A Very Long Term Forecast for the development of the Cargo Flows in the le-Havre – Hamburg range

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Abstract

The development of the Dutch ports and waterways has historically gone hand in hand since the waterways have always provided a primary access route to the Hinterland. Any vision on the development of the Dutch waterway system will therefore require a vision on the developments of the ports in the region and vice versa.

The Dutch waterway system contains hundreds of hydraulic structures such as storm surge barriers, sluices, ship locks, and bridges. The projected lifetime of these structures is generally about 100 years and the total replacement costs are estimated at about 15 billion Euros. Rijkswaterstaat, the responsible waterway authority, now desires to develop a replacement strategy that takes the possible developments over the lifetime of the infrastructure into account in their asset management process.

In March 2009 a project commenced to, amongst others, develop a model that provides insight in the possible developments of (and on) the main waterway network in the Netherlands up to the year 2100. On the basis of this model a methodology will be developed for the evaluation of various replacement strategies.

Insight in the future use of the inland waterways depends on the development of continental and port related cargo flows as well as on the competitiveness of river barge transportation versus other modes of transport. The port related import/export flows can be based on a very long term forecast for the Le-Havre – Hamburg range in combination with some assumptions on the market share of the various ports within this range.

This paper discusses the challenging task of providing a very long term forecast for the Le-Havre – Hamburg Range. The methodology and preliminary results discussed will indicate the possibility to develop a very long term forecast up to 2100.

Keywords*:* Long Term, Probabilistic Forecast, Port Throughput, Le-Havre-Hamburg Range.

1. Introduction

1.1 Background of the Project

The Dutch waterway system contains hundreds of hydraulic structures such as storm surge barriers, sluices, ship locks, and bridges. The projected lifetime of these structures is generally about 100 years and the total replacement costs are estimated at about 15 billion Euros. One-by-one substitution will result in, metaphorically speaking: *"replacing all parts of an old car, and delivering a good as new old timer"* (Heijer et al., 2010). Clearly it makes no sense to provide a 21st century waterway network on the basis one hundred year old specifications. The world has changed and will be changing. Transport demand will further increase, climate change will have an effect on the height and fluctuation of the water levels, and new vessel types may enter the waterways. In order to meet future challenges Rijkswaterstaat now desires to develop a very long term substitution strategy. In March 2009 a project commenced to, amongst others, develop a model that provides insight in the possible developments of (and on) the main waterway network up to the year 2100. Such a model requires insight in the potential development of barge transportation, a subject closely related to the development of the main cargo flows in the Dutch and Belgium seaports.

1.2 Relevance of seaports for inland water transport

The development of the ports and waterways has historically gone hand in hand since the waterways have always provided a primary access route to the European Hinterland. The importance of the main West-European ports for the European inland waterway transport sector can be evaluated by comparing port statistics with EU statistics. In 2006 and 2007 the total volumes transported on the inland waterways were respectively 503 and 515 million tonnes (De La Fuente Layos, 2007 and 2009). The total volume of cargo loaded and unloaded in barges in the ports of Rotterdam, Amsterdam and Antwerp have been compared to the total transport volumes in the EU. The findings are listed in Table 1.

Port Data	**Loaded on Barges**		**Unloaded from Barges**	
	million tonnes	**% of IWT in EU**	**million tonnes**	**% of IWT in EU**
Rotterdam (2007)	133.0	25.8%	55.4	10.8%
Amsterdam (2006)	37.8	7.5%	21.6	4.3%
Antwerp (2007)	49.4	9.6%	39.9	7.7%
Total		42.9%		22.8%

Source: Eurostat bulletin 132/2007 and 27/2009; Port of Rotterdam Website (2010); Port of Amsterdam Website; Port of Antwerp Statistical Yearbook 2008.
Note: IWT stands for Inland Water Transport.

Table 1. Barge loading/unloading in main ports compared to EU inland water transport

From the table it can be expected that over 50% of all inland water transport in the EU is port related (listed ports indicate at least 43-66% market share[1]). Therefore a vision on the development of the inland waterway system should take the development of port throughput volumes into account. This paper discusses the challenging task of providing a very long term forecast for the Port Throughput in the Le-Havre – Hamburg range[2] up to the year 2100.

[1] Exact figures can not be given without knowing the amount of the cargo volumes shipped between the ports.
[2] The Le-Havre – Hamburg range contains the West European ports located between Le-Havre and Hamburg.

1.3 Research questions

Normally a long term port forecasts looks 20 to 30 years ahead. Providing a 90 year forecast is a different league. To develop a very long term forecast for the port throughput volumes in the Le-Havre – Hamburg range the following research questions have been defined:

1. What techniques are common in port forecasting and to what extend are these techniques suitable for the very long term?

2. What techniques are common in very long term forecasting and how suitable are these techniques for forecasting port throughput volumes?

3. What would be a sensible approach for the development of a very long term forecast of the port throughput volumes in the Le-Havre – Hamburg range up to 2100?

4. Is there sufficient historical data available to develop such a very long term forecast?

5. Is it possible to identify a causal relationship that can be used to develop a sound forecast or at least a reasonable estimate of the order of magnitude?

6. Does the forecast methodology require input from other forecasts (such as a GDP forecast) and how can this input data be obtained?

7. What is the expected development of the port throughput in the le-Havre – Hamburg range up to the year 2100?

The answers to each of these questions will be discussed in the various sections of this paper. A summary of the conclusions is provided in the last section.

1.4 Outline of the paper

The aim of this paper is to discuss the questions listed above. Section 2 discusses the available techniques applied in the fields of port forecasting (Q1) and very long term forecasting (Q2). Finally section 2 will conclude with a discussion of the methodology applied in this paper (Q3). As will be concluded later in this paper there is a long term relation between GDP and Port Throughput. Section 3 discusses the availability of historic data required to understand this very long term relationship (Q4). The functional shape of the forecast relation is not clear from forecasting literature. For this reason section 4 discusses a number of different causal relationships between GDP and Port Throughput. For each of these causal relationships the challenges with the statistical (or econometric) and theoretical soundness of the forecast relation will be discussed. Finally it will be indicated if a sound forecast can be developed (Q5). The evaluated causal relations require a probabilistic very long term GDP forecast as input. Section 5 discusses how the probabilistic very long term GDP forecast has been obtained (Q6). Section 6 uses the GDP forecast and causal relation to develop a very long term forecast of the Port Throughput in the le-Havre – Hamburg range up to 2100 (Q7). A summary of the conclusions is provided in section 7.

2. Forecasting Methodology

How to provide a 90 year forecast for the le-Havre – Hamburg range? In an attempt to answer this question a benchmark study on forecasting literature and articles related forecasting has been carried out. Section 2.1 discusses common practice and available literature on port forecasting, section 2.2 indicates the availability literature on very long term forecasting techniques, and Section 2.3 concludes with the methodology applied in this paper.

2.1 Review of Port Throughput Forecasting Methodology

On the basis of a library search and various discussions with experts in the field of port economics, econometrics and forecasting it had to be concluded that most likely there does not exist a handbook on port throughput forecasting. Port throughput forecasting is generally applied by port authorities and specialised consultants. In practice forecasts are, to our best knowledge, usually based on causal relationships between port throughput volumes and demographic, economic, or industrial developments. There is sufficient support for the use of causal relationships. Economic textbooks indicate the existence of a relationship between economic activity (measured in GDP) and freight transport (measured in tonnes or tonne kilometres). For example Meersman and van de Voorde (2008, p. 67-92) recently discussed the relation between economic activity and internal transport within the European Union.

A review of port throughput forecasting articles has revealed that the subject has not received much attention. A search on Scopus and Google Scholar provided seven relevant articles of which full text documents were accessible[3]. Quite interesting is to observe that most of these articles do not relate to the causal models applied in practice. Instead they refer to methods that are somehow based on mere trend extrapolation of historic data such as *autoregressive integrated moving average models* (Klein, 1996), *vector autoregressive models* (Veenstra and Haralanbides, 2001), *grey models* (Guo, Song and Ye, 2005), and *neural networks* (Weiqun and Nuo, 2003; Li, Chen and Cui, 2008; S.H. Chen and J.N. Chen, 2010). By definition models based on mere trend extrapolation are not suitable for very long term predictions. The same is also likely to hold for models based on a combination of autoregressive and causal relationships such as the *vector error correction model* applied by Fung (2001).

Hui, Seabroke and Wong (2004, p.196) discuss that the *"classical regression"* (as usually applied in many practical forecast studies) identifies causal relationships by measuring the co-movement between variables. They warn that this approach *"… is only valid if the data used are stationary and not displaying any trend over time. When the classical model is used to estimate relationships of, say, certain economic variables which show distinct upward trends, the strength of the relationship is likely to be inflated. This is because for trending variables, even if they are completely independent, they often move in the same direction under the common trend, creating an illusion of causal relationships. Spurious regression refers to instances where unrelated variables are estimated to hold a causal relationship, which can happen when the regression is fitted with trending time series"*. They also discuss that a common approach to avoid problems with spurious regression is the use of a first-

[3] Most of the research on port throughput forecasting is recently published by Asian universities. Not all of these documents are accessible from the Delft University Library. There were for example some articles published in the *Journal of Wuhan University of Technology* and *Journal of Shanghai Jiaotong University* which have not been included in this study.

differences model. Such a model for example relates the annual change of GDP to the annual change of the Port Throughput. However, *"a first-differenced model considers only short-run adjustments which relate how changes in one variable correlate with changes in another. It neglects the underlying long-run relationship linked by the levels or the original (nondifferenced) values of the variables"*. Under certain conditions the regression of two non-stationary series does not result in spurious regression. If this is the case the error term of the regression is stationary and the variables are referred to as co-integrated. For co-integrated series an alternative model approach can be applied which is referred to as the error correction model (ECM). The error correction model combines the advantages of the long term levels approach and the short term differences approach. Suppose that the long term model is defined as:

- $Y_t = \alpha + \beta X_t + e_t$ (Long-Term Model)

Then the corresponding error correction model can be defined as:

- $\Delta Y_t = \alpha' + \beta' \Delta X_t + \lambda e_{t-1} + u_t$ (Error Correction Model)

The error correction model is developed by a two step approach. The first step consists of regression of the parameters of the long-term model and estimation of the error terms. In the second step the error correction model is developed. By adding the error term to the equation of the short-term differences model the obtained error correction model is forced to follow the long-term trend. Important is that this approach is only valid if the variables in the long term equation are co-integrated. In other words, if a true relationship between these variables exists. In the case of the forecast discussed by Hui, et al. (2004, p.197) this was not the case, but they managed to "make" the forecast co-integrated by taking the natural logarithms.

2.2 Review of Very Long Term Forecasting Methodology

An evaluation of ten mainstream forecasting textbooks with a general or wide coverage[4] has revealed that the subject of (very) long term forecasting has, despite its importance, received almost no attention in textbooks. Makridakis et al. (1998) is the only author writing a full chapter on the subject. In this chapter reference is made to the construction of scenarios and the use of analogies. However, *"Scenarios are not predictions. It is simply not possible to predict with certainty"* (Schwartz, 1996, p.6). Armstrong (2001, p. 516) discusses the use of scenarios to gain acceptance for forecasts, but warns not to use scenarios to make forecasts as they are likely to be wrong and convincing at the same time. A review of articles published in the *'Journal of Forecasting'* and *'International Journal of Forecasting'* has also indicated that hardly anything has been written on the subject[5]. This has been confirmed by Fildes (1986, p.4; and 2006, p.420) who concluded twice that hardly anything has been published on the subject of (very) long term forecasting.

The fact that hardly anything is written on very long term forecasting is probably related to the fact that it will be inevitable to bring insight into the forecast and move beyond mere

[4] Evaluated textbooks included: Armstrong, J.S., ed. (2001), Bails et al. (1993), Bowerman et al. (2005), DeLurgio S.A. (1997), Diebold (2004), Hanke et al. (2008), Levenbach et al. (2005), Makridakis et al. (1998), Mentzer et al. (1998), and Wilson et al. (2009).

[5] Except for a special section on: "Global Income Growth in the 21st Century: Determinants and Forecasts" in the International Journal of Forecasting (Vol. 23, issue 4, 2007).

trend extrapolations. The *"Strategic Foresight Group"* defines *foresight* as *"forecasting with insight"* (www.strategicforesight.com, 2009). To bring insight into the forecast use can be made of a less common subfield of forecasting referred to as Bayesian forecasting[6]. In Bayesian forecasting probabilistic forecasts are developed on the basis of system dynamic models and Bayesian statistics. M. West and J. Harrison (1999, p.20) indicate that *"Bayesian statistics is founded on the fundamental premise that all uncertainties should be presented and measured by probabilities"*. As a result Bayesian forecasting requires a priori statements on the mean and uncertainty of all the parameters applied in the model. The benefit of this approach is that it clearly indicates the uncertainty levels in the forecast. Bayesian techniques have been successfully applied to develop probabilistic very long term population forecasts and are suitable for the preparation of probabilistic GDP forecasts. Bayesian methodology has been adopted in this paper for the development of a probabilistic forecast of the port throughput volumes.

2.3 Methodology applied for the 90 year Forecast up to 2100

Port throughput forecasting and *very long term forecasting* methodology have not received much attention in literature and no article has been found that refers to a combination of both issues. Nevertheless current practice and available literature points in the direction of causal relations and leading indicators. Therefore the following approach has been applied:

1. Define the very long term causal relation between Port Throughput and GDP,
2. Obtain a very long term probabilistic forecast for the GDP of the Hinterland,
3. Estimate the Port Throughput on the basis of the GDP forecast and causal relation.

The first step is complicated by the fact that the reviewed literature does not indicate the type of relationship that should be applied. For this reason a number of options has been evaluated to define a reasonable forecast relation. The second step is complicated by the fact that no probabilistic GDP forecast of the Hinterland is available. A first simplification can be made by assuming that the GDP of the countries in the combined Hinterland (defined as the Netherlands, Belgium, Germany, and France) move along quite similar. This allows the Dutch GDP to be used as an estimator for the GDP of the combined Hinterland. However, no probabilistic GDP forecast was available for the Netherlands either. The forecast has therefore been developed by multiplying the following variables:

- The population in the working age class of 20-65 years old;
- The labour participation fraction of the working class of 20-65 years old;
- The annual number of hours worked per employee;
- The development of the GDP output per employee per hour.

The required very long term probabilistic forecast of the Dutch population was also not available and has been obtained by combining various sources. For the other variables assumptions have been made on the type, mean and variance of distribution function. The final step is straight forward but requires advanced statistical methods to perform the calculations. For this purpose use has been made of the Excel Add-on @Risk.

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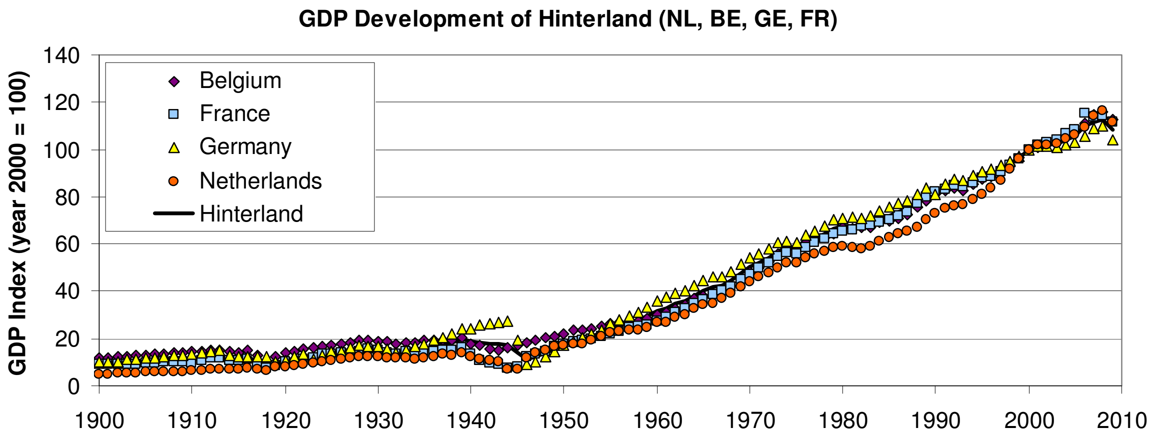
[6] Bayesian forecasting refers to the use of statistical methods in forecasting. It has been named after Bayes' theorem of conditional probabilities. This field has been almost completely ignored by mainstream textbooks. Journals pay somewhat more attention to the subject. A special issue on "Bayesian Forecasting in Economics" was recently published in the International Journal of Forecasting (Vol. 26, issue 2, 2010).

3. Historic GDP and Port Throughput Data

In order to evaluate the existence of a long term causal relation between GDP and Port Throughput a long data range is required. This section discusses the available long term GDP and Port Throughput data series applied in this study.

3.1 GDP development for the Hinterland of the Le-Havre – Hamburg port region

The Le-Havre – Hamburg range does not serve a distinct number of countries exclusively. The actual boundaries of the region are vague and contain overlap with other port regions. For the purpose of this paper a pragmatic approach has been obtained in which the Hinterland is defined as The Netherlands, Belgium, Germany and France[7]. This simplification is acceptable because integrated economic regions tend to move simultaneously – and we are not interested in the actual throughput of the ports per unit of GDP, but in the way that GDP and Port Throughput move along together. To allow for comparison between countries the GDP of the Hinterland has been measured as an index of the year 2000. Figure 1 shows the historic development of the GDP in the assumed Hinterland.



Source: GDP Index derived from Real GDP data provided by Maddison (2010)

Figure 1. Historic development of GDP in the Hinterland of the Le-Havre – Hamburg range

From the figure it can be observed that the GDP of the selected Hinterland areas follows a similar trend. Growth has generally been quite stable though a trend breach can be observed at the instance of the Second World War.

3.2 Port Throughput data for the Le-Havre – Hamburg range

The Le-Havre – Hamburg range includes many ports of various sizes. The Rotterdam Port Authority includes the ports of Le-Havre, Dunkirk, Zeebrugge, Antwerp, Gent, Zeeland

[7] Luxembourg has not been included due to its small size and unavailability of sufficient long data series.

Seaports, Rotterdam, Amsterdam, Wilhelmshaven, Bremen, and Hamburg in their statistics but provides only a few years of data on their website (www.portofrotterdam.com; 2010). Long data series from 1936 onwards (excluding 1939-1947) have been obtained from the Antwerp Port Authority for the ports of Le-Havre, Dunkirk, Antwerp, Gent, Rotterdam, Amsterdam, Hamburg and Bremen (refer Table 2).

Year	Le-Havre		Antwerp		Dunkirk		Gent		Rotterdam		Amsterdam		Hamburg		Bremen	
	In	Out	In	Out	In	Out	In	Out	In	Out	In	Out	In	Out	In	Out
1936	4,831	1,179	12,426	12,771	2,745	1,854	2,295	1,132	18,016	15,208	3,125	1,876	14,535	6,848	2,647	4,140
1937	5,076	1,260	14,274	14,094	3,279	1,573	2,897	1,125	22,440	19,913	3,521	2,338	16,246	8,184	3,328	4,754
1938	5,182	1,507	11,873	11,706	2,837	1,407	2,287	1,045	24,504	17,867	3,485	2,170	18,047	7,238	4,028	4,971
1948	7,076	1,811	13,810	7,261	1,648	955	2,227	513	10,223	5,537	3,021	1,357	5,891	1,911	5,044	1,123
1949	7,850	2,345	11,382	8,577	2,111	1,873	1,592	429	12,557	8,186	3,206	1,819	7,117	2,343	4,987	1,614
1950	7,136	2,770	10,662	10,846	2,063	2,850	1,332	895	17,415	12,272	3,194	2,039	7,418	3,420	2,883	3,101
1951	9,357	3,705	15,280	14,080	2,840	2,536	1,601	999	25,787	11,094	3,853	2,460	9,889	4,158	4,622	3,510
1952	10,061	3,260	15,740	11,890	3,809	2,452	1,572	936	28,092	11,690	3,786	2,401	10,849	4,319	5,765	3,966
1953	9,852	2,738	14,417	13,767	3,472	2,218	1,402	915	27,474	13,539	3,834	2,459	11,142	5,322	5,134	4,750
1954	10,071	2,593	15,311	13,094	3,649	2,705	1,361	1,020	32,003	16,756	4,371	2,637	13,960	6,697	5,121	4,696
1955	11,025	2,385	17,519	14,822	3,629	3,512	1,856	1,415	45,287	20,928	4,794	2,965	16,569	7,419	7,085	4,937
1956	13,395	2,683	22,480	15,491	4,961	2,525	2,616	986	53,043	19,181	6,572	3,134	19,862	7,656	8,272	5,478
1957	13,294	2,397	21,937	14,724	5,207	2,127	2,528	943	55,196	18,918	8,026	3,108	20,127	6,507	9,311	5,566
1958	13,602	2,528	20,880	14,652	5,125	2,656	2,161	983	54,393	19,451	8,611	2,693	20,087	7,324	7,812	5,513
1959	13,740	2,522	20,326	15,305	4,317	2,527	1,865	1,012	51,190	19,503	6,982	2,967	21,466	7,694	7,939	6,124
1960	14,139	2,488	21,981	15,543	4,884	3,134	2,128	855	61,552	21,853	7,789	3,039	22,976	7,789	8,917	6,221
1961	16,455	3,620	23,347	15,425	4,984	3,339	2,166	730	67,025	23,115	8,257	2,988	22,257	7,624	8,609	6,263
1962	17,775	3,468	26,500	15,592	5,579	2,769	1,889	838	71,558	25,168	9,380	2,829	24,436	6,928	9,926	6,027
1963	20,952	4,184	33,382	15,416	8,746	3,140	1,939	800	79,004	24,277	11,728	2,766	25,903	7,503	9,478	5,897
1964	22,902	4,235	36,960	16,943	10,043	3,435	2,179	935	87,691	25,915	11,347	3,366	26,707	8,725	9,850	5,918
1965	24,123	3,914	40,340	19,051	11,717	4,171	1,811	1,343	95,126	27,581	10,431	3,446	26,727	8,550	11,626	5,868
1966	26,728	4,077	40,989	18,186	12,077	3,970	1,894	920	99,429	30,951	10,831	3,688	28,337	9,148	11,556	5,765
1967	32,392	5,118	42,199	20,205	12,934	3,586	1,633	891	106,011	35,363	10,587	3,675	26,298	9,132	11,098	6,292
1968	36,553	6,859	48,524	23,909	14,249	3,640	1,350	1,168	119,109	37,773	13,516	4,445	28,531	7,921	11,967	7,019
1969	42,199	8,692	49,394	23,950	17,065	3,711	4,564	4,067	137,766	44,881	14,579	5,325	30,392	10,511	13,715	6,881
1970	50,119	9,706	57,107	23,615	21,505	3,682	5,668	4,521	165,183	60,607	15,567	5,788	36,069	10,890	15,967	7,417
1971	51,061	10,564	48,537	24,974	21,287	4,161	7,396	2,984	169,759	62,961	17,179	6,956	35,090	10,213	15,688	7,021
1972	54,584	11,777	39,054	28,268	22,717	4,637	8,596	4,276	198,853	69,567	13,503	7,455	35,581	10,673	16,332	7,816
1973	68,866	20,164	41,896	30,402	26,878	4,505	9,840	5,010	224,503	85,236	14,352	7,058	37,154	12,696	17,208	8,165
1974	67,386	18,891	42,550	33,307	29,751	4,807	10,235	4,900	196,668	70,388	12,113	5,993	36,527	15,822	15,744	9,813
1975	57,574	16,307	32,722	27,762	24,521	5,366	8,960	5,387	199,872	73,252	11,902	6,454	34,240	13,941	13,504	7,526
1976	65,191	16,560	39,124	27,023	27,873	5,640	10,569	4,533	217,020	76,479	13,403	6,253	38,120	14,940	14,558	7,568
1977	62,789	17,209	37,283	32,748	26,976	5,797	11,142	3,593	210,197	71,721	12,501	5,242	38,788	14,786	13,169	8,680
1978	61,924	17,795	36,326	32,121	28,357	7,288	12,009	2,935	207,712	65,902	12,823	4,982	39,614	14,982	14,009	9,568
1979	69,311	18,803	40,558	31,717	32,680	8,080	14,145	3,552	227,296	73,239	14,131	6,265	46,758	15,892	16,291	10,177
1980	62,649	16,313	46,549	35,387	33,369	7,849	15,147	3,277	214,908	66,203	17,125	5,252	44,947	17,504	16,857	10,104
1981	*60,645	*15,822	43,724	36,036	29,725	7,904	15,723	3,595	191,243	59,775	15,471	5,637	39,234	17,482	*16,908	*10,626
1982	*58,640	*15,331	50,067	34,136	25,805	7,112	19,011	3,883	185,482	57,614	16,730	6,618	38,482	23,099	*16,959	*11,148
1983	*56,636	*14,840	46,469	33,853	23,350	6,811	18,943	5,037	178,876	53,842	17,083	6,277	29,935	20,696	*17,011	*11,670
1984	*54,632	*14,349	50,048	40,291	26,691	6,653	20,478	6,114	186,587	58,667	19,808	7,296	32,959	20,530	*17,062	*12,192
1985	*52,628	*13,859	48,122	38,124	25,074	7,093	19,769	6,904	*192,667	*59,671	20,669	6,943	38,380	21,155	17,113	12,714
1986	*50,623	*13,368	53,681	36,523	24,611	7,782	18,990	5,169	*198,746	*60,675	22,068	7,357	36,584	18,112	17,671	11,822
1987	*48,619	*12,877	53,047	38,054	23,969	8,395	19,410	4,845	*204,826	*61,679	20,560	9,029	37,482	19,245	18,027	11,955
1988	*46,615	*12,386	57,834	39,074	26,003	9,655	18,711	5,447	*210,906	*62,683	19,871	8,372	39,114	19,828	18,796	12,314
1989	*44,610	*11,895	56,927	38,474	28,573	10,568	17,604	5,443	*216,985	*63,687	19,906	8,802	36,630	20,952	19,774	12,683
1990	42,606	11,404	62,333	39,676	27,020	9,540	19,066	5,372	223,065	64,691	22,202	9,129	39,449	21,911	18,872	11,448
1991	44,470	13,484	60,654	40,692	30,336	10,401	20,525	4,930	227,730	64,048	22,788	9,629	42,795	22,738	19,515	11,836
1992	41,693	11,416	62,066	41,561	30,119	10,085	18,073	4,746	228,729	64,437	37,461	11,694	42,002	23,082	18,870	11,070
1993	42,372	12,545	57,639	44,217	29,450	11,377	17,346	4,688	219,999	64,209	36,981	11,809	42,147	23,703	17,173	11,177
1994	42,081	12,295	62,926	46,569	28,085	9,083	19,370	4,463	229,001	64,872	36,976	11,106	41,788	26,535	18,515	12,413
1995	42,068	11,714	65,112	42,962	30,202	9,178	18,332	3,250	230,656	63,647	39,465	10,803	44,530	27,594	19,140	12,053
1996	43,671	12,989	59,894	46,632	27,417	7,532	17,513	3,495	228,690	63,330	43,523	11,155	44,079	27,059	19,214	12,346
1997	46,109	14,044	63,066	48,829	29,202	7,345	19,299	3,677	242,159	66,477	45,399	11,111	48,320	28,367	20,802	13,191
1998	51,664	15,258	71,791	47,998	31,829	7,401	19,794	3,838	249,455	65,319	46,283	9,512	47,006	28,815	20,964	13,520
1999	49,204	15,219	66,150	49,504	30,335	7,951	18,925	4,980	234,328	69,064	44,929	10,796	49,165	31,838	21,031	14,992
2000	51,122	16,370	75,210	55,321	35,081	10,203	19,974	4,066	249,041	73,032	51,761	12,290	50,116	34,977	25,759	19,209
2001	52,023	16,978	74,227	55,823	32,922	11,528	19,673	3,784	247,550	67,905	54,440	13,943	55,710	36,651	26,030	20,104
2002	51,013	17,104	72,595	59,033	35,633	11,952	19,694	4,287	248,642	73,464	54,498	15,919	58,249	39,392	25,946	20,612
2003	53,010	18,483	77,596	65,278	36,395	13,693	18,926	4,612	255,434	72,365	50,363	15,099	63,508	42,775	27,148	21,825
2004	56,752	19,423	83,109	69,217	37,634	13,365	20,663	4,293	271,011	81,348	55,960	17,216	67,645	46,839	28,199	24,086
2005	55,659	19,364	87,077	72,977	38,401	15,036	17,723	4,499	281,317	88,916	56,682	18,174	72,931	52,812	28,418	25,924
2006	54,314	19,584	91,973	75,400	40,266	16,376	19,121	5,022	285,542	92,643	61,248	23,102	78,828	56,033	34,223	30,333
2007	57,427	20,901	99,829	83,068	41,076	16,016	20,146	4,956	299,449	107,363	63,417	24,423	82,461	57,920	36,265	32,947
2008	58,914	21,612	105,018	84,371	40,783	16,906	21,185	5,842	313,020	108,116	67,351	27,484	82,054	58,321	38,824	35,823
2009	54,297	19,396	81,600	76,206	30,232	14,617	15,795	4,991	273,252	113,616	60,487	26,191	62,226	48,155	32,450	30,586

Note: Figures in 1,000 tonnes; Figures indicated with * based on linear interpolation

Source: Port of Antwerp (1936-2007), Port of Rotterdam (2008, 2009)

Table 2. Historic development of cargo volumes in the Le-Havre – Hamburg range

The forecast presented in this paper refers to the eight ports listed in Table 2. For 2008 and 2009 these ports accounted for about 90% of the total throughput in the Le-Havre Hamburg range (based on statistics of Rotterdam Port Authority). The forecast therefore refers to about 90% of the total throughput in the range.

4. Defining the relation between GDP and Port Throughput

The relation between GDP and Port Throughput has been defined on the basis of regression analysis. Regression analysis of time series is not straight forward as the basic assumptions of the regression model are often violated. This section starts with a warning from econometrics and continues with the discussion of possible regression models. Finally a forecast approach will be suggested on the basis of the model properties and an ex-post evaluation.

4.1 A warning from econometrics

Regression of two time series, that follow and upward or downward trend, can result in a virtual correlation that in reality does not exist. Granger and Newbold (1974, p.111) provided a bold statement and warned for *"spurious"* (meaningless) regression as they wrote that: *"It is very common to see reported in applied econometric literature time series regression equations with an apparently high degree of fit, as measured by the coefficient of multiple correlation R^2 or the corrected coefficient $*R^2$, but with an extremely low value for the Durbin-Watson statistics. We find it very curious that whereas virtually every textbook on econometric methodology contains explicit warnings of the dangers of autocorrelated errors, this phenomenon crops up so frequently in well-respected applied work"*. The standard methodology for hypothesis testing and goodness of fit is only valid if the regression parameters are stationary, or in a special case where the time series are co-integrated (i.e. the error term is stationary). In practice many time series are non-stationary and referred to as following a random walk or containing a unit root. If a time series follows a random walk the effects of a temporary shock will not dissipate after several years, but instead remain. To avoid unnecessary misspecification and misinterpretation of the regression model it is important to test for stationarity of the error term.

Granger and Newbold mentioned the danger of (positive) autocorrelation in time series. Durbin-Watson[8] provided a test for autocorrelation of which the test statistics lie in the range of 0 to 4. A value of 2 indicates that there is no autocorrelation. High values indicate negative correlation. Low values indicate positive correlation. Low Durbin-Watson statistics are therefore a warning for non-stationary data series. A formal F-test for random walks is provided by Dickey-Fuller. A low F-value indicates a high probability of unit roots. For a sample size of 50 data points one can reject the hypothesis of a random walk at the 95% confidence level if the critical value is above 6.73 (and for 100 data points the critical value is 6.49). For larger samples the critical value will be lower. Apart from stationarity it also is important to test for normality of the error term. This because the standard theory[9] for the calculation of prediction intervals is only valid if the error term is normal distributed. Normality can be tested by using the Jarque-Bera (JB) statistics that follows a chi-square distribution with two degrees of freedom. If the JB- statistics are greater than 5.99 the null hypothesis of normality can be rejected at the 95% confidence level.

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[8] The description of the Durbin-Watson statistics, Dickey-Fuller tests, and Jarque-Bera statistics mentioned in this section is based on Pindyck and Rubinfeld (1998, p. 45-58, 164-166, 507-513).

[9] The standard theory for the calculation of prediction intervals states that the prediction interval can be calculated as: $\hat{y}_p \pm t_{a/2} \cdot s^2 \cdot [1 + 1/n + (x_p - x_{avg})^2 / \{\Sigma(x_i^2) - [(\Sigma (x_i)^2)/n]\}]$ with $\hat{y}_p$: the point estimate, 1-α: the confidence belt, $t_{a/2}$: the t-statistics for α based on t-n degrees of freedom, n: the number of points in the dataset, s: the standard deviation of the sample, x_p: the value of x for which $\hat{y}_p$ is calculated, x_{avg}: the average x value of the dataset, x_i: the individual x values of the i^{th} point in the dataset.

4.2 Defining the relationship between GDP and Port Throughput

In order to obtain a useful forecast relation between GDP and Port Throughput three simple linear relations have been considered (refer Equation 1 to 3).

- $PT_t = \alpha + \beta \cdot GDP_t + \varepsilon_t$ (Equation 1)
- $\ln(PT_t) = \alpha + \beta \cdot \ln(GDP_t) + \varepsilon_t$ (Equation 2)
- $\Delta PT_t = \alpha + \beta \cdot \Delta GDP_t + \varepsilon_t$ (Equation 3)

in which:

α	: Intercept value,
β	: Linear coefficient,
PT_t	: Port Throughput level in year t,
GDP_t	: GDP index level in year t,
ΔPT_t	: Difference in Port Throughput between year t and year t-1,
ΔGDP_t	: Difference in GDP index between year t and year t-1,
ε_t	: Error term in year t.

For each of these three functions a regression analysis has been applied (refer Figure 2-4). The coefficients and results of the statistical tests are indicated in Table 3.

GDP-Throughput Relation	Equation 1	Equation 2	Equation 3
Data			
- DF-test GDP/ln(GDP)/ΔGDP	1.85	49.93	10.05
- Unit Root**	Yes	No	No
- DF-test PT/ln(PT)/ΔPT	1.90	10.68	17.59
- Unit Root**	Yes	No	No
Function			
- F-test	1402*	2390*	65
- R^2	0.957*	0.974*	0.516
- Adjusted R^2	0.956*	0.974*	0.508
- Durbin-Watson Statistics	0.23	0.25	2.06
Intercept α	-39.92	1.28	-17.46
- t-Stat	-2.52*	13.11*	- 3.55
Linear Coefficient β	8.76	1.19	20.76
- t-Stat	37.44*	48.88*	8.06
Error Term ε			
- DF-test on Error Term	1.79	2.82	32.16
- Unit Root**	Yes	Yes	No
- JB-Statistics	7.89	5.20	0.28
- Normal Distributed**	No	Yes	Yes

Note (*): meaningless value due to non-stationarity of error series,
Note (**): the value "Yes" for unit roots in (or normality of) the error term implies that the hypothesis of unit roots (or normality) could not be rejected at the 95% confidence level.

Table 3. Historic development of cargo volumes in the Le-Havre – Hamburg range

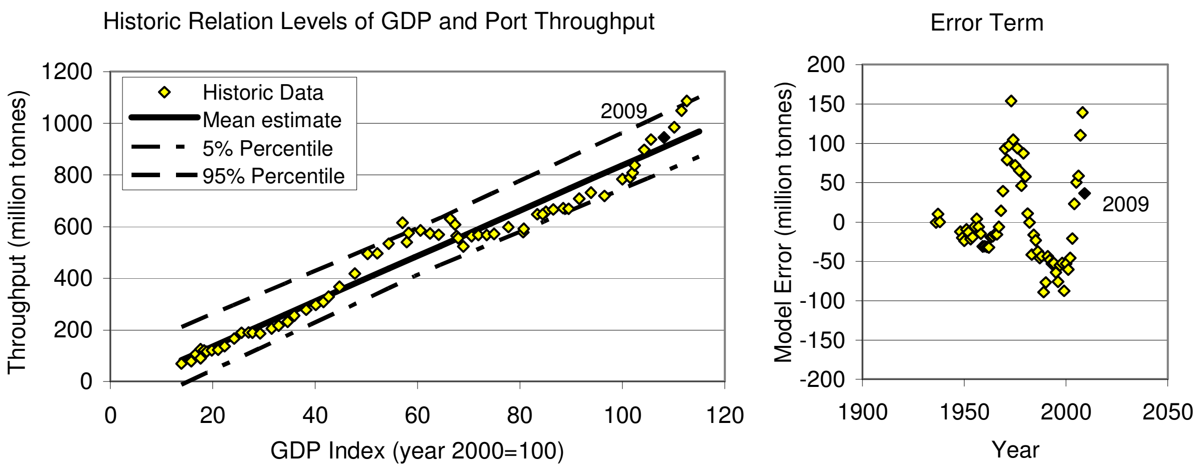


Figure 2. Simple Linear Regression between levels of GDP and Port Throughput

Figure 2 shows the results of the simple linear regression between the levels of the GDP and Port Throughput. A clear trend can be observed that holds throughout the data series and that does not even has a trend breach at the Second World War. However from the analysis of the regression statistics it should be concluded that one has to be careful with the interpretation of the model. The error term is highly autocorrelated and likely to contain a unit root. Therefore the model is likely to be misspecified in the sense that it is sensitive to trend breaches of common drivers such as globalisation. Besides this the prediction intervals are too small as a result of the virtually high fit. Finally the error term does not follow a normal distribution and therefore an additional error in the calculation of the prediction intervals will occur if the standard technique for defining prediction intervals is applied (as in Figure 2).

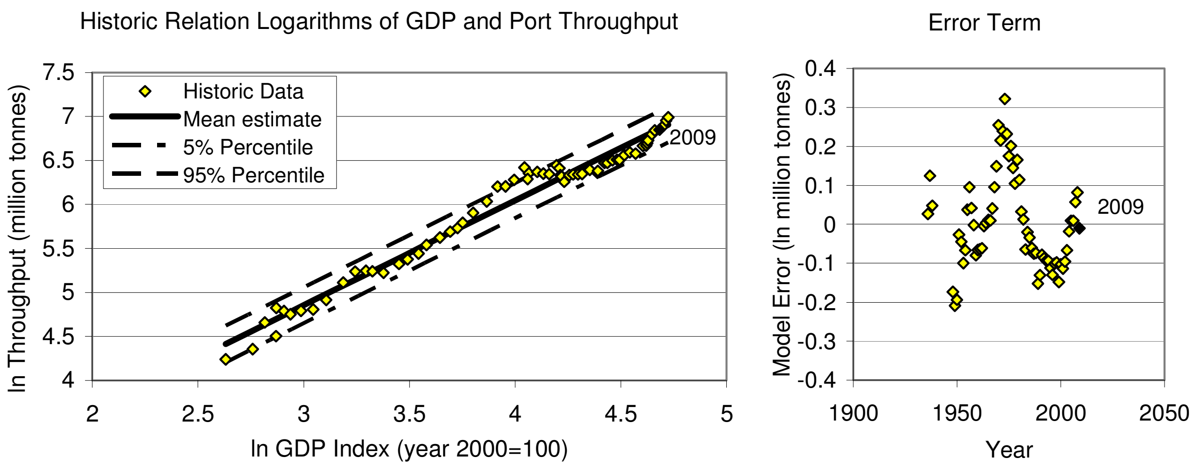


Figure 3. Linear Regression between natural logarithm of GDP and Port Throughput Levels

Figure 3 shows the results of the regression between the logarithms of the GDP and Port Throughput. The forecast value can be calculated indirectly by taking the exponent of Equation 2 or directly by applying Equation 4.

$$PT_t = EXP(\alpha + \varepsilon_t) \cdot GDP_t\hat{}\beta \qquad \text{(Equation 4)}$$

From Equation 4 it becomes clear that the coefficient β has a special meaning. It equals the elasticity between the GDP and Port Throughput. For this reason double logarithms are often used in transport literature. However, it is not likely that the elasticity remains constant over a very long time span. This makes the function not very desirable from a theoretical point of view. Now let's look at the statistical performance. Figure 3 (right) indicates that there is still autocorrelation in the error term. This is confirmed by the regression statistics. Though it appears from the Dickey-Fuller statistics that the logarithms of GDP and Port Throughput are stationary, this is not the case as the error term is non-stationary and any linear combination of stationary series would have also been stationary. Unlike the case presented by Hui et al. (2004) taking the natural logarithms does not make the model stationary and the model is therefore still likely to be misspecified. In addition to this the error term does still not fit the normal distribution well. The hypothesis of normality survived at 95% level, but failed at the 90% level. The statistical performance of Equation 2 is therefore also not satisfactory.

Pindyck and Rubinfeld (1998, p.497-499) discuss that *"Probably very few of the series one meets in practice are stationary. Fortunately, however, many of the nonstationary series that are encountered (and this includes most of those which arise in economics and business) have the desirable property that if they are differentiated one or more times, the resulting series will be stationary"*. Therefore Equation 3 relates the annual differences in GDP to the annual differences in Port Throughput (refer Figure 4). The basic statistics indicate that this model no longer contains a unit root and has a normal distributed error term[10]. The fit of the model, as measured by the R^2, is less satisfactory and leaves room for improvement.

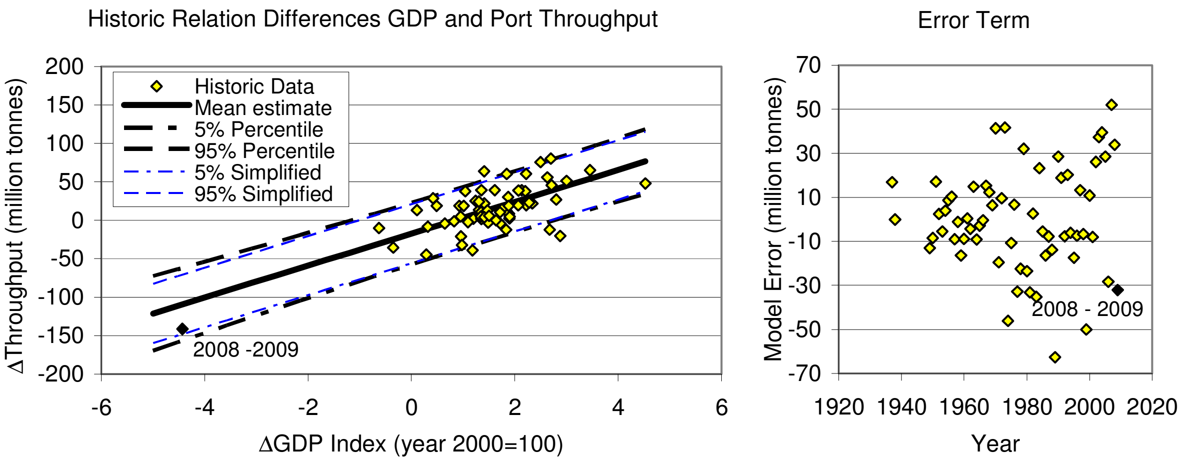


Figure 4. Linear Regression between differences of GDP and Port Throughput

There are not many observations related to a decline in GDP. The exception to this is the 2008-2009 value. It is difficult to judge whether this value should be regarded as valuable information or as an unwelcome outlier. For the purpose of this paper it has been argued that there is no reason to exclude the data point. However, if the data point would have been excluded the absolute value of the α coefficient would have been 40% lower (at value of -10.42) and the β coefficient would have been 20% lower (at value of 16.72). Therefore, if the 2008-2009 value turns out to be an outlier, the predicted throughput will be too low. Particularly in case of a decreasing future GDP growth as predicted in the next section.

[10] Though no unit roots can be observed from the test it can be observed from Figure 4 (right side) that it may be possible that there remains some heteroscedasticity in the model. This has not been further investigated.

Equation 3 can not be used to derive the throughput value directly from the GDP. In order to obtain a forecast the last observation (at t=0) is taken as a starting point. For each succeeding year the annual change in throughput is derived from the annual change in GDP and added to the value of the previous year. The main complication of this approach is that the calculation requires the growth path of the GDP to be known. This is not the case in our probabilistic forecasts. A simplified approach that directly relates the throughput value to the GDP is provided by Equation 5. This equation however still has the less obvious complication that the error term (required in the simulation process) is still path dependant. This complication can be solved by neglecting the variance of the line (i.e. the β coefficient) in the prediction interval. The simplified prediction intervals in Figure 4 indicate that this is an acceptable approach.

$$PT_{t=n} = PT_{t=0} + n \cdot \alpha + \beta \cdot (GDP_{t=n} - GDP_{t=0}) + \sum_{t=1}^{n} \varepsilon_t \qquad \text{(Equation 5)}$$

with:

n	: Number of years forecasted ahead,
α	: Annual decrease in throughput at constant GDP,
β	: Linear coefficient between throughput and GDP,
PT_t	: Port Throughput in forecast t-years ahead,
GDP_t	: GDP in forecast t-years ahead,
ε_t	: Stochastic error term of forecast in year t.

Now we have derived a statistically sound relationship the next question is whether it is also defendable from a theoretic point of view. The negative α coefficient indicates that Port Throughputs will decrease with a constant annual value as soon as GDP stabilizes. Theoretical evidence supports the existence of a negative α coefficient. A possible explanation is the increased share of services and virtual goods in the economy that results in a decoupling of transportation and economic growth. On the contrary it can also be argued that the existence of a constant negative α coefficient is fundamentally wrong on the very long run as it implies that port throughput drops to zero after the predicted future stabilisation of the GDP output (refer Section 5). This contradicts the fundamental theory of comparative advantage of David Ricardo. There will always be incentives for trade. The very long term perspective therefore requires a model with an α coefficient that phases out gradually.

To verify if the decline in α can be observed from the data a multiple regression model containing dummy variables for each decade has been built. Table 6 indicates the model.

	Coefficients	*Standard Error*	*t Stat*	*P-value*
Intercept	-17.69	6.86	-2.58	0.01
ΔGDP	21.25	2.42	8.80	0.00
Dummy 1960-1969	1.63	9.33	0.17	0.86
Dummy 1970-1979	-0.76	9.33	-0.08	0.94
Dummy 1980-1989	-17.72	9.24	-1.92	0.06
Dummy 1990-1999	-2.05	9.26	-0.22	0.83
Dummy 2000-2009	12.63	9.23	1.37	0.18

Table 6. Multiple Regression Model with Dummy Variables

Unfortunately the empirical evidence of the dummy model does not support the theory of a declining α coefficient (intercept + dummy). As it is not possible to estimate the rate of decline it will also not be possible to develop a sound model with a declining α coefficient.

4.3 Evaluation of findings

From the above discussion it has to be concluded that none of the evaluated regression functions is completely satisfactory from both a theoretical and a statistical point of view. There remain drawbacks related to the use of each of the equations taken into consideration:

- Equation 1 refers to a simple linear model that is non-stationary and therefore likely to be misspecified. This means that it is sensitive to trend breaches (most likely downwards) and has a prediction interval that is based on a virtual high fit caused by (common) driving factors not specified by the model (such as globalisation).

- Equation 2 refers to a model based on the natural logarithms of both data series. The model therefore assumes an exponential relation between Port Throughput and GDP. Such a relation is however not supported by theory and unlikely to hold on the very long term. The error term indicates that the model still contains a unit root.

- Equation 3 refers to a model based on a differences approach that is statistically sound in the sense that the error term it is stationary and normal distributed. However the fit of the model leaves room for improvement. The constant α coefficient has proved to be fundamentally wrong. Particularly in case of decreasing economic growth the model is likely to produce outcomes that are structurally too low on the very long run.

Considering the fact that Equation 1 and 2 are not statistically sound (misspecified model) and that Equation 2 and 3 are not sound from a theoretical point of view (wrong model) the question raises how to proceed. A possible option is to consider the (ab)use of the error correction model as this model is likely provide more realistic prediction intervals for Equation 1 and 2 and solves the issue with the zero cargo flows on the very long term in Equation 3. However the correct use of the error correction model requires the variables of the levels model to be co-integrated which is not the case. This approach is therefore misleading because the models looks sophisticated while in fact it is misspecified.

It appears that there is no easy solution to solve the issues with the statistical and theoretical unsoundness of the regression models. For this reason the question raises what model to select and how to proceed. Since the models are statistically unsound the measures of fit do not provide any guidance. A more convenient way to evaluate the performance is to compare them by means of an ex-post evaluation of the regression models.

4.4 Ex-post performance of the regression models

An ex-post forecast has been derived for each of the models referred to in the previous section. The forecast assumes that that someone back in 1970 had perfect foresight on the development of the GDP and was asked to develop a forecast of the Port Throughput up to 2009 on the basis of post war data. The results of this forecast as well as the real development of the Port Throughput over the past four decades are indicated in Figure 5.

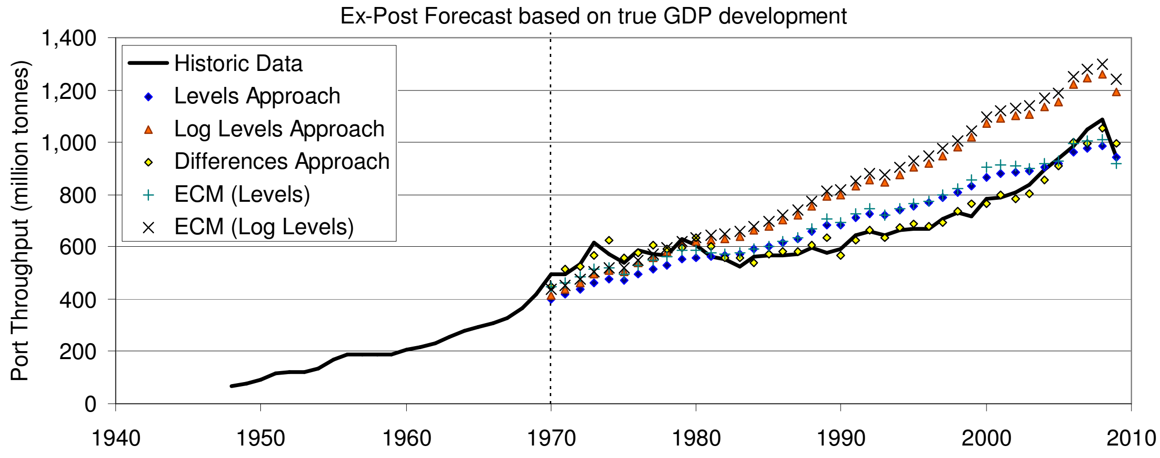


Figure 5. Ex-Post forecast from 1970 to 2009 for various forecast approaches

From the results indicated in Figure 5 it can be concluded that the difference approach has performed remarkably well as it shows almost no deviation from the true development of the Port Throughput. The use of a linear model is also not bad from the perspective of the very long term as it appears to be unbiased towards the long term trend. The use of an exponential model derived from the natural logarithms of GDP and Port Throughput should be avoided as this approach deviates significantly from the real trend[11]. The (ab)use of an error correction model is likely to improve Equation 1 in the sense that it follows the trend slightly closer. Besides this it was also expected to provide more realistic prediction intervals. The downside of this approach is however that it gives the impression of a highly sophisticated and sound approach while in fact the model is still misspecified. This is not a desirable property. An alternative approach that does not create the illusion of a perfectly sound model is to combine Equation 1 and 3 by taking the averages of the forecasts.

4.5 Combining forecasting models

Forecasting literature indicates that it is good practice to combine forecast in order to obtain more stable results. This is particularly the case when it is uncertain which method provides the most accurate forecast (Armstrong, 2001, p.417). On the very long run Equation 1 is likely to overestimate the trend as result of trend breaches (that are likely to have a negative impact on throughput volumes). On the contrary Equation 3 is expected to underestimate the very long term trend as a result of the constant negative α coefficient. Combining both forecasts is therefore expected to reduce bias. The same holds for the width of the prediction intervals as the variance of Equation 1 is too small and the variance of Equation 3 will, due to the poor fit, be larger than the prediction intervals of the real unknown perfect forecast. For this reason the average of the forecasts based on the relations of Equation 1 and 3 is expected to provide a reasonable indication of the order of magnitude and uncertainty related to the future port throughput volumes in the Le-Havre – Hamburg region.

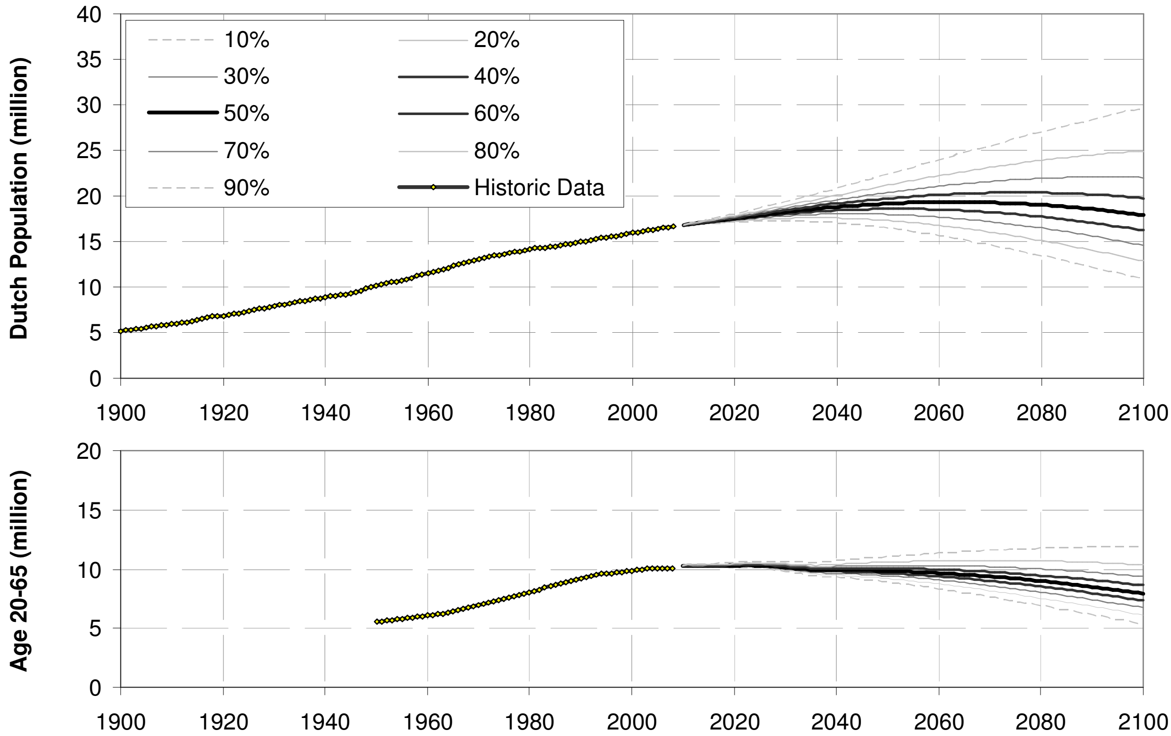
[11] There is a tradeoff between statistical soundness and theoretical soundness of the model. Particularly in applied econometrics the logarithm is often taken to improve the statistical soundness of model. This approach however comes with the risk of producing a model that is theoretically unsound and therefore biased.

5. Obtaining a Probabilistic Population and GDP Forecasts

Probabilistic GDP forecasts have, to the best of our knowledge, not been published and are therefore unavailable[12]. For this reason a probabilistic GDP forecast has been developed on the basis of available information and expected trends. In order not to complicate the issue it has been assumed that the very long term development of the Hinterland GDP is similar to the development of the Dutch GDP. This simplification is justified by the fact that the relative development of the GDP moves along quite similar for the *The Netherlands*, *Belgium*, *Germany* and *France* (refer Section 2).

5.1 Obtaining a probabilistic population forecast

The development of a probabilistic very long term GDP forecast up to 2100 requires a probabilistic very long term forecast of the population in the working age class of 20-65 years. No such forecast is available for the Netherlands. For this reason a forecast has been compiled from three different sources which include the *probabilistic projections for West-Europe of the World Population Program* (IIASA, 2007 update, www.iiasa.ac.at), the *probabilistic projections for the Dutch population up to 2050 of the project Uncertain Population of Europe* (Alho and Nikander, 2004), and the *four very long term scenarios for the development of the total population up to 2100* (de Jong, 2008). The discussion of the methodology applied is beyond the scope of this publication. The population forecasts and prediction intervals are indicated in Figure 6. The percentages in the legend refer to the percentiles of the forecast of which the 50% percentile represents the mean.



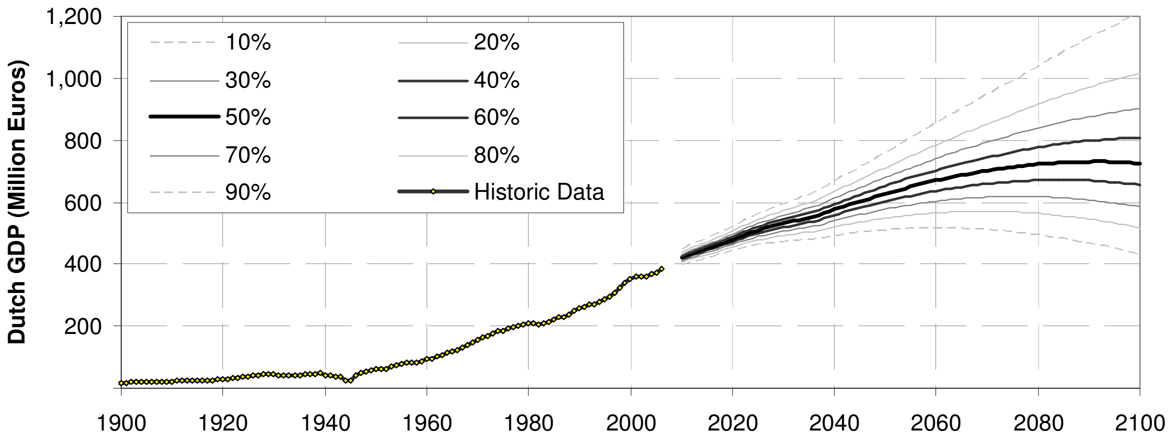
Source: Historic Data obtained from Maddison (2010) and CBS (2010)

Figure 6. Probabilistic Forecast of the development of the Dutch Population

[12]No attempt has been made to verify if probabilistic forecasts are available in the private sector. It is not unlikely that for example insurance companies have developed similar forecasts themselves.

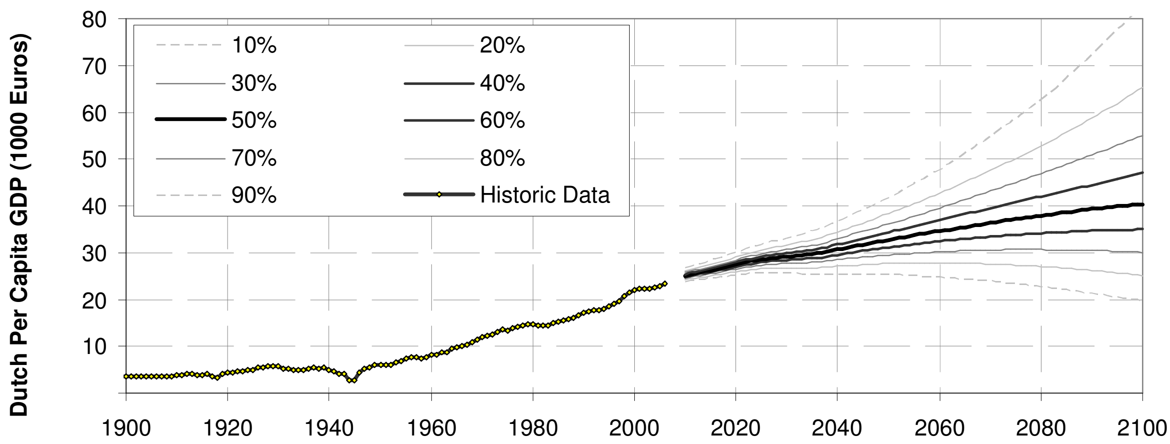
5.2 Obtaining a probabilistic GDP forecast

The probabilistic GDP forecast has been developed on the basis of the available population forecasts and Bayesian modelling techniques. For this purpose use has been made of the Excel Add-on @Risk, a simulation program designed for stochastic calculations. For each of the variables *population (between 20-65)*, *labour participation (working class 20-65)*, *working hours per employee per year*, and *GDP contribution per working hour* a distribution function (type, mean, and variance) has been defined for the period up to 2100. This has been done on the basis of historic data and expected trends. The historic data used in the estimate has been obtained from the Bureau of Statistics (www.cbs.nl), The Conference Board (www.conference-board.org), and Maddison (www.ggdc.net/maddison/). The discussion of the parameter estimates goes beyond the scope of this paper. The probabilistic forecast of the GDP and GDP per capita up to 2100 are indicated in Figure 7 and 8.



Source: Historic Data obtained from Maddison (2010)

Figure 7. Probabilistic Forecast of the development of the Dutch GDP



Source: Historic Data obtained from Maddison (2010)

Figure 8. Probabilistic Forecast of the development of the Dutch GDP per Capita

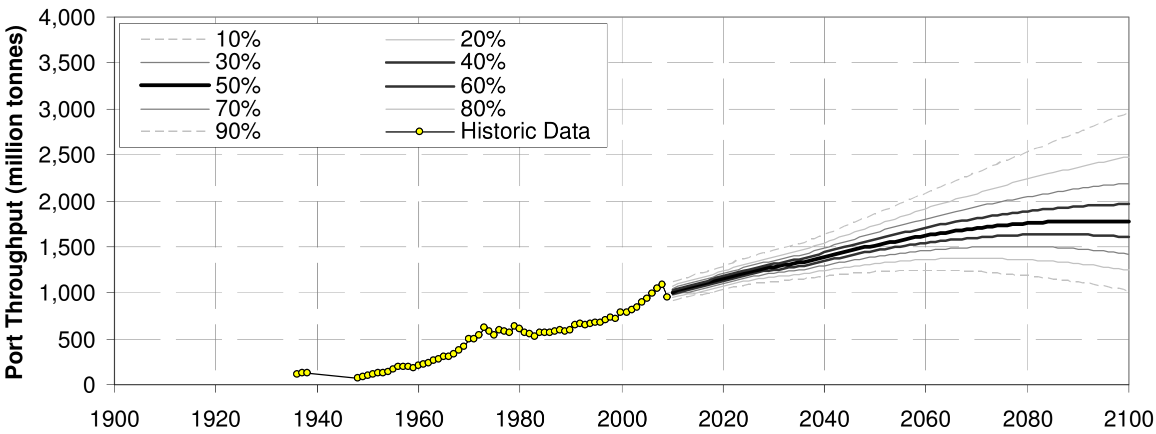
The figures indicate that the GDP (and GDP per capita) growth will reduce over the next two decades as a result of the retirement of the baby boom generation. This effect cannot be fully compensated by the increase in labour productivity. After stabilisation of the labour outflow the GDP will further increase until the working population inflow starts to decrease.

6. Very Long Term Forecast for the Le-Havre – Hamburg Range

It has not been possible to derive a forecast relation that is both theoretically and statistically sound. In absence of a single sound relation it has been concluded that it would be best to combine two counter biased forecasts in order to provide a more robust forecast of the Port Throughput in the Le-Havre – Hamburg range.

6.1 Preparation of a very long term forecast based on a levels approach

The first (naïve) forecast of Equation 1 compares the levels of the GDP directly to the levels of the Port Throughput. In order to obtain the probabilistic forecast for each year 10.000 simulations have been made in the Excel Add-on @Risk. For each simulation the GDP value has been drawn from the distribution function of the year under consideration. This value has been used in the stochastic relation between GDP and Port Throughput to obtain an estimate of the throughput volume of the ports. Finally the outcome statistics have been summarized in order to derive the prediction intervals. The results are indicated in Figure 9.



Source: Historic Data obtained from Port Authority of Antwerp (1936-2007) and Rotterdam (2008, 2009)

Figure 9. Naïve Forecast based on Levels Approach of Equation 1

Please note that the model is **statistically unsound** and is likely to be misspecified in the sense that it is vulnerable to trend breaches, and has a prediction interval that is too small. There was also a problem with the fact that the error term was not normal distributed, but this problem has been solved by using more advanced techniques for the calculation of the prediction intervals[13].

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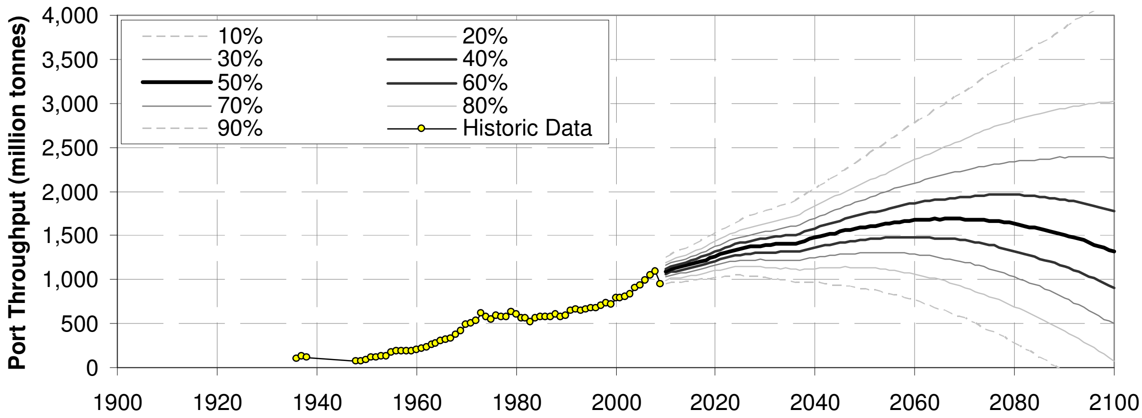
[13] The prediction interval consists of a variance towards the line and a variance of the line. The variance towards the line has been defined by fitting the error term of the regression analysis in @Risk. The distribution fitted well with the lognormal distribution. This relation has been applied in the forecast for defining the variance towards the line. The variance of the line has been analyzed by bootstrapping 10.000 datasets and defining the slope of the line for each of the datasets. From this analysis it could be concluded that the slope of the line fits well with a normal distribution. Therefore the variance of the β coefficient obtained from the regression statistics can be used to define the slope of the line. The contribution of the variance of the β coefficient to the error term is calculated as the error in the slope times the difference between the forecast GDP and the mean of the GDP of the original dataset.

6.2 Preparation of a very long term forecast based on a differences approach

The forecast based on the differences approach has been derived using a similar methodology as discussed for the levels approach of Equation 1. The results are indicated in Figure 10.



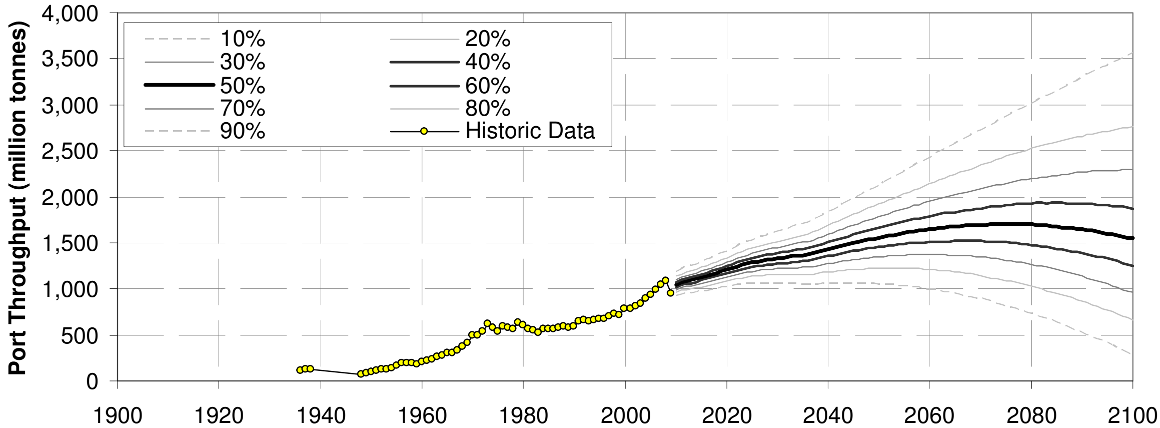
Source: Historic Data obtained from Port Authority of Antwerp (1936-2007) and Rotterdam (2008, 2009)

Figure 10. Single Forecast based on Differences Approach of Equation 5

The differences approach is statistically sound and therefore much more robust than the levels approach but also **theoretically unsound** as the negative α coefficient forces the model downwards to a zero throughput on the very long run. Therefore the forecast can be expected to be increasingly downward biased as time passes. In addition to this the forecast ignores the fact that there will remain some common drivers (the ones that cause the risk for trend breaches in the levels approach) and therefore the variance estimate can be expected to be too conservative (compared to the real unknown perfect forecast).

6.3 Final forecast based on a combined approach

Combining both forecasts is expected to reduce the bias in the mean and prediction intervals. The final forecast has been derived by taking the averages of both forecasts (refer Figure 11).



Source: Historic Data obtained from Port Authority of Antwerp (1936-2007) and Rotterdam (2008, 2009)

Figure 11. Final Forecast based on a Combined Levels and Differences Approach

From the forecast it can be concluded that the overall Port Throughput in the Le-Havre – Hamburg range will likely increase by a factor 1½ - 2 up to 2080 after which it will slowly stabilize and finally decrease. The reduced pace of growth between 2010 and 2030 is caused by the mass retirement of the baby boom population[14]. After 2030 the labour outflow stabilizes and both GDP and Port Throughput are expected to grow as a result of increased labour productivity. Finally from 2080 onwards the overall population decrease is expected to result in a stabilisation and decline of GDP and Port Throughput volumes.

6.4 Some things remain unpredictable

Throughput volumes estimated in this paper are derived on the basis of socio-economic foresight and insight in the co-movement of Port Throughput and GDP. As always with Bayesian forecasting it contains estimates of the mean and uncertainty of known variables. However not everything is predictable. In addition to the forecast it will be necessary to investigate if there are possible future events (trend breaches) that have a dramatic impact on the future, but are not covered by the forecast. In the presence of such events the future may turn out to follow a completely different path. The forecast should therefore be supplemented by a trend breach analysis. This will be subject of further investigation.

7. Conclusions

The research questions have been defined in section 1.2. This section concludes with the discussion of the findings related to the questions.

Question 1: A review of *port throughput forecasting* and *very long term forecasting* methodology indicated that there is not much published on both subjects and no article on the combined subject of very long term forecasting of port throughput volumes has been found. To the best of our knowledge there does not exist a handbook on the subject of port throughput forecasting. A search on Scopus and Google Scholar listed a small number of articles mostly related to the use of specific techniques for which the arena of the port is chosen as an application. Little reference is made to the actual practice in port throughput forecasting, which is (to our best knowledge) generally based on causal relationships and leading indicators. The applied models are mainly based on mere trend extrapolation techniques in the sense that they fully rely on historic data. Mere trend extrapolation techniques are however not suitable for very long term predictions. An exception to the observed is the error correction model discussed by Hui et al. (2004) and to some extend also the vector error correction model developed by Fung (2001). These models contained causal relationships and the articles also referred to the current practice in applied port forecasting.

Question 2: The review of very long term forecast methodology indicated that little has been written on the subject. To move beyond the classical forecast horizon set by mere trend extrapolation the use of scenarios was suggested. However, it was also indicated that scenarios are not predictions, but simply visualisations of a likely future. A more profound approach is the development of probabilistic forecast on the basis of Bayesian techniques. In Bayesian forecasting a priori statements are made on the mean and variance of all the

[14] It should be noticed that the slowdown of the economic growth and Port Throughput matches the downswing of the 5th Kondratieff wave. This is however a coincident as economic cycles are not forecasted in the model.

variables included in the model and the results are calculated by applying statistic calculation methods. Bayesian techniques have been successfully applied to develop probabilistic very long term population forecasts and are also suitable for the preparation of probabilistic GDP forecasts. The Bayesian methodology has been adopted in this paper for the development of a probabilistic very long term forecast of the port throughput volumes in the Le-Havre – Hamburg range up to 2100. If desired scenarios for the development of future cargo flows can be developed on the basis of the probabilistic forecast presented in this paper.

Question 3: Taking the above into account a sensible forecast approach is to develop a probabilistic forecast of the Port Throughput in the Le-Havre – Hamburg range on the basis of a probabilistic GDP forecast and the causal relation between Port Throughput and GDP.

Question 4: Long term historic data series on the development of the Port Throughput have been obtained from the Antwerp Port Authority for the period 1936 to 2009. A comparison with statistics obtained from the Rotterdam Port Authority indicates that that the data series of the Antwerp Port Authority (that contain fewer ports) account for about 90% of the total throughput in the Le-Havre – Hamburg range. For some individual ports the throughput data was incomplete. Missing years have been interpolated. Historic data on the development of the GDP of the Hinterland has been obtained from Maddison. It was observed that the GDP of the main countries in the Hinterland (NL, BE, GE, FR) follows a similar trend.

Question 5: An attempt has been made to develop a sound causal relationship between GDP and Port Throughput. For this purpose three different equations have been evaluated. Equation 1 compares the GDP levels directly to the Port Throughput levels. The regression results however turned out to be statistically unsound. Therefore the model is sensitive to trend breaches (most likely downwards) and has a virtual high fit that results in prediction intervals that are too small. Equation 2 tries to solve the statistical problems by taking the natural logarithm of the GDP and Port Throughput. This approach was not successful as the error term still contains a unit root. The transformation however introduced a considerable upward forecast bias as a result of the imposed exponential relationship between the variables which is not supported by theory. Equation 3 is statistically sound but proved to be fundamentally wrong from a theoretic point of view as the fixed α coefficient forces the Port Throughput to drop to zero after the predicted stabilisation of the GDP on the long run. An attempt to develop a model with a diminishing α coefficient failed because the decline was not supported by empirical evidence. Therefore none of the considered forecast relations is both theoretically and statistically sound. Some improvement may be possible by (ab)using the error correction model. However this model is only valid for co-integrated variables. The variables applied in our models are not co-integrated. The use of the error correction model would therefore give the impression of a highly sophisticated and sound approach while the model is in fact still misspecified. An alternative approach suggested by forecasting literature is to combine the forecasts. This approach works particularly well in case of counter biased forecasts such as Equation 1 and 3. It is therefore suggested to combine the levels and differences approach of Equation 1 and 3 in order to provide a reasonable indication of the order of magnitude of the throughput volumes in the le-Havre – Hamburg region up to 2100.

Question 6: The development of a probabilistic forecast for the port throughput volumes in the le-Havre – Hamburg range requires a probabilistic forecast for the development of the GDP of the Hinterland. Since the GDP of the various countries located in the Hinterland follow a similar trend it has been assumed that the forecast can be based on a forecast of the

Dutch GDP. However, no probabilistic GDP forecast was available for the Netherlands. The GDP forecast has therefore been developed on the basis of a probabilistic forecast of the Dutch population in the working age class of 20-65 and some assumptions on the overall development of the labour productivity. The required population forecast was also not available and has been compiled from various sources. Though the population and GDP forecasts have been constructed carefully it can be expected that there is still room for improvement. Demographic and socio-economic experts are therefore challenged to improve the probabilistic very long term population and GDP forecasts presented in this paper.

Question 7: Though the forecast relation does not allow for the development of a sound forecast it is likely to provide a reasonable estimate of the order of magnitude of the future port throughput volumes in the Le-Havre – Hamburg range (that can for instance be used to define throughput scenarios). From the combined forecast it can be concluded that it is reasonable to expect an overall increase in cargo volumes by a factor 1½ to 2 up to 2080. A possible decline thereafter is not unlikely. However, not everything is predictable. There remains the possibility of fundamental changes that lead to a completely different future. The forecast therefore still has to be supplemented by a trend breach analysis.

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