growth of per-capita income, per capita emissions in China are already catching up with those of North-European economies such as Denmark, Finland and Germany. The question arises, what if Vietnam followed China's development path. Using econometric models of GDP and CO_2-emissions, two scenarios for Vietnam are analyzed, a scenario following China's development path and one alternative scenario pursuing the current development patterns until 2050. The results show that the additional impact of following China's economic development path is minor. Vietnam would only have a 0.5% percentage point per annum higher GDP growth. In other words, Vietnam would grow relatively quickly anyway. However, following China's development path also in terms of high CO_2-emissions per capita, would increase the growth of CO_2-emissions in Vietnam by 2.3 percentage points per annum and would lead to an increase of CO_2-emissions in 2050 by 2.6 bn. tons compared with the scenario in which Vietnam sticks to its own development patterns. However, in that case, Vietnam also had a 25% lower per capita income compared with the scenario following China's development path. Here, the people and government in Vietnam have to make a strategic choice.

Keywords

Vietnam, China, Economic Development, CO_2-Emissions per Capita, Co-Integration Analysis

1. Introduction

Vietnam and China are quickly growing and emerging market economies with increasing economic welfare in terms of growing disposable per-capita income [1]. The two Asian economies, however, also have to cope with development related problems such as increasing disparities of macro-economic income distribution or negative environmental side effects such as growing local emissions of sulfur dioxide (SO_2) or nitrogen oxide (NO_x) as well as growing global greenhouse gas emissions, especially carbon dioxide (CO_2). China introduced economic reforms in the late 1970's when Deng Xiaoping got Prime Minister in China [2] [3]. Vietnam initiated its reforms, called "Doimoi" (renovation) a few years later in 1986 with the aim—such as China—of creating a "socialist-oriented market economy" [4].

Starting from a comparable per capita GDP level, since the late 1980s, China's development has been much quicker than that of Vietnam. Between 1980 and 2013, China's GDP per capita grew by 11.8%, Vietnam only by 7.8% [5]. However, Vietnam is catching up economically. E.g. its trade with Germany—although starting from a low level—has reached the highest growth in Asia [6]. Against this background, research has been done and published on whether Vietnam could follow China's footsteps and join the group of emerging countries in Asia in a third wave (e.g. [7]). The divergence in the development in China and Vietnam has been explained by differences in the political economy of development [8] [9], inter alia, by differences in the governance reforms in China and Vietnam [10]. International linkages to development have been drawn in empirical studies of trade between Vietnam and China (e.g. by ANH-DAO [11]). Granger causality between economic growth and CO_2-emissions has been done on China [12] and on Vietnam [13]. New research had been undertaken on other countries such as Ghana [14] [15].

Currently, the question, however, is open, whether Vietnam should follow China's development path or continue its own way of development. This article is focusing on this issue and assesses the empirical difference of the development paths of the two countries and which economic and environmental implications it would have, if Vietnam followed China's development patterns in the future. In order to answer these questions, an econometric analysis of Vietnam's and China's development paths is undertaken (Section 2), analyzing how many years Vietnam is lagging behind China economically. Based on the results of this analysis, a forecast of Vietnam's GDP, CO_2-emissions and CO_2-intensities per capita and GDP is made until 2050, if Vietnam followed China's development path compared with a scenario with autonomous economic development patterns

(Section 3). A summary (Section 4) concludes the article.

2. Econometric Analysis of Vietnam's and China's Development Path

Since the 1960s, sequential regional economic development in Asia is being observed and described as a "flying geese formation" phenomenon of one or more countries following others ([16] [17] [18] etc.). Japan's economy roughly started to develop in the 1960s, followed by the four little dragons (Hong Kong, Singapur, South Korea and Taiwan) in the 1970s, China in the 1980s and South-East Asian countries such as Thailand, Malaysia, Philippines or Vietnam in the 1990s.

Assessing Vietnam's economic development relative to that in China, **Figure 1** shows GDP per capita (calculated as power purchasing parities) in Vietnam and China between 1980 and 2013. During the 1980s, Vietnam and China had a similar per-capita income (Vietnam 1980: 437 US$; 1990: 936 US$; China 1980: 304 US$; 1990: 953 US$). Since the 1990's, however, China's economy grew much faster than that of its southern neighbor Vietnam. By 2000, China already had a per-capita income of 2,843 US$, Vietnam only 2,029 US$. By 2013, China's per capita income already reached 11,880 US$, whereas Vietnam only had 5,239 US$ GDP per capita.

In order to assess, how many years Vietnam is lagging behind China in terms of its economic development, a simple regression of GDP per capita in Vietnam ($GDP\_POP\_VN_t$) on GDP per capita in China ($GDP\_POP\_CH_{t-n}$) for different time lags ($L_n = t - n$) is performed using an ordinary least squares (OLS) estimator. Applying this model, it will be assessed which time lag of per-capita GDP

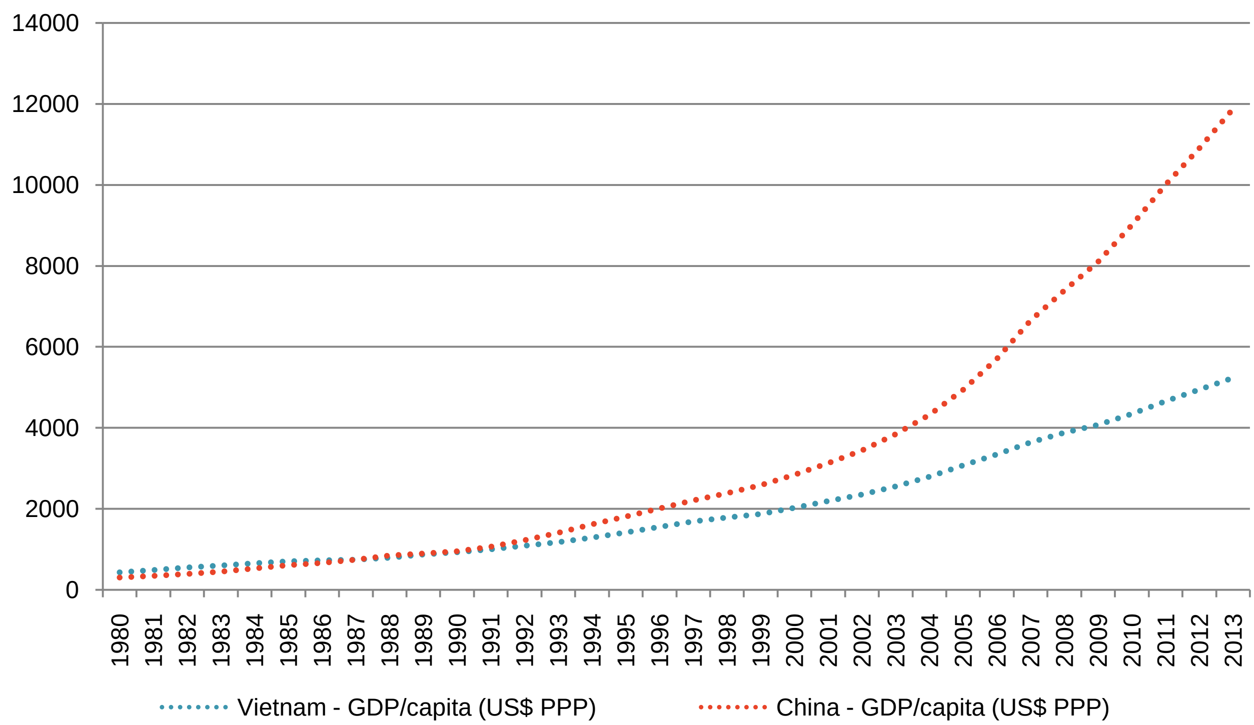

Figure 1. Comparison of GDP per capita in Vietnam and China (1980-2013, in kg and t/1000 US$ PPP). Source: [5] [19].

in China fits to the current time series of per-capita GDP in Vietnam between 1993 and 2013. A simple assessment, when the two countries had the same per-capita GDP does not take into account the deviations in the development paths over time. Thus, the logarithmic model employed here is:

$$\ln\left(\text{GDP\_POP\_VN}_t\right) = C + \alpha \cdot \ln\left(\text{GDP\_POP\_CH}_{t-n}\right) + \varepsilon_t. \quad (1)$$

In the model, ε_t represents the error term and C a constant. Before being able to run the model, however, the question of stationarity of the two time series has to be addressed. Estimating OLS including variables which follow a random walk may yield spurious results, *i.e.* the regressions present a relationship between these variables which in reality does not exist [20]. In order to assess the existence of a random walk of GDP per capita in Vietnam and China, the unit root test, introduced by DICKEY and FULLER [21] is applied. The augmented DICKEY-FULLER (ADF) test results indicate that both, GDP per capita in China as well as in Vietnam, follow a random walk. However, per-capita GDP in Vietnam and China could be converted into a stationary time series taking the first differences. In other words, Vietnam's and China's per capita GDP is integrated of Order 1 [I (1)].

Spurious regressions will also not result, if there is a stable-long-term economic relationship between the two variables, or in other words, if the linear combination of the two variables is co-integrated [22] [23]. Applying ADF-tests to the OLS-residuals shows that the residuals of Equation 1 are stationary on the 1% level. That means, the linear combination of the variables as given the GDP per capita Model 1 appears to be co-integrated. The coefficients in the co-integration function are super-consistent [24], *i.e.* that its variance converges to zero at a rate proportional to 1/T rather than the usual rate, which is proportion to $1/T^{0.5}$.

In order to assess how many years Vietnam is lagging behind China in terms of its economic development patterns, the Model 1 above is run for of ln(GDP_POP_VN$_t$) and different lags (n = 0 - 13) of ln(GDP_POP_CH$_{t-n}$). **Table 1** shows that China's per capita GDP is integrated of order 1 [I (1)] for all lags (n = 0 - 13).

Figure 2 shows the correlation coefficient in the regression of GDP per capita in Vietnam on GDP per capita in China for different lags. The highest correlation between the Vietnamese GDP per capita and the Chinese GDP per capita is for a lag of 11 years, *i.e.* on the basis of the econometric analysis; we assume here that Vietnam's economic development path is lagging behind that of China for 11 years.

Hence, following China's development path would mean that Vietnam in the next year (t) would have the same growth patterns of GDP per capita as China had (t − 11) years ago. **Table 2** presents the estimation results for Model 1 with the lag of 11 years.

Compared to China, Vietnam's current GDP is less CO_2-intensive (2013: Vietnam 0.3 t/1000 US$ PPP; China 0.6 t/1000 US$ PPP. Both countries, especially

Table 1. Integration order of GDP per capita in Vietnam and China for different lags (n = 0 - 13).

ADF-Test	Integration order	Significance level
log(gdp_pop_vn)	I (1)	5%
log(gdp_pop_ch)	I (1)	1%
log(gdp_pop_ch(−1))	I (1)	1%
log(gdp_pop_ch(−2))	I (1)	1%
log(gdp_pop_ch(−3))	I(1)	5%
log(gdp_pop_ch(−4))	I (1)	1%
log(gdp_pop_ch(−5))	I (1)	5%
log(gdp_pop_ch(−6))	I (1)	5%
log(gdp_pop_ch(−7))	I (1)	5%
log(gdp_pop_ch(−8))	I (1)	5%
log(gdp_pop_ch(−9))	I (1)	1%
log(gdp_pop_ch(−10))	I (1)	1%
log(gdp_pop_ch(−11))	I (1)	1%
log(gdp_pop_ch(−12))	I (1)	5%
log(gdp_pop_ch(−13))	I (1)	5%

Source: Own calculations based on data from [5] [19].

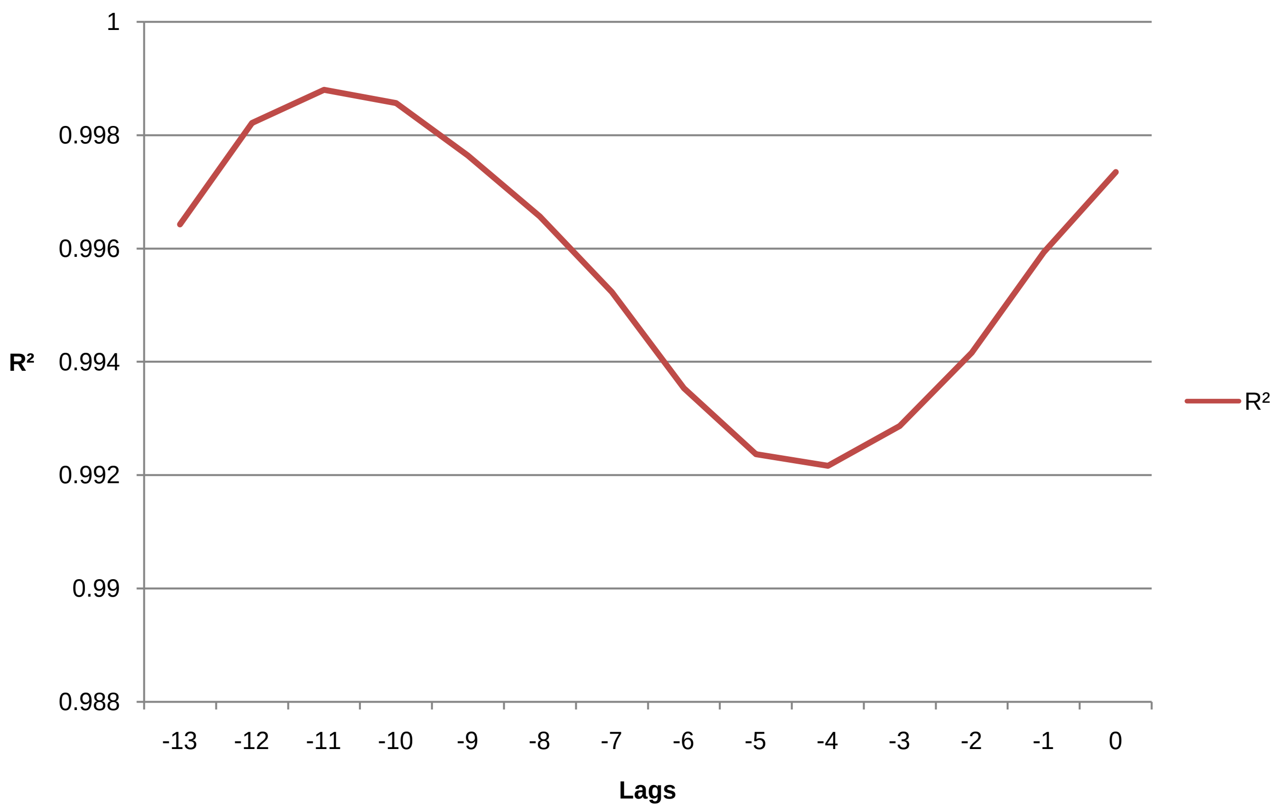

Figure 2. Correlation coefficient in the regression of GDP per capita in Vietnam on GDP per capita in China for different lags (L) (L = 0 - 13). Source: Own calculations based on data from [5] [19].

China, reduced their CO_2-intensity of GDP considerably and both intensities are converging (Figure 3).

Looking at the sect oral structure of GDP in China and Vietnam [25] [26] makes this difference clear: Vietnam's economy is still much more agriculturally driven (18.4%) compared to China (10.0%). The share of industry in total GDP in China is about 5 percentage points higher than in Vietnam (Table 3).

Vietnam's industry is more light-industry driven (food processing, garments, shoes, mobile phones etc.) [25], compared to China being the world leader in gross value of industrial output for many energy-intensive heavy industry products such as iron and steel, cement, aluminum etc. [26].

Table 2. Estimated coefficients and t-values of the per-capita GDP model with a lag of 11 years.

Variable	Coefficient estimates	t-Values
$\ln(GDP\_POP\_CH_{t-11})$	7.711098**	2002.489
C	0.688950**	132.1147

adj. R^2: 0.99; DW: 0.90, ** denotes significance at the 1% level.

Table 3. Sectoral structure of GDP in China and Vietnam (2013, in %).

Sector	China	Vietnam
Agriculture	10.0%	18.4%
Industry	43.9%	38.3%
Services	46.1%	43.3%

Source: [25] [26].

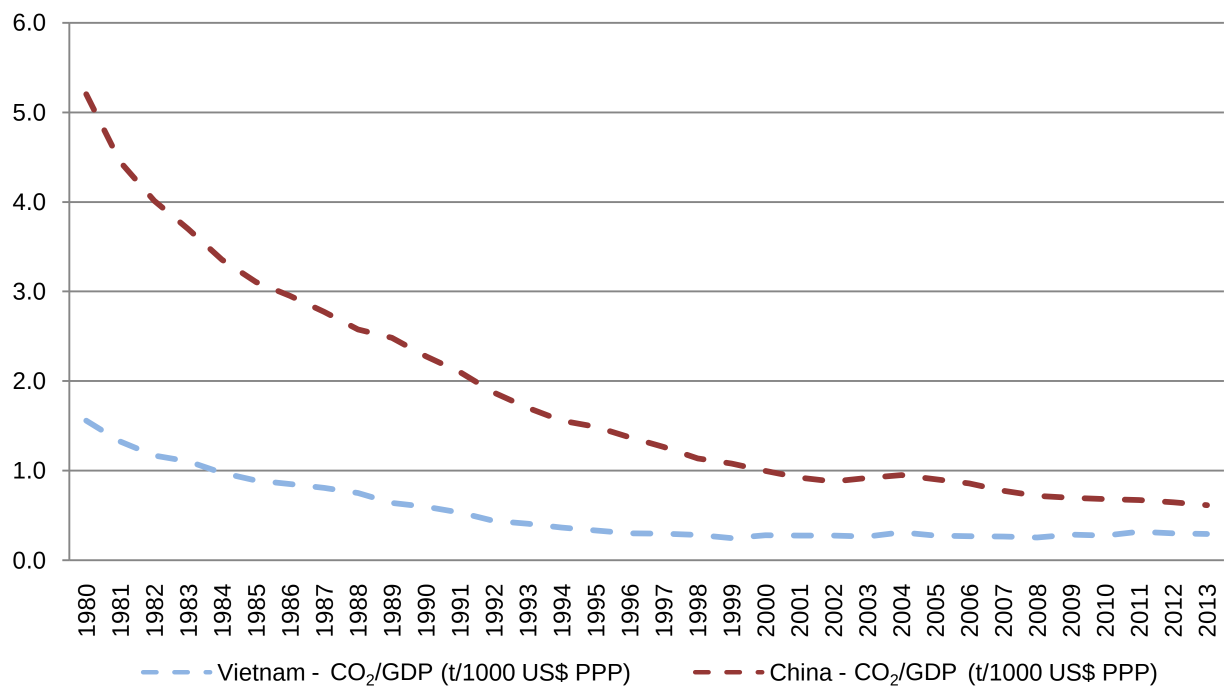

Figure 3. Comparison of CO_2-intensity of GDP in Vietnam and China (1980-2013, in t/1000 US$ PPP). Source: Own calculations based on data from [5] and [27].

To understand China's high CO_2-intensity of GDP compared to Vietnam does not only include to analyze energy intensity of GDP as discussed above, but also CO_2-intensity of primary energy supply (Figure 4). Based on China's rich coal reserves (second largest in the world after the US; BGR, 2013), China's primary energy mix is largely coal driven, in Vietnam carbon-intensive coal only plays a smaller role and zero-carbon intensive hydro energy is much more prominent than in China. Until the late 1980s, CO_2-intensity in Vietnam and China were similar, in both countries coal represented about 70% of total primary energy supply. Then, primary energy mix in Vietnam changed dramatically in favor of less carbon-intensive or zero carbon sources of energy.

Since 1989, Vietnam massively invested into hydro energy, especially in the mountainous northern part of the country. With increasing per-capita income, oil demand for transportation purposes grew. In 2013, in China carbon-intensive coal still took about 67% of primary energy supply. In Vietnam, coal nowadays only represents less than 30% of total primary supply. Vietnam uses much more hydro energy for power generation than China (Table 4).

In 2013, in Vietnam, the share of zero-carbon intensive hydro energy in total primary energy supply was 22.5%, much more compared to 7.2% in China. The share of oil and gas, which are less carbon intensive than coal, is also much higher in Vietnam (oil: 32.1%, gas: 16.1%) compared to China (oil: 18.2%, gas: 5.1%). The high share of gas in Vietnam is even more astonishing as it has only started to be used large scale since 2010.

Due to China's one-child-policy introduced in the late 1970s [25], between 1980 and 2013, average annual population growth (1.1%) was significantly lower

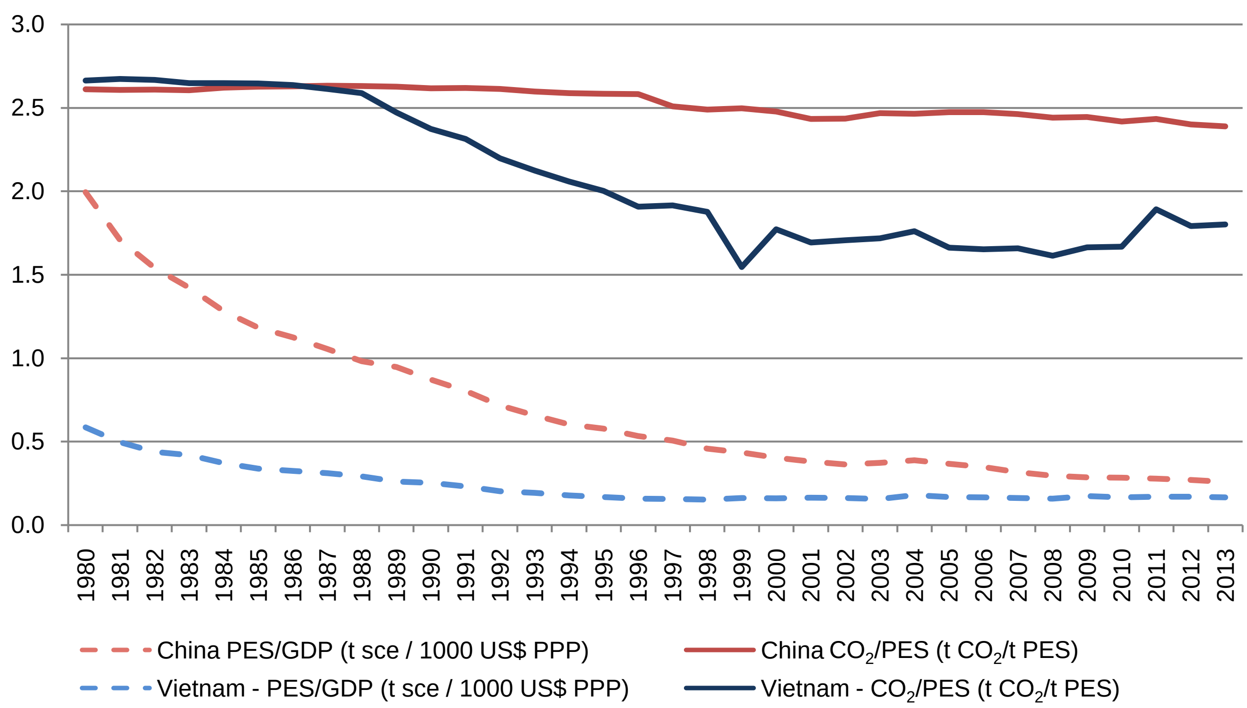

Figure 4. Comparison of energy intensity of GDP and CO_2-intensity of primary energy supply in Vietnam and China (1980-2013, in t sce/1000 US$ PPP and t CO_2/t PES). Source: Own calculations based on data from [5] [27].

Table 4. Structure of primary energy supply in Vietnam and China (2013, in Mtsce and %).

Primary energy source	Vietnam		China	
	Mtsce	%	Mtsce	%
Coal	22.7	29.2	2762	67.1
Oil	24.9	32.1	750	18.2
Gas	12.5	16.1	211	5.1
Nuclear	0.0	0.0	36	0.9
Hydro	17.5	22.5	295	7.2
Bio-fuels	0.0	0.0	2	0.1
Other renewables	0.0	0.1	61.3	1.5
Total	77.7	100.0	4117	100.0

Source: [27].

than in Vietnam (1.6%) during the same period of time. By the end of 2013, China had a population of 1.4 billion people, Vietnam had 91 million inhabitants [26] [28].

Translated into CO_2-emissions per capita, in 2013, Vietnam accounted for 1.5 t CO_2 per inhabitant, China (7.3 t) for over four times more (Figure 4). With 1.5 t, Vietnam is still far below world average per capita CO_2-emissions (2013: 5.0 t). By 2013, China, however, with a fast growing per capita income is already exceeding the per capita CO_2-emissions of South-European economies such as Portugal (5.0 t) and Spain (6.1 t) and is closing up to North-European economies such as Denmark (8.0 t), Finland (8.9 t) or Germany (2013: 10.9 t). However, China is still far away e.g. from the high per capita CO_2-emissions in the US (2013: 19.0 t) [27]. In Asia, e.g. Japan's per capita CO_2-emissions in 2013 were 11.2 t, South Korea emitted 16.0 t per inhabitant.

Figure 5 shows at a glance, where the upper limit for Vietnam would be following China's economic development role model in ecological terms. However, as Vietnam's CO_2-intensity of primary energy supply is significantly lower than that of China, the ecological side-effects of quick economic growth in Vietnam would be less severe. To assess these effects more in detail, based on the econometric model presented above, in the following section, a forecast of Vietnam's GDP, CO_2-intensity and CO_2-emissions following China's development path are made.

3. Forecast of Vietnam's GDP, Primary Energy Supply, CO_2-Emissions and CO_2-Intensities Following and Not Following China's Development Path

Forecasting Vietnam's GDP following China's development path until 2050, the estimated results of GDP per capita (Model 1) are multiplied with population (POP_VN_t). For China, a GDP growth rate of 7% p.a. is assumed for 2014-2020, 6% p.a. for 2021-2030, 5% p.a. for 2031-2040 and 4% p.a. for 2041-2050. This

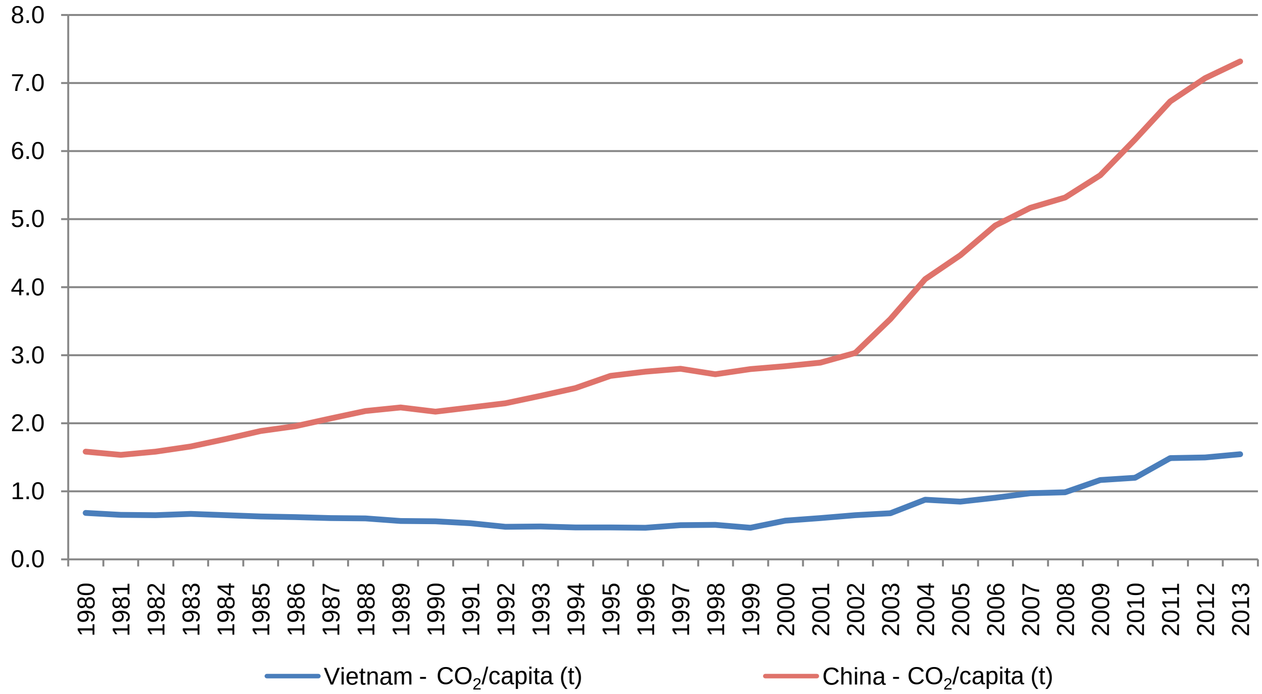

Figure 5. Comparison of per capita CO_2-emissions in Vietnam and China (1980-2013, in kg). Source: Own calculations based on data from [19] [27].

development is compared to a business-as-usual path in Vietnam with an autonomous GDP growth without following China's development patterns. To represent this autonomous growth path of GDP, the following model of Vietnam's GDP is applied (Equation (2)):

$$\ln\left(GDP\_VN\_NOT_t\right) = \alpha \cdot \ln\left(GDP\_VN\_NOT_{t-1}\right) + \beta \cdot \ln\left(INVEST\_VN_t\right) + \varepsilon_t. \quad (2)$$

$GDP\_VN\_NOT_t$ is Vietnam's GDP at a given time t, $INVEST\_VN_t$ is the share of investments in total GDP and ε_t is the error term. $GDP\_VN\_NOT_{t-1}$ represents the inertia in GDP development as based on long-term investment cycles, the macro-economic capital stock does not change completely from year to year [12]. The resulting GDP growth rate for Vietnam is 6.8% p.a. **Table 5** shows the estimated coefficients and t-values of the model.

The estimates of the logarithmic lagged GDP ($\ln(GDP\_VN\_NOT_{t-1})$) is significant at the 1% level, the logarithmic share of investments ($\ln(INVEST\_VN_t)$) is significant at the 5% level. All variables are stationary or integrated of order 0 [I (0)] on the 10% level.

Table 6 reveals the difference in GDP growth in Vietnam according to the scenarios of following (GDP_VN_t) or not following ($GDP\_VN\_NOT_t$) China's development path. Following China's development patterns, Vietnam's GDP would grow by 7.4% p.a. Following the autonomous GDP growth patterns, the annual increase of GDP in Vietnam is only half a percentage point lower (6.9%). Thus, the economic effects of following China's development patterns do not seem to have a major growth impact in Vietnam: Economic growth in Vietnam will be considerably high anyway.

Table 5. Estimated coefficients and t-values of the model of Vietnam's GDP not following China's development path.

Variable	Coefficient estimates	t-Values
$\ln(GDP\_VN\_NOT_{t-1})$	1.004888***	154.1402
$\ln(INVEST\_VN_t)$	0.020889**	2.093097

adj. R^2: 0.99; DW: 0.35, *** denotes significance at the 1% level, ** at the 5% level, respectively.

Table 6. Development of Vietnam's GDP following and not following China's development path (2015-2050, in bn. US$ PPP).

	2015	2020	2025	2030	2035	2040	2045	2050	Annual growth rate (%)
GDP_VN_t	616	1136	1784	2488	3361	4515	5852	7516	7, 4
$GDP\_VN\_NOT_t$	547	776	1091	1091	1525	2123	4083	5648	6, 9

Source: Own calculations based on data from [5].

Estimating and forecasting primary energy, based on the exogenous resp. retrieved GDP per capita paths (GDP_VN_t/POP_VN_t resp. $GDP\_VN\_NOT_t$, $/POP\_VN_t$), the lagged primary energy supply $PES\_VN\_(NOT)_{t-1}$, a linear technological trend T, Dummy variables DOIMOI, D104 and D108 for atypical impact factors in the years 2004 and 2008, a constant (C) and the error term ε_t, the following model is applied (Equation (3), resp. (3a)):

$$\ln(PES\_VN_t) = C + \alpha \cdot \ln(GDP\_VN_t/POP\_VN_t) + \beta \cdot \ln(PES\_VN_{t-1}) + \gamma \cdot \ln(T_t) + \delta \cdot D104_t + \varepsilon_t \quad (3)$$

$$\ln(PES\_VN\_NOT_t) = C + \alpha \cdot \ln(GDP\_VN\_NOT_t/POP\_VN_t) + \beta \cdot \ln(PES\_VN\_NOT_{t-1}) + \gamma \cdot \ln(T_t) + \delta \cdot D104_t + \varepsilon_t. \quad (3a)$$

Assessing the stationarity of the time series mentioned above reveals that PES_VN_t and $PES\_VN\_NOT_t$ are both integrated of the Order 1 I (1) on the 1% level. PES_VN_t/POP_VN_t, $PES\_VN\_NOT_t/POP\_VN_t$ and $CO_2\_VN\_NOT_t$ are all integrated of the Order 1 (I (1)) on the 5% level. Co-integration analysis shows that although the exogenous variables are non-stationary, the residuals of their linear combinations (Models 3, 3a and 4) are stationary. Thus, the model variables are co-integrated. Table 7 presents the estimated coefficients and t-values of energy demand model in Vietnam not following China's development path.

The coefficient estimates for GDP per capita, the lagged primary energy supply and the Dummy variable for the year 2004 are significant on the 1% level; the coefficient for the technological trend is significant on the 5% level. All variables are expressed as logarithmic values.

Vietnam's CO_2-emissions following China's development path ($CO_2\_VN_t$) are calculated by multiplying Vietnam's per-capita emissions ($CO_2\_POP\_VN_t$) with its population (POP_VN_t):

$$CO_2\_VN_t = CO_2\_POP\_VN_t \cdot POP\_VN_t. \quad (4)$$

Vietnam's per-capita emissions of CO_2 are estimated by the following logarithmic model (Equation (5)):

$$Ln\left(CO_2\_POP\_VN_t\right) = \alpha \cdot LOG\left(GDP\_VN/POP\_VN\right) + \beta \cdot DOIMOI + \varepsilon_t. \quad (5)$$

$GDP\_VN\_NOT_t/POP\_VN_t$ is GDP per capita following China's development path, $DOIMOI_t$ is a dummy variable being 0 for the years before the economic reforms in 1986 (Doimoi) and 1 taking into account potential increases of per capita income in the post-reform period. ε_t is the error term.

Table 8 presents the estimated coefficients and t-values of per-capita CO_2-emission model in Vietnam following China's development path.

The coefficient estimates for the logarithmic GDP per capita and the dummy variable are all significant on the 1% level. GDP per capita is integrated of the order 1 (I (1)) on the 1% level.

Vietnam's CO_2-emissions ($CO_2\_VN\_NOT_t$) are estimated and forecasted in the following logarithmic model (Equation (4)):

$$\ln\left(CO_2\_VN\_NOT_t\right) = C + \alpha \cdot \ln\left(GDP\_VN\_NOT_t/POP\_VN_t\right) + \beta \cdot DOIMOI_t + \varepsilon_t. \quad (6)$$

$GDP\_VN\_NOT_t/POP\_VN_t$ is GDP per capita not taking China's development path, $DOIMOI_t$ is a dummy variable being 0 for the years before the economic reforms in 1986 (Doimoi) and 1 taking into account potential increases of per capita income in the post-reform period. ε_t is the error term.

Table 9 gives an overview of the estimated coefficients and t-values of CO_2-emission model in Vietnam not following China's development path.

Table 7. Estimated coefficients and t-values of primary energy demand model in Vietnam following and not following China's development path.

Variable	Coefficient estimates	t-Values
$\ln(GDP\_VN\_(NOT)_t/POP\_VN_t)$	0.082394***	3.305562
$\ln(PES\_VN\_(NOT)_{t-1})$	0.938683***	3.305562
$Log(T_t)$	0.026446**	2.253827
$D104_t$	0.171312***	5.156001

adj. R^2: 0.99; DW: 2.31. *** denotes significance at the 1% level, ** significance on the 5% level and * significance on the 10% level respectively.

Table 8. Estimated coefficients and t-values of the per-capita CO_2-emission model in Vietnam following China's development path.

Variable	Coefficient estimates	t-Values
LOG(GDP_VN/POP_VN)	0.538914***	8.802027
DOIMOI	−0.719350***	−12.29030

adj. R^2: 0.82; DW: 0.35. *** denotes significance at the 1% level.

The coefficient estimates for the logarithmic GDP per capita, the dummy variable DOIMOI and the constant are all significant on the 1% level. All variables are integrated of the order 1 (I (1)) on the 1% level.

Primary energy supply and CO_2-emissions in China are modelled in a similar way employing the following logarithmic functions:

$$\ln\left(PES\_CH_t\right) = C + \alpha \cdot \ln\left(GDP\_CH_t\right) + \beta \cdot \ln\left(POP\_CH_t\right) + \gamma \cdot \ln\left(TEMPA\_CH_t\right) + \delta \cdot D100_t + \zeta \cdot D113_t + \varepsilon_t \quad (7)$$

$$\ln\left(CO_2\_CH_t\right) = \alpha \cdot \ln\left(GDP\_CH_t / POP\_VN_t\right) + \beta \cdot \ln(CO_2\_CH_t(-1)) + \gamma \ln\left(TEMPA\_CH_t\right) + \delta \cdot D100_t + \zeta \cdot D101_t + \varepsilon_t . \quad (8)$$

PES_CH_t is the primary energy supply in China at a given time t, C is a constant, GDP_CH_t the Chinese GDP in purchasing power parities, POP_CH_t the population, $TEMPA\_CH_t$ are representing temperature anomalies in China in a given year compared to the average of 1970-1999 as calculated in the UNDP Climate Change Country Profiles [29] [30] [31]; $D100_t$, and $D101_t$ are dummy variables for special single impacts in the years 2000 and 2001, ε_t is the error term. All variables are integrated of the order 1 (I (1)) on the 5% level, expect $TEMPA\_CH_t$ being I (1) on the 1% level. Table 10 shows the coefficients and t-values of primary energy demand model in China.

The coefficient estimates for GDP per capita ($\ln(GDP\_CH_t/POP\_CH_t)$) and the constant (C) are all significant on the 1%, the coefficient estimates for the temperature anomaly (TEMP_CH) is significant on the 10% level, the coefficients of

Table 9. Estimated coefficients and t-values of the CO_2-emission model in Vietnam not following China's development path.

Variable	Coefficient estimates	t−Values
C	4.004558***	45.25037
$\ln(GDP\_VN\_NOT_t/POP\_VN_t)$	0.681714***	11.20636
$DOIMOI_t$	−0.476986***	−4.062471

adj. R^2: 0.82; DW: 0.35. *** denotes significance at the 1% level.

Table 10. Estimated coefficients and t-values of primary energy demand model for China.

Variable	Coefficient estimates	t-Values
$\ln (GDP\_CH_t/POP\_CH_t)$	0.559628***	33.45186
$TEMPA\_CH_t$	−0.057354*	−1.726528
$D100_t$	−0.221263**	−2.603360
$D101_t$	−0.188529**	−2.380397
C	6.888359***	422.5090

adj. R^2: 0.99; DW: 0.46. *** denotes significance at the 1% level, ** significance on the 5% level, * significance on the 10% level.

the dummy variables D100 and D101 are significant on the 5% level. An increase of average temperature as signaled by the development of the temperature anomalies leads to a reduction of heating energy demand in China. The variables employed in the primary energy demand model (Model 7) are co-integrated as the residual of the co-integration function is stationary.

Table 11 presents the estimated coefficients and t-values of CO_2-emission model in Vietnam not following China's development path.

The coefficient estimates for the GDP per capita in China (GDP_CH_t/POP_CH_t), the lagged CO_2-emissions ($CO_2\_CH_{t-1}$) and the dummy variable for the year 2000 ($D100_t$) are significant on the 1% level, the coefficients for the temperature anomaly ($TEMPA\_CH_t$) and the dummy variable for 2001($D101_t$) are significant at the 5% level. The linear combination of the variables employed in the CO_2-emission model (Model 6) is co-integrated as the residual of the co-integration function is stationary.

Using the Models 1 - 6 to forecast GDP per capita, primary energy supply, CO_2-emissions, CO_2-emissions per capita and per GDP as well as CO_2-intensity of primary energy supply in Vietnam and China, Table 12 shows that the additional economic impact in Vietnam of following China's development path is minor (only 0.5 percentage points p.a.), the positive environmental impacts of not following this development path and sticking to the own Vietnamese development strategy, however, much larger.

Econometric analysis indicates that CO_2-emissions (−2.3 percentage points), CO_2-emissions per capita (−2.3 percentage points), CO_2-emissions per GDP (−0.2 percentage points) and CO_2-intensity of primary energy supply (−1.6 percentage points) are considerably lower, if Vietnam does not follow China's development path. In 2050, CO_2-emissions per GDP would even be lower than 2015.

Based on these results, Vietnam is able to choose for a considerable environmental advantage of saving about 2.6 billion t of CO_2 in 2050 compared to following China's development path, but to the cost of about 19,000 US$ PPP or a 25% lower per capita income compared to a China-like economic growth (72,298 US$ PPP). Finally to decide which path to pursue is the task of the Vietnamese people and government.

Table 11. Estimated coefficients and t-values of the CO_2-emission model for China.

Variable	Coefficient estimates	t-Values
$\ln(GDP\_CH_t/POP\_CH_t)$	0.124254***	3.054925
$\ln(CO_2\_CH_{t-1})$	0.801008***	10.33984
$TEMPA\_CH_t$	−0.036435**	−2.485593
$D100_t$	−0.101756***	−2.596669
$D101_t$	−0.079399**	−2.145220
C	1.600703***	2.657431

adj. R^2: 0.99; DW: 1.15. *** denotes significance at the 1% level, ** at the 5% level respectively.

Table 12. Development of selected macro-economic variables in Vietnam following and not following China's development path (2015-2050).

	2015	2020	2025	2030	2035	2040	2045	2050	Annual growth rate (%)
					Following China's development path				
Population (Mill.)	616	1136	1784	2488	3361	4515	5852	7516	7.4
GDP per capita (US$ PPP)	92	96	99	101	103	104	104	104	0.3
Primary energy supply (Mtsce)	6662	11,785	17,963	24,518	32,620	43,391	56,057	72,298	7.0
CO_2-emissions (Mt)	105	211	343	485	661	894	1175	1532	8.0
CO_2-emissions per capita (t)	207	463	790	1148	1601	2212	2927	3826	8.7
CO_2-emissions per GDP (t/1000 US$ PPP)	2.2	4.8	8.0	11.3	15.5	21.3	28.0	36.8	8.3
CO_2-intensity of primary energy supply (t CO_2/t PES)	2.0	2.2	2.3	2.4	2.4	2.5	2.5	2.5	0.7
					Not following China's development path				
Population (Mill.)	547	776	1091	1525	2123	2947	4083	5648	6.9
GDP per capita (US$ PPP)	92	96	99	101	103	104	104	104	0.3
Primary energy supply (Mtsce)	5922	8052	10,981	15,025	20,603	28,324	39,108	54,326	6.5
CO_2-emissions (Mt)	91	132	191	274	391	556	789	1120	7.4
CO_2-emissions per capita (t)	143	191	258	351	479	655	902	1250	6.4
CO_2-emissions per GDP (t/1000 US$ PPP)	1.5	2.0	2.6	3.5	4.6	6.3	8.6	12.0	6.0
CO_2-intensity of primary energy supply (t CO_2/t PES)	1.6	1.4	1.4	1.3	1.2	1.2	1.1	1.1	−0.9

Source: Own calculations based on data from [5] [19] [27].

4. Summary

Vietnam and China are emerging economies in Asia with a tremendous economic growth and subsequent increase of economic welfare in terms of GDP per capita. Between 1980 and 2013, in China, GDP per capita grew by 11.8% p.a., in Vietnam more slowly by 7.8% p.a. Observing this development, the question arises, what if Vietnam followed China's development path? Regressing Vietnam's GDP per capita on China's GDP per capita for different time lags shows that Vietnam is lagging behind China for 11 years. Hence, following China's development path would mean that Vietnam in the next year would have the same growth patterns of GDP per capita as China had 11 years ago. Although the two time series of GDP per capita in Vietnam and China both are non-stationary, the linear combination of the time series in the GDP per capita model is co-integrated. Hence, OLS estimators can be used without producing spurious results.

Comparing CO_2-intensity of GDP in Vietnam and China shows that China's CO_2-intensity is higher than Vietnam's due to a higher share of (carbon-intensive) industry such as iron and steel, cement or aluminum. However, China realizes considerable gains in energy efficiency so that the intensities in China and Vietnam are converging. The comparatively high CO_2-intensity of GDP in China, however, is also due to its high share of coal in primary energy supply. In China, the share of coal is still about 70%, in Vietnam only about 30%. Since the late

1980s, Vietnam developed zero carbon hydro power on large scale to produce clean electricity. Due to China's one-child-policy since the late 1970s, between 1980 and 2013, population in China only grew by 1.1% p.a. In Vietnam, annual population growth during the same period of time was 1.6%. Together with the quick growth of CO_2-emissions, high CO_2-intensity of primary energy supply and a slower population growth, China's CO_2-emissions per capita (7.1 t) were considerably higher than those of Vietnam (1.5 t). Vietnam is still well below world average (5.0 t), China already surpasses e.g. those of South-European economies such as Portugal and Spain and is already about to catch up with North-European economies such as Denmark, Finland or even Germany.

Forecasting Vietnam's GDP, CO_2-emissions and CO_2-intensities following China's development path and comparing the results with an autonomous growth path not following China's development path, GDP, primary energy supply and CO_2-emissions in Vietnam are modeled econometrically. Co-integration analysis revealed a stable long-term economic relation between the variables in the models. Hence, here as well, no spurious regressions result. The comparison of the two scenarios shows that following China's economic development path would imply an additional growth in Vietnam of 0.5% p.a. This means, Vietnam's economy would grow considerably anyway. However, pursuing Vietnam's current development path would result in much lower CO_2-emissions (−2.3 percentage points per annum). By 2050, Vietnam's CO_2-emissions could be 2.6 bnt lower, if the country did not follow China's way. GDP per capita, however, in 2050 would be about 18,000 US$ or about 25% lower than that if Vietnam would follow China's development path. Here, the population and government of Vietnam have to make a strategic choice.

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