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Keywords

- Imperial Austria, Wagner's law, public expenditure.

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Drivers of public sector growth in Imperial Austria 1870-1913[1]

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Abstract

We test several hypotheses concerning the growth of public expenditure by the Austrian monarchy between 1870 and 1913 in relation to Wagner's law, as well as the impact of increasing public indebtedness and the expanding role of the Imperial Council towards the end of the analyzed period, using the bounds testing approach and Granger-causality analysis. We find evidence for Wagner's law in the case of public investment, but not general public expenditure. Increases in general public expenditure were mostly driven by the public debt, rather than by increasing national income. We do not find evidence that institutional reforms by the Imperial Council changed the trends in public expenditure.

JEL Classification: N13, N43, H50
Keywords: Imperial Austria; Wagner's law; public expenditure

1. Introduction

The first scholar to propose a long-term relationship between the level of economic development and the size of government was Adolph Wagner (Wagner, 1893). Ever since Wagner's contribution in this area, an extensive body of empirical literature has emerged, reporting on whether his theoretical prediction was supported by the data with mixed results. Notably, not many studies have been conducted on the period before the Second World War, including back to the 19th century, whereas, in fact, Wagner's original hypothesis was conceived as applicable to countries in the early stages of development. In this work, we want to test Wagner's law, as well as other hypotheses concerning the reasons for public sector growth over time, in the case of Austria in the late 19th and early 20th centuries.

Austria-Hungary, at the beginning of the 19th century, was among the least developed countries of Europe, with real gross domestic product (GDP) per capita comparable to that of Russia (Pammer, 2010). Towards the end of the 19th century, particularly after 1895, Austria has witnessed an increase in the growth rate of industrial production, although growth was lower than in most

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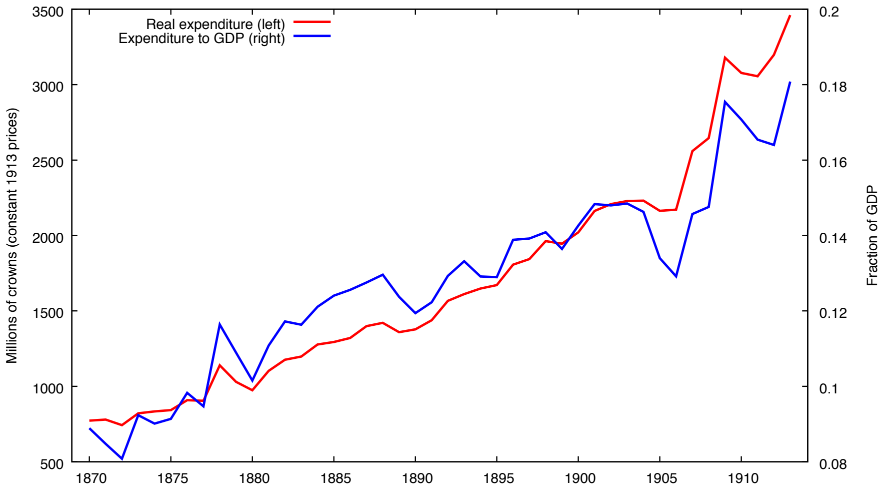
Western European countries. Nevertheless, the secondary sector grew at the fastest rate, with an annual growth rate of 2.46% between 1871 and 1912, and 3.34% between 1895 and 1912 (primary and tertiary sectors grew at a rate of about 1% lower during the same period) (see Schulze, 2000, Table 4 for more details). During the period 1895-1908, the production sector contributed to a total of 47% of aggregate economic growth (see Schulze, 2000, Table 10).

During the same period, central government expenditure grew at a quick rate, as visualized in Figure 1.

Figure 1: Development of central government expenditure 1870-1913, constant 1913 prices (red) and as a fraction of GDP (blue)



Source: own calculations based on Wysocki (1975), Schulze (1997) and Mühlpeck et al. (1979)

In this work, we are interested in several hypotheses regarding the interrelationship between the industrialization process and rapidly increasing government expenditure. We test the classical Wagner hypothesis, but also look at the relationship between expenditure and public debt, as well as political economy explanations.

The next section contains theoretical predictions. Section 3 presents the data sources and the empirical approach to be taken. Section 4 presents the results of the investigation. Section 5 concludes the paper.

2. Theoretical considerations and previous literature

The "law of public sector growth", also known as Wagner's law, has been found to be associated with diverse demographic, socioeconomic and political factors[3]. The classical Wagner hypothesis claims that demand for public services increases along with increasing income. In other words, if demand for publicly provided goods and services is income-elastic (i.e., income elasticity above 1), an increase in national income (per capita) should result in increasing public expenditure. This is the main hypothesis tested in this work. We also test the alternative theory that increases in public expenditure (in particular, in public investment) are followed by increases in national income in line with the Keynesian view. Some other hypotheses, such as in relation to the aging of the population, are not of much relevance to the analyzed period, while other theories, e.g., Baumol's hypothesis, cannot be tested with the available data.

We also look at the relationship between public expenditure and changes to the franchise in the Imperial Council. In line with the classical model of Meltzer and Richard (1983), government should grow more when the franchise is extended to include more voters below the median income, such that the growth of incomes provides revenues for increased redistribution. The Imperial Council underwent a series of changes, most importantly, in the form of a general franchise starting in 1896[4] and continuing until 1906[5]. In particular, the latter reform allowed for greater representation of members of the working class: from 1907 onwards, social democrats represented the strongest factions in parliament[6]. Our second research question, therefore, concerns whether these institutional changes had an impact on the development of public expenditure.

Finally, we look at the relationship between public expenditure, national income and public debt. Expenditure on public debt constituted a large part of public expenses. Moreover, recent research (Reinhart and Rogoff, 2010; Panizza and Presbitero, 2014) has suggested a negative (or non-linear) long-term relationship between public debt and economic growth. We subsequently test whether such a relationship can be established in our case.

Although the question of drivers of increases in public expenditure constitutes a major topic of interest, comparatively few works have looked at the developments in the period before the First World War. The earliest work looking at developments spanning back to the 19th century

[3]These include population growth and aging, growth of cities, demand for public services, political factors and conflicts.

[4]Introduction of the fifth "curia", which granted universal suffrage to all men over the age of 24.

[5]Abolishment of the curiae system and the introduction of universal suffrage for men.

[6]The "Christsozialen" in 1907 and the "Sozialdemokraten" in 1911.

is Gupta (1967), which supports Wagner's hypothesis. Subsequently, Henrekson (1993) looked at the development of public finance in Sweden since 1860, criticizing the inconsistency of previous estimates due to unit roots in the series. Oxley (1994), using cointegration analysis, confirms the validity of Wagner's hypothesis in the case of Great Britain in the period 1870-1913. Of late, Thornton (1999) finds evidence of Wagner's hypothesis in 19th century Europe[7]. Recently, Sideris et al. (2007) and Antonis et al. (2013) find support for Wagner's hypothesis in 19th century Greece. While, for instance Gratz (1949), Wysocki (1975) and und Reinhard Neck (2002) provided descriprive evidence regarding developments of public finance for the period 1870-1913, they did not conduct a formal econometric analysis. To the best of our knowledge, this is the first work to examine Wagner's hypothesis, as well as other theoretical results in a formal econometric way, in the case of Imperial Austria.

3. Data and the model

3.1. Data sources

Our reason for selecting the period 1870-1913 is driven by the historical changes taking place at that time in the Austrian Empire. Until 1867, it had only one state budget without any distinction made between Austrian and Hungarian affairs. Following the constitutional change, from 1868 onwards, Austria and Hungary, being essentially two countries, had separate budgets. However, some policy fields, notably defense and foreign policy, were subject to a common government with its own budget, consisting of expenditures mostly for military purposes, along with other revenues that were comparably negligible (Pammer, 2010). This common military spending fluctuated at the level of 2% of GDP throughout the analyzed period.[8] A second major aspect of expenditure in Austria was public debt. Finally, a large amount of public expenditure during this period was allocated to the development of transportation infrastructure, particularly railways. Although the railways were almost completely absent from Austrian state budgets in 1870, the share of railways in terms of gross expenditures amounted to 2% in 1879, 15% in 1884, 19% in 1897, 20% in 1908 and 32% in 1909 (Pammer, 2010).

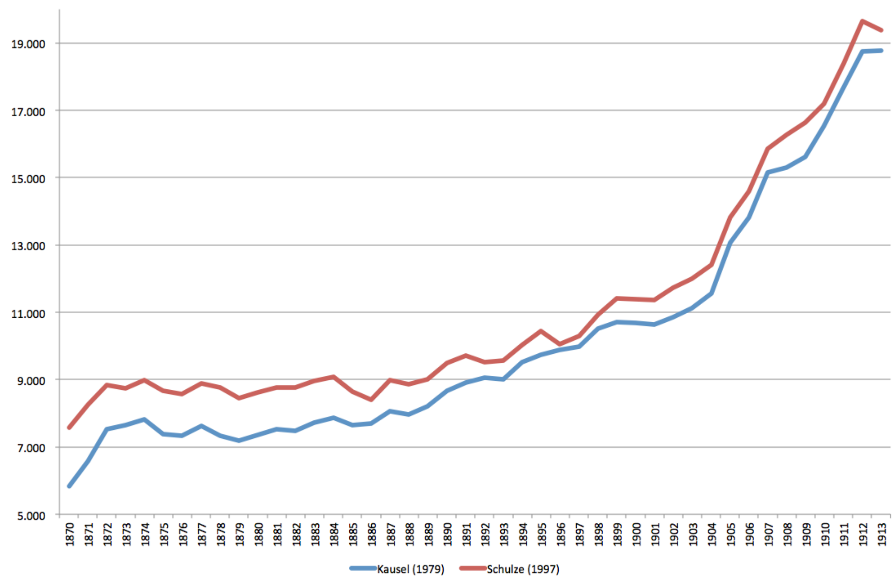
There are several available time series that consider national income or, in modern terms, GDP for the Austrian part of the Austro-Hungarian monarchy. Kausel (1979) and Schulze (1997)

[7] The countries analyzed by Thornton (1999) are Denmark, Germany, Italy, Norway, Sweden and the United Kingdom.

[8] In the peak years of international conflicts (1848, 1854-5, 1859 and 1866), Austria-Hungary spent 5-6% of its GDP on military expenses (Pammer, 2010).

are two examples, which are presented in Figure 2. We can observe that levels estimated by Kausel (1979) are slightly lower at the beginning before catch up to levels, as reported Schulze (1997), towards the end of the analyzed period. This implies a higher growth of income predicted by Kausel (1979) for the period 1870-1890 of 1.24% per annum, compared to 0.63%. We have decided to use the data set of Schulze (1997), which, to date, is the most precise estimate, while taking into account factors that have not been previously included.

Figure 2: Development of national income (current prices, in millions of crowns) 1870-1913



Source: Kausel (1979) and Schulze (1997)

Data on public expenditure and public investment come from Wysocki (1975) and refer to the territory of Cisleithania, which was the Austrian part of the Austro-Hungarian monarchy consisting of land that nowadays belongs to the Czech Republic, Slovakia, Croatia, Slovenia, Bosnia-Herzegovina, Italy, Poland, Romania, Ukraine and most of the current territory of Austria (with the exception of Burgenland). Data are taken from the balance of accounts of the central state (German: *"Centralrechnungsabschluss"*) of Cisleithania, which means that state and municipal government expenditures, as well as those of other public entities, are not considered. Regional and local governments had little authority over administration and expenditure, although, according to Wysocki (1975), their expenditures could have been significant, particularly towards the end of the analyzed period (und Reinhard Neck, 2002). According to Wysocki (1975), the states' expenditure equalled about 0.36% of total expenditure in 1870, whereas, in 1910, it equalled 11.90% (Wysocki, 1975, p. 25). This means that our time series underestimates the overall expenditure levels; in particular, it also underestimates the *growth rate* of expenditure, which, in fact, was higher if we add the states' expenditure. Nevertheless, despite the latter data issue, a clear increasing trend in central state expenditure is visible in Figure 1, most of which can be associated with increasing infrastructure expenditure: transportation (railway), schooling, research and administration (Wysocki, 1975).

During peaceful times, 20-25% of gross state expenses were used to pay the interest of state loans and (to a much lesser degree) pay off the debt. In the decade before the First World War, this share fell to about 15%. This represented about 30-35% of net expenses. These numbers include railway debt-related costs, that is, the debt of private railway companies as assumed by the state in the course of the nationalization of railways. Railway debt-related costs were about one fifth of the overall Austrian state debt around 1890, one quarter around 1900 and 45% in 1911 (Pammer, 2010).

Data on inflation come from the estimates of Mühlpeck et al. (1979).

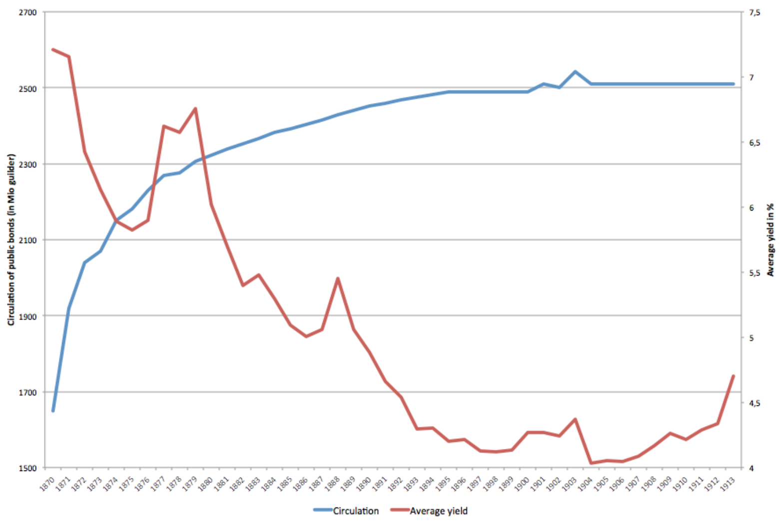
Information on circulation of public bonds can be found in Komlos (1983), comprising information on the circulation and yield of diverse public debt papers with diverse coupons. We sum up the circulation of bonds denominated in different currencies, as well as calculate average yields, weighted by the composition. Data are visualized in Figure 3. Most of the public debt was issued in the first half of the analyzed period, before stabilizing after 1896. Towards the end of the monarchy, the yield of the bonds started to climb up, suggesting a lack of confidence in the fiscal capacity of the state.

More recent studies on Wagner's hypothesis highlight the necessity to include population structure in the analysis (see, e.g, Shelton, 2007), in particular, how population aging drives social expenditure. Yet, this factor should not be of significant relevance to the analyzed period. Censuses conducted in this period show that the population share of those above 65 years increased from 7.8% in 1869 to 9.4% in 1910[9] (the population share of those above 60 years from 13.5% to 15.5%), an increase which can be safely disregarded. This is not surprising, given that major breakthroughs in medicine, such as the mass use of antibiotics, only occurred in the 20th century.

Finally, we look at the institutional changes using the Political Constraint Index (POLCON) data set by Henisz (2002b). This measure of political constraints estimates the feasibility of policy change, that is, the extent to which a change in the preferences of any one actor may lead to a change in government policy (Henisz, 2002a). It combines information about the institutional

[9]Source: population statistics from the Austrian Statistical Office.

Figure 3: Circulation and yield of public bonds 1870-1913



Source: own calculations based on Pammer (2010)

setup (branches of government with veto power), as well as ideological alignments between them, which affect the feasibility of reforms. Until 1898, the value of the index was virtually 0, before becoming a positive value after the above-described institutional and political changes took place.

3.2. Integration and choice of econometric model

To choose the appropriate econometric model, in the first step, we need to determine the (non)-stationarity of the analyzed time series and, in the case of integration, whether cointegration can be found. Table 1 presents the test results for each series using ADF and KPSS unit root tests. The variables are defined as follows: $GGDP$ is the ratio of public expenditure to GDP, $IGDP$ denotes the ratio of public investment to GDP, $YPOPR$ is real GDP per capita (in constant 1913 prices), and $CIRC$ is the circulation of public debt (in millions of guilders).

Table 1: Unit root tests of the series (p-values)

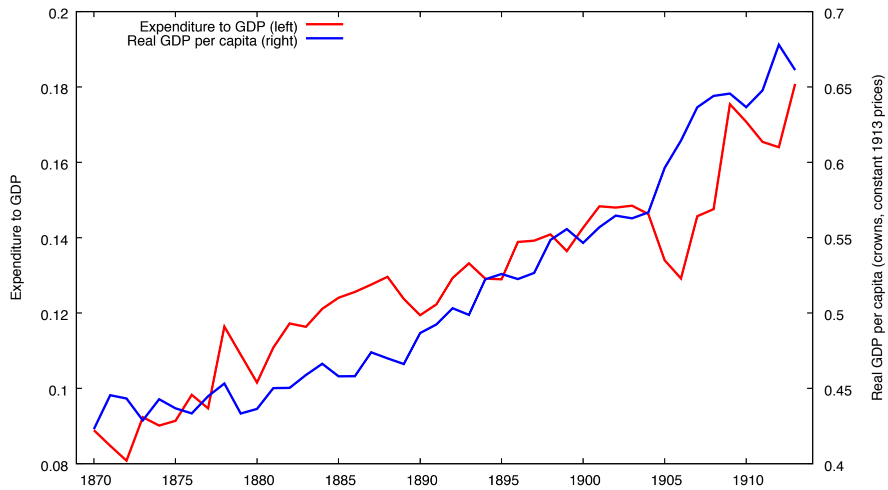
Variable[a][b]	ADF		KPSS	
	Const.	Const. & trend[c]	Const.	Const. & trend
$GGDP$	0.87	0.06***	0.01	0.03
$YPOPR$	0.99	0.65**	0.01	0.01
$IGDP$	0.96	0.41**	0.01	0.01
$CIRC$	0.00	0.00*	0.95	0.26

[a] The number of lags chosen according to Akaike's information criterion
[b] Tests of first differences point to stationarity.
[c] In DF regressions, the trend is significant at the * 0.1, ** 0.05 and *** 0.01 level

For all except the $CIRC$ variables, both the ADF and the KPSS tests point to the existence of unit roots, whereas the first differences are stationary. For the $GGDP$ variable, evidence suggests trend stationarity. In order to conduct an analysis of a long-term relationship, we therefore need to use the Pesaran et al. (2001) bounds testing approach, which is appropriate for testing the existence of a level relationship between a dependent variable and a set of regressors, when it is not known with certainty whether the underlying regressors are trend or first difference stationary.

A visual inspection of Figure 4 suggests that central government expenditure as a percentage of GDP and GDP per capita could be cointegrated, a relationship which will be subsequently tested.

Figure 4: Central government expenditure and GDP per capita



Source: own calculations based on Wysocki (1975) and Kausel (1979)

4. Results

4.1. Cointegration

We can test for a long-term relationship between $GGDP$, $YPOPR$, $CIRC$ and other variables using the Pesaran et al. (2001) bounds testing approach. We shall estimate an unrestricted error correction model of the form:

$$\Delta GGDP_t = \beta_0 + \sum_{j=1}^{p} \lambda_j^* \Delta GGDP_{t-j} + \sum_{j=0}^{q} \delta_j^* \Delta YPOPR_{t-j} + \\ + \sum_{j=0}^{s} \kappa_j^* \Delta CIRC_{t-j} + \theta_0 GGDP_{t-1} + \theta_1 YPOPR_{t-1} + \theta_2 CIRC_{t-1} + \epsilon_t, \quad (1)$$

and correspondingly a model, with public investment $\Delta IGDP$ as a dependent variable. In each case, Δ denotes the rate of change. The Pesaran et al. (2001) approach involves testing whether $\theta_0 = \theta_1 = \theta_2 = 0$, as well as comparing the obtained F-statistic with the critical values of Pesaran et al. (2001). If we are able to reject the joint insignificance, we can conclude that a long-term relationship exists, before proceeding with the estimation of a restricted error correction model.

First, we choose the appropriate model in error correction form, using information criteria, with reference to a case involving $p = 1$ and $q = s = 0$. The detailed results of the regression can be found in Table A.6 in the Appendix. We can test for the existence of a long-term relationship using the F-statistic. The F-statistic for $\theta_0 = \theta_1 = \theta_2 = 0$ equals 6.51946 and is therefore higher than the critical value of 5.855[10] at a 1% significance level. This result implies that there is indeed a long-term relationship in the levels of the variables, as well as the circulation of public debt.

Similarly, we proceed with a model, in which the dependent variable is $\Delta IGDP$. Information criteria refer to a case involving $p = 1$, $q = 1$ and $s = 0$; the detailed regression can be found in Table A.7 in the Appendix. The test statistic in this case equals 11.384 and is significantly above the value of 4.470, thereby rejection the non-existence of a long-term relationship at a 5% significance level.

In summary, we can estimate a restricted error correction model, with which we are able to explain the levels of public spending and investment spending. We estimate the restricted model of the form:

$$\Delta GGDP_t = \sum_{j=1}^{p} \lambda_j^* \Delta GGDP_{t-j} + \sum_{j=0}^{q} \delta_j^* \Delta YPOPR_{t-j} + \sum_{j=0}^{s} \kappa_j^* \Delta CIRC_{t-j} \\ - \theta_0 (GGDP_{t-1} - \theta_1^* YPOPR_{t-1} - \theta_2^* CIRC_{t-1} - \theta_3^* const - \theta_4^* PolCon) + \epsilon_t, \quad (2)$$

[10] Instead of Pesaran et al. (2001) critical values, we use Narayan (2005) values, which are more appropriate when dealing with small samples. Nevertheless, it is also higher than the Pesaran et al. (2001) value of 5.84 for the 97.5% test.

that is, with a restricted constant, as well as the index of political constraints using non-linear least squares, whereas the unrestricted estimates serve as starting values.

Table 2: Restricted error correction model for $\Delta GGDP$

	Estimate	Std. error	t-ratio	p-value
θ_0	0.578177	0.149361	3.8710	0.0005
$YPOPR_{t-1}$	0.243303	0.0696009	3.4957	0.0013
$CIRC_{t-1}$	5.51126e–05	3.12020e–05	1.7663	0.0863
Pol.Con. III	−0.0862291	0.135776	−0.6351	0.5296
Const.	−0.121339	0.0648492	−1.8711	0.0700
$\Delta GGDP_{t-1}$	−0.0167966	0.153581	−0.1094	0.9136
$\Delta YPOPR$	−0.175458	0.100061	−1.7535	0.0885
ΔCirculation	−5.61565e–05	8.06188e–05	−0.6966	0.4908

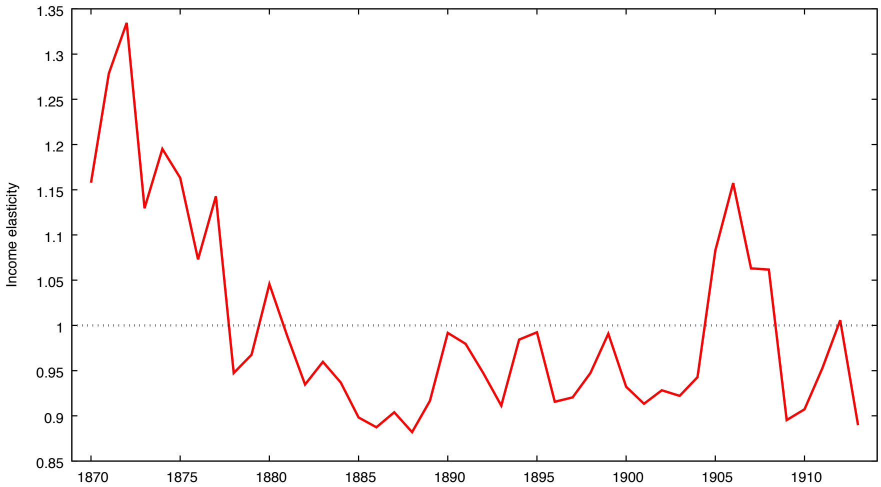
According to Table 2, the estimated long-term relationship is:

$$GGDP = 0.24YPOPR + 0.00CIRC - 0.09Pol.Con.III - 0.12 + u,$$

suggesting a significant long-term relationship between public expenditure and national income per capita. Given the coefficient for $YPOPR$, the long-term elasticity of public expenditure with respect to per capita income evaluated at the mean equals 0.988, which means that Wagner's hypothesis does not find an exact confirmation; this would require the income elasticity to be larger than 1. Nevertheless, if we look at the development of elasticity for the whole time period, as visualized in Figure 5, we can observe that, at least for the first 10 years in the sample, the income elasticity of public expenditure was significantly higher than 1.

On the other hand, circulation of debt is positively associated with public expenditure, whereas the index of political constraints is not. The latter means that, although social democratic movements were given some legislative powers towards the end of the analyzed period, it did not result in increasing the growth rate of public expenditure. The positive association between public debt circulation and public expenditure confirms the findings of Pammer (2010), showing that a large part of the public expenses were financed by debt, while interest payments constituted a significant part of public expenditure. We do not, however, find confirmation of the hypothesis that public debt is necessarily associated with lower income growth. Regarding the impact of public expenditure on income, as well as the causality between debt and income, we shall use Granger causality analysis in the following subsection. We report the results of the estimation with a restricted trend in the Appendix (the results hardly change).

Figure 5: Long-term income elasticity of public expenditure over time



Source: own calculations

4.2. Granger causality

This interesting alternative to Wagner's hypothesis is concerned with whether increased public expenditure has an impact on the growth of national income ("Keynesian hypothesis"). We can test the two competing theories using Granger causality. Whereas most readers will be familiar with Granger causality testing in the context of stationary data, the procedure for cointegrated data needs to be adjusted accordingly. In order to perform the causality test, we need to use a VAR model for the two variables of interest, $GGDP$ and $YPOPR$, additionally augmented with a one period lagged error correction term obtained in the previous step (see, e.g., Engle and Granger, 1987). The model is, therefore:

$$\begin{aligned}
\Delta GGDP_t &= \sum_{j=1}^{p} \lambda_{1j}^{*} \Delta GGDP_{t-j} + \sum_{j=0}^{q} \delta_{1j}^{*} \Delta YPOPR_{t-j} + \sum_{j=0}^{s} \kappa_{1j}^{*} \Delta CIRC_{t-j} + \gamma_1 ECT_{t-1}, \\
\Delta YPOPR_t &= \sum_{j=0}^{p} \lambda_{2j}^{*} \Delta GGDP_{t-j} + \sum_{j=1}^{q} \delta_{2j}^{*} \Delta YPOPR_{t-j} + \sum_{j=0}^{s} \kappa_{2j}^{*} \Delta CIRC_{t-j} + \gamma_2 ECT_{t-1}, \quad (3) \\
\Delta CIRC_t &= \sum_{j=0}^{p} \lambda_{3j}^{*} \Delta GGDP_{t-j} + \sum_{j=0}^{q} \delta_{3j}^{*} \Delta YPOPR_{t-j} + \sum_{j=1}^{s} \kappa_{3j}^{*} \Delta CIRC_{t-j} + \gamma_3 ECT_{t-1}
\end{aligned}$$

According to information criteria, the correct number of lags for the system is two. Full results of the estimation are presented in the Appendix. Table 3 presents an overview of the results.

Table 3: t- and F-statistics and p-values (in brackets) for testing short- and long-term Granger causality

Source of causation →	ΔYPOPR	ΔGGDP	ΔCIRC	ECT_{t-1}
ΔYPOPR		3.0243*	5.9102***	-1.425
		[0.0622]	[0.0064]	[0.1635]
ΔGGDP	2.3105		0.13896	-2.193**
	[0.1150]		[0.8708]	[0.0355]
ΔCIRC	6.6030***	2.8397*		-3.757***
	[0.0039]	[0.0728]		[0.0007]

*** p<0.01 ** p<0.05 * p<0.1

There is long-term Granger causality, running from national income, debt circulation and public expenditure to public expenditure and debt circulation, which is significant at the 5% level. We do not find short-term causality running from the changes in national income to changes in public expenditure. There is weak (significant at the 10% level) evidence of short-term Granger causality from the changes in public expenditure to the changes in national income, in line with the Keynesian hypothesis. In summary, income elasticities of public expenditure of around 1, along with the limited amount of evidence regarding Granger causality from national income to public expenditure, suggest no evidence to support Wagner's hypothesis.

4.3. Results: public investment model

Similar to the previous steps, we can estimate a model for investment expenditure, the results of which are presented in Table 4.

Table 4: Restricted error correction model for $\Delta IGDP$

	Estimate	Std. error	t-ratio	p-value
θ_0	0.685728	0.122601	5.593	3.20e-06
Const.	-0.129820	0.0272310	-4.767	3.66e-05
$YPOPR_{t-1}$	0.255873	0.0302019	8.472	8.65e-10
$CIRC_{t-1}$	1.86843e-05	1.22911e-05	1.520	0.1380
Pol.Con.III	0.0342882	0.0585624	0.5855	0.5622
ΔYPOPR	-0.100479	0.0501621	-2.003	0.0534
$\Delta YPOPR_{t-1}$	-0.146627	0.0635881	-2.306	0.0275
$\Delta IGDP_{t-1}$	0.150103	0.132851	1.130	0.2667
ΔCIRC	5.93928e-06	3.99358e-05	0.1487	0.8827

The estimated long-term equation is, thus:

$$IGDP = 0.25YPOPR + 0.00CIRC + 0.03Pol.Con.III - 0.13 + u$$

while the long-term elasticity of public investment, with respect to per capita income evaluated at the mean, equals 3.06, that is, strictly above 1. Therefore, unlike the case of general public expenditure, evidence for Wagner's law in the case of public investment is stronger. This is further confirmed by Granger causality analysis (Table 5), which shows significant long-term causality from the error correction term to investment, as well as short-term causality from income to investment. Similar to the case of public expenditure, we find no evidence in this case that parliamentary reforms had an impact on the levels of public investment.

Table 5: t- and F-statistics and p-values (in brackets) for testing short- and long-term Granger causality: public investment

Source of causation →	ΔYPOPR	ΔIGDP	ΔCIRC	ECT_{t-1}
ΔYPOPR		0.30118	3.9437**	-0.935*
		[0.7420]	[0.0294]	[0.0620]
ΔIGDP	2.6908*		1.5824	-0.629***
	[0.0832]		[0.2211]	[0.0006]
ΔCIRC	2.6949*	0.37979		-1148
	[0.0829]	[0.6870]		[0.1084]

*** p<0.01 ** p<0.05 * p<0.1

5. Conclusions

In this study, we looked at the development of public consumption and investment and national income in Imperial Austria in the period 1870-1913. Using cointegration analysis and Granger causality, we established that there is no evidence to support Wagner's law in the case of general public expenditure. Rather, there is weak evidence that short-term causality runs from public expenditure to national income, in line with the Keynesian view. On the other hand, we find stronger evidence to support Wagner's hypothesis in the case of public investment. The estimated long-term income elasticity of public investment lies above 3, and therefore much above one, which is necessary for Wagner's law to hold. Moreover, there is evidence of short- and long-term Granger causality running from income to public investment. Moreover, levels of debt have a significant impact on increasing public expenditure, in line with previous qualitative studies. Finally, parliamentary reforms towards the end of the 19th century, which gave more power to the Imperial Council and social democratic movements, did not seem to change the overall trends in public expenditure.

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Appendix A. Detailed results

Table A.6: Unrestricted error correction model for ΔGGDP

	Coefficient	Std. error	t-ratio	p-value
Const.	−0.0701555	0.0456500	−1.5368	0.1336
YPOPR_{t-1}	0.140673	0.0404076	3.4813	0.0014
GGDP_{t-1}	−0.578177	0.149361	−3.8710	0.0005
CIRC_{t-1}	3.18649e–05	2.25799e–05	1.4112	0.1673
Pol.Con.III	−0.0498557	0.0756664	−0.6589	0.5144
ΔYPOPR	−0.175458	0.100061	−1.7535	0.0885
ΔCIRC	−5.61565e–05	8.06188e–05	−0.6966	0.4908
ΔGGDP_{t-1}	−0.0167965	0.153581	−0.1094	0.9136

Mean dependent var.	0.002287	SD dependent var.	0.008035
Sum squared resid.	0.001463	SE of regression	0.006560
R^2	0.447155	Adjusted R^2	0.333334
$F(7, 34)$	3.928576	P-value(F)	0.003061
Log-likelihood	155.9639	Akaike criterion	−295.9278
Schwarz criterion	−282.0264	Hannan-Quinn	−290.8324
$\hat{\rho}$	−0.105406	Durbin's h	−0.767546

Table A.7: Unrestricted error correction model for ΔIGDP

	Coefficient	Std. error	t-ratio	p-value
Const.	−0.0890210	0.0237225	−3.7526	0.0007
YPOPR_{t-1}	0.175459	0.0323107	5.4304	0.0000
IGDP_{t-1}	−0.685728	0.122601	−5.5932	0.0000
CIRC_{t-1}	1.28123e–05	8.86724e–06	1.4449	0.1579
POLCON	0.0235124	0.0412444	0.5701	0.5725
ΔYPOPR	−0.100479	0.0501621	−2.0031	0.0534
ΔYPOPR_{t-1}	−0.146627	0.0635881	−2.3059	0.0275
ΔCIRC	5.93928e–06	3.99358e–05	0.1487	0.8827
ΔIGDP_{t-1}	0.150103	0.132851	1.1299	0.2667

Mean dependent var.	0.001695	SD dependent var	0.004610
Sum squared resid.	0.000374	SE of regression	0.003366
R^2	0.570765	Adjusted R^2	0.466708
$F(8, 33)$	5.485114	P-value(F)	0.000194
Log likelihood	184.6131	Akaike criterion	−351.2262
Schwarz criterion	−335.5872	Hannan-Quinn	−345.4939
$\hat{\rho}$	−0.037523	Durbin's h	−0.478087

Table A.8: Restricted error correction model for $\Delta GGDP$ with trend

	Estimate	Std. error	t-ratio	p-value
θ_0	0.577672	0.148060	3.9016	0.0004
$YPOPR_{t-1}$	0.250651	0.0691790	3.6232	0.0009
$CIRC_{t-1}$	5.82530e–05	3.22648e–05	1.8055	0.0799
Pol.Con. III	−0.0852936	0.135657	−0.6287	0.5337
trend	−7.01417e–05	3.69354e–05	−1.8990	0.0661
$\Delta GGDP_{t-1}$	−0.0188269	0.153250	−0.1229	0.9029
$\Delta YPOPR$	−0.174348	0.0996918	−1.7489	0.0893
ΔCIRC	−5.32644e–05	8.11390e–05	−0.6565	0.5159

VAR system, lag order 2

OLS estimates, observations 1873-1913 ($T = 41$)

Portmanteau test: LB(10) = 80.1126, df = 72 [0.2397]

Equation 1: ΔYPOPR

	Coefficient	Std. error	t-ratio	p-value
Const.	0.0528071	0.0272701	1.9364	0.0614
ΔYPOPR_{t-1}	−0.399050	0.164611	−2.4242	0.0210
ΔYPOPR_{t-2}	−0.427611	0.146043	−2.9280	0.0061
ΔGGDP_{t-1}	−0.523505	0.214292	−2.4430	0.0201
ΔGGDP_{t-2}	−0.207120	0.235323	−0.8802	0.3851
ΔCIRC_{t-1}	−0.000279303	0.000101111	−2.7623	0.0093
ΔCIRC_{t-2}	−2.20307e–05	5.30603e–05	−0.4152	0.6807
ECT_GGDP_{t-1}	−0.293235	0.205772	−1.4250	0.1635

R^2	0.465471	Adjusted R^2	0.352086
$F(7, 33)$	4.105228	P-value(F)	0.002421
$\hat{\rho}$	0.000772	Durbin-Watson	1.889517

F-tests of zero restrictions

All lags of ΔYPOPR	$F(2, 33) = 6.7756$	[0.0034]
All lags of ΔGGDP	$F(2, 33) = 3.02432$	[0.0622]
All lags of ΔCIRC	$F(2, 33) = 5.91017$	[0.0064]
All vars., lag 2	$F(3, 33) = 3.20777$	[0.0356]

Equation 2: ΔGGDP

	Coefficient	Std. error	t-ratio	p-value
Const.	0.0430535	0.0200891	2.1431	0.0396
ΔYPOPR_{t-1}	0.127289	0.121264	1.0497	0.3015
ΔYPOPR_{t-2}	0.209004	0.107585	1.9427	0.0606
ΔGGDP_{t-1}	−0.0882241	0.157862	−0.5589	0.5800
ΔGGDP_{t-2}	0.0451813	0.173355	0.2606	0.7960
ΔCIRC_{t-1}	−1.01224e–05	7.44858e–05	−0.1359	0.8927
ΔCIRC_{t-2}	−1.46874e–05	3.90880e–05	−0.3758	0.7095
ECT_GGDP_{t-1}	−0.332370	0.151586	−2.1926	0.0355

R^2	0.364305	Adjusted R^2	0.229461
$F(7, 33)$	2.701672	P-value(F)	0.024969
$\hat{\rho}$	−0.024726	Durbin-Watson	1.985937

F-tests of zero restrictions

All lags of ΔYPOPR	$F(2, 33) = 2.3105$	[0.1150]
All lags of ΔGGDP	$F(2, 33) = 0.240988$	[0.7872]
All lags of ΔCIRC	$F(2, 33) = 0.138963$	[0.8708]
All vars., lag 2	$F(3, 33) = 1.29571$	[0.2922]

Equation 3: ΔCIRC

	Coefficient	Std. error	t-ratio	p-value
Const.	148.597	36.6400	4.0556	0.0003
ΔYPOPR_{t-1}	−598.118	221.170	−2.7043	0.0107
ΔYPOPR_{t-2}	−511.145	196.222	−2.6049	0.0137
ΔGGDP_{t-1}	679.904	287.922	2.3614	0.0243
ΔGGDP_{t-2}	86.5869	316.179	0.2739	0.7859
ΔCIRC_{t-1}	−0.325827	0.135853	−2.3984	0.0223
ΔCIRC_{t-2}	0.158939	0.0712916	2.2294	0.0327
ECT_GGDP_{t-1}	−1038.70	276.475	−3.7569	0.0007

R^2	0.591734	Adjusted R^2	0.505132
$F(7, 33)$	6.832816	P-value(F)	0.000048
$\hat{\rho}$	−0.012770	Durbin-Watson	1.984697

F-tests of zero restrictions

All lags of ΔYPOPR	$F(2, 33) = 6.60304$	[0.0039]
All lags of ΔGGDP	$F(2, 33) = 2.83968$	[0.0728]
All lags of ΔCIRC	$F(2, 33) = 3.59791$	[0.0386]
All vars., lag 2	$F(3, 33) = 3.53083$	[0.0253]

VAR system, lag order 2

OLS estimates, observations 1873-1913 ($T = 41$)

Portmanteau test: LB(10) = 69.1093, df = 72 [0.5747]

Equation 1: ΔYPOPR

	Coefficient	Std. error	t-ratio	p-value
Const.	0.0546884	0.0228435	2.3940	0.0227
ΔYPOPR_{t-1}	−0.607982	0.217665	−2.7932	0.0087
ΔYPOPR_{t-2}	−0.656175	0.196057	−3.3469	0.0021
ΔIGDP_{t-1}	−0.301866	0.390580	−0.7729	0.4453
ΔIGDP_{t-2}	−0.0484496	0.405852	−0.1194	0.9057
ΔCIRC_{t-1}	−0.000202385	9.71995e–05	−2.0822	0.0454
ΔCIRC_{t-2}	−1.22068e–05	5.15945e–05	−0.2366	0.8145
ECT_IGDP_{t-1}	−0.935954	0.483996	−1.9338	0.0620

R^2	0.426497	Adjusted R^2	0.283121
$F(8, 32)$	2.974676	P-value(F)	0.013129
$\hat{\rho}$	0.013507	Durbin-Watson	1.873189

F-tests of zero restrictions

All lags of ΔYPOPR	$F(2, 32) = 6.77273$	[0.0035]
All lags of ΔIGDP	$F(2, 32) = 0.301182$	[0.7420]
All lags of ΔCIRC	$F(2, 32) = 3.9437$	[0.0294]
All vars., lag 2	$F(3, 32) = 3.80795$	[0.0193]

Equation 2: ΔIGDP

	Coefficient	Std. error	t-ratio	p-value
Const.	0.0293264	0.00774838	3.7848	0.0006
ΔYPOPR_{t-1}	−0.0763539	0.0738307	−1.0342	0.3088
ΔYPOPR_{t-2}	0.0965337	0.0665013	1.4516	0.1563
ΔIGDP_{t-1}	0.184546	0.132483	1.3930	0.1732
ΔIGDP_{t-2}	0.147589	0.137663	1.0721	0.2917
ΔCIRC_{t-1}	4.26365e–06	3.29695e–05	0.1293	0.8979
ΔCIRC_{t-2}	−2.60664e–05	1.75006e–05	−1.4895	0.1462
ECT_IGDP_{t-1}	−0.629083	0.164169	−3.8319	0.0006

R^2	0.566907	Adjusted R^2	0.458633
$F(8, 32)$	5.235881	P-value(F)	0.000310
$\hat{\rho}$	−0.019570	Durbin-Watson	2.017169

F-tests of zero restrictions

All lags of ΔYPOPR	$F(2, 32) = 2.69079$	[0.0832]
All lags of ΔIGDP	$F(2, 32) = 1.4569$	[0.2480]
All lags of ΔCIRC	$F(2, 32) = 1.5824$	[0.2211]
All vars., lag 2	$F(3, 32) = 1.69205$	[0.1884]

Equation 3: ΔCIRC

	Coefficient	Std. error	t-ratio	p-value
Const.	70.1661	32.8128	2.1384	0.0402
ΔYPOPR_{t-1}	−604.114	312.658	−1.9322	0.0622
ΔYPOPR_{t-2}	−557.202	281.620	−1.9786	0.0565
ΔIGDP_{t-1}	480.454	561.037	0.8564	0.3982
ΔIGDP_{t-2}	−62.8467	582.974	−0.1078	0.9148
ΔCIRC_{t-1}	−0.240303	0.139619	−1.7211	0.0949
ΔCIRC_{t-2}	0.216980	0.0741113	2.9278	0.0062
ECT_IGDP_{t-1}	−1148.06	695.221	−1.6514	0.1084

R^2	0.499352	Adjusted R^2	0.374190
$F(8, 32)$	3.989648	P-value(F)	0.002251
$\hat{\rho}$	0.012140	Durbin-Watson	1.907300

F-tests of zero restrictions

All lags of ΔYPOPR	$F(2, 32) = 2.6949$	[0.0829]
All lags of ΔIGDP	$F(2, 32) = 0.379786$	[0.6870]
All lags of ΔCIRC	$F(2, 32) = 4.28819$	[0.0224]
All vars., lag 2	$F(3, 32) = 3.94071$	[0.0168]