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PUBLIC INVESTMENT IN TRANSPORTATION INFRASTRUCTURES AND INDUSTRY PERFORMANCE IN PORTUGAL

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The objective of this paper is to evaluate the effects at the industry level of public investment in transportation infrastructures in Portugal. The empirical results are based on VAR/ECM models for the Portuguese economy and for eighteen industries covering the whole spectrum of economic activity in the country. These models consider private-sector output, employment and investment as well as public investment. Empirical results at the aggregate level indicate that public investment has a positive effect on both private inputs as well as on private output and that it affects labor productivity positively. These aggregate results, however, hide a wide variety of industry-level effects. In absolute terms, the industries that benefit the most from public investment are Construction, Trade, Transportation, Finance, Real Estate, and Services. In turn, relative to their size, the industries that benefit the most are Mining, Non-Metal Products, Metal Products, Construction, Restaurants, Transportation, and Finance, and, therefore, public investment tends to shift the industry mix toward these industries. Accordingly, our empirical results suggest that although public investment has been a powerful instrument to enhance the long-term economic performance in Portugal it does so in a way that is rather unbalanced across industries.

Keywords: Infrastructures, Industry Performance, Portugal
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1. INTRODUCTION

In this paper we focus on the impact at the industry level of public investment in transportation infrastructures in Portugal. The backwardness of the Portuguese economy relative to its European Union (EU) partners led to the establishment in 1989 of the EU structural transfers programs for Portugal. The cornerstone of these programs has been the development of a modern transportation infrastructure network intended to improve accessibility among regions and to external markets. Therefore, for the last fifteen years, the strategy of long-term development in Portugal has been largely based on the development of transportation infrastructures.

There is now strong evidence suggesting that public investment in transportation infrastructures has been a powerful instrument to promote long-term growth in Portugal and in bringing the country up to EU standards [see Pereira and Andraz (2005)]. Despite this evidence, the question of the impact of these investments at the industry level and the relation between aggregate and industry-specific effects remains unanswered. This is a critical issue, however, since the relevance of the effects of public investment at the aggregate level does not provide any useful information as to the industry incidence of such effects. In fact, significant positive aggregate effects could be associated with balanced positive industry-level effects or they could mask uneven gains across industries. Also, it is conceivable that small effects at the aggregate level could hide significant effects for specific industries. Ultimately, there is the question of how the development of a transportation infrastructure has affected the industry mix in the country.

The analysis of the effects of public infrastructures on private output was brought to the limelight by the work of Aschauer (1989) which identifies, in the case of the US, very large aggregate effects. Subsequent studies, both of the US case and of a variety of other countries, however, failed to replicate such large effects and often even failed to find meaningful positive results [see Gramlich (1994) and Munnell (1992) for detailed surveys of this literature].

Probably due to the lack of consensus on the aggregate effects of public infrastructures, the issue of their relative effects across industries has been largely neglected. Although several studies for the US make reference to specific industries they have essentially a regional focus [see, for example, Evans and Karras (1994), and Moomaw and Williams (1991)]. The sectoral dimension is more directly relevant in the studies of Fernald (1993), Gokirmak (1995), Nadiri and Mamuneas (1994, 1996), Greenstein and Spillar (1995), Holleyman (1996), Pinnoi (1992) and more recently Pereira and Andraz (2003). The estimates of the effects of public investment at the industry level tend to be smaller than the ones in Aschauer (1989) and the variations across industries tend to be within relatively small ranges.

The international evidence at the industry level is even less abundant. It includes contributions such as Berndt and Hansson (1991) for Sweden, Seitz (1994), Seitz and Licht (1995) for Germany, Lynde and Richmond (1993) for the U.K., Shah (1992) for

Mexico, and Pereira and Roca (2001) for Spain. The magnitude and significance of the effects vary greatly among countries and international comparisons are difficult due to the use of different measures of public capital, different levels of aggregation, and different methodologies.

In this paper, we follow the methodology for the analysis of the impact of public infrastructures in the US developed in Pereira (2000) and applied at the industry level in Pereira and Andraz (2003). In doing so, we adopt a vector auto-regressive approach to analyze the effects of public investment on output, employment and investment. We develop separate models for the Portuguese economy and for each of eighteen different industries. This approach highlights the relevance of dynamic feedbacks among the different variables as well as the possible endogeneity of public investment decision. Furthermore, it allows us to identify the effects of public investment at the industry level in a way that is methodologically consistent with the evaluation of the effects of public investment at the aggregate level.

2. DATA SOURCES AND DESCRIPTION

We use annual data for the period 1976-1998. The private sector data was obtained from the Bank of Portugal (1997) and different annual issues of the National Accounts published by National Institute of Statistics available on-line at http://www.ine.pt. Output and private investment are measured in constant 1995 prices, while employment is measured in full-time equivalent employees. Summary statistics are provided in Table 1. Agriculture (S1), Construction (S11), Trade (S12), Real Estate (S17) and Services (S18) are the five most important industries in terms of their share on the GDP. On average, they account for 55.2% of the GDP. In terms of the share of employment, the five most important industries now include Textiles (S5) instead of Real Estate (S17) and account for 70.7% of aggregate employment. Finally, the five most important industries in terms of their share of private investment are also the top-five industries in terms of output with Transportation (S14) in place of Agriculture (S1) and represent 61.8% of aggregate investment.

The data for public investment in transportation infrastructures is obtained from Pereira and Andraz (2001) and is also measured in constant 1995 prices. This database is the result of a long and meticulous research effort, sponsored by the Portuguese Ministry of Planning. It includes data on public investment in national roads, municipal roads, highways, ports, airports, and railways. It covers, in a consistent manner, the period from 1976 to 1998. Summary statistics are provided in Table 2.

One cannot talk about the main features of the public investment data in Portugal for this time period without mentioning at the outset the existence of EU-sponsored structural transfer programs in the form of Community Support Frameworks (CSF) for Portugal. The backwardness of the Portuguese economy relative to its European Union partners led to the establishment of the EU Structural Funds Programs for Portugal in 1989.

Table 1. Shares of Private Sector Variables and Public Investment (in percentage)

Industries	Output			Employment			Private Investment		
	1976-88	1989-98	Sample average	1976-88	1989-98	Sample average	1976-88	1989-98	Sample average
Agriculture (S1)	10.91	6.17	8.85	18.62	12.77	16.07	4.00	2.73	3.45
Mining (S2)	0.54	0.69	0.60	0.44	0.28	0.37	2.32	1.23	1.85
Food (S3)	4.84	4.70	4.78	2.86	3.02	2.93	3.23	3.69	3.43
Textiles (S4)	6.52	5.82	6.21	8.58	8.82	8.69	4.41	3.60	4.06
Paper (S5)	1.97	2.13	2.04	1.31	1.44	1.37	2.82	2.40	2.64
Chemicals (S6)	2.90	2.08	2.54	1.91	1.07	1.55	3.55	1.11	2.49
Non-Metal Products (S7)	2.06	1.35	1.75	1.75	1.04	1.44	0.49	0.43	0.46
Metal Products (S8)	5.73	4.19	5.06	5.40	4.37	4.95	4.27	3.99	4.15
Other Manufacturing (S9)	3.28	3.21	3.25	3.87	3.72	3.80	3.29	2.67	3.02
Utilities (S10)	2.97	3.82	3.34	0.72	0.68	0.70	6.82	2.01	4.73
Construction (S11)	9.22	6.85	8.19	10.23	9.44	9.89	4.80	5.07	4.92
Trade (S12)	16.62	15.62	16.18	11.45	13.77	12.46	5.86	6.91	6.32
Restaurants (S13)	2.34	3.25	2.73	2.95	4.27	3.52	0.97	1.75	1.31
Transportation (S14)	4.74	4.14	4.48	3.79	3.07	3.48	7.97	5.63	6.95
Communications (S15)	1.87	2.53	2.16	1.17	0.97	1.08	3.24	3.57	3.38
Finance (S16)	5.66	6.25	5.92	1.84	1.96	1.89	2.47	4.25	3.25
Real Estate (S17)	5.15	9.17	6.90	0.97	3.94	2.26	26.34	27.86	27.00
Services (S18)	12.70	18.13	15.07	22.12	25.39	23.54	13.16	21.09	16.61
Portugal	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

The first CSF covered the period from 1989 to 1993 and the second CSF covered the period from 1994 to 1999. Therefore, our sample includes 13 years prior to and 10 year with the CSF programs. This fact is incorporated in this analysis in that we systematically allow for structural breaks related to the two CSF programs.

From our standpoint, there are two characteristics of these programs that should be mentioned. First, in terms of their magnitude, these are extremely large programs. When both EU transfers and domestic financing are considered, the CSF for the period of 1989 to 1993 represented about 9.0% of the Portuguese GDP for the period while the CSF for the period of 1994 to 1999 represented about 6.7%. Second, in terms of their composition, the cornerstone of these programs has been the development of a modern infrastructure in order to improve accessibility among regions and to external markets. Infrastructure programs, transportation and otherwise, represented 46.6% of the projected program investment for the period of 1989 to 1993 and 40.0% for the period of

1994 to 1999. For further details see, for example, Gaspar and Pereira (1995) and Pereira (1998).

Overall, public investment averages 1.55% of the GDP for the sample period. Its share of the GDP shows an increasing trend during the sample period, which is more visible during the 1990's. In fact, the share of the GDP changes from an average of 1.2% for 1976-88 to an average of 2.0% for 1989-98. Therefore, the data fully reflect the conventional wisdom that the CSFs brought a greater dynamism to the public investment in infrastructures in the country. Furthermore, it is also possible to detect a significant change from the first CSF to the second CSF, in that the share of public investment increased from an average of 1.8% to 2.2% from the first to the second CSF.

Table 2. Shares of Public Investment on GDP and on Private Investment

Aggregate Public Investment	1976-80	1981-85	1986-88	1989-93	1994-98	Averages		
						1976-88	1989-98	Sample
Share of GDP (%)	1.21	1.26	1.27	1.76	2.16	1.24	1.96	1.55
Share of Private Investment (%)	7.61	7.86	6.50	8.38	9.49	7.45	8.94	8.10

3. PRELIMINARY EMPIRICAL RESULTS

In this section we analyze the unit root characteristics of the individual time series as well as the possibility of cointegration. Then we determine the appropriate VAR/ECM model specification, both at the aggregate level and at the industry level. In all of these steps we allow for the presence of structural breaks associated with the two CSFs. For the sake of brevity details of the test results are not presented in the paper but are available from the authors upon request.

3.1. Unit Root Tests

To determine the order of integration of the variables, we use the Augmented Dickey-Fuller (ADF) t-test. The Bayesian Information Criterion (BIC) is used to determine the optimal number of lagged differences to be included in the regressions. We include deterministic components and dummies for the periods of the two CSF programs when they are statistically significant.

We start by applying the ADF t-tests to the different variables, aggregate and disaggregated private output, employment, and investment, and public investment, in log-levels. The test results suggest overwhelmingly that these variables are not stationary. We then test for stationarity in growth rates. The results of the ADF t-tests at the aggregate level suggest that the null hypothesis of a unit root in the growth rate can be rejected for all variables at the level of significance lower than 1%. Also, for almost all of the industry-level variables, the values of the t-statistics are smaller than the 1% critical values. For the private employment variable, there is only one case where the value of the t-statistics is higher than the 5% critical value. We take this as an indication that stationarity in growth rates is a good approximation for all the variables. This evidence is consistent with the conventional wisdom in the macroeconomics literature that aggregate output, employment, and private investment are I (1). Although, most of our series are more disaggregated, the same pattern of stationarity in growth rates is not surprising.

3.2. Cointegration Analysis

We now test for cointegration among output, employment, investment and public investment at both the aggregate and industry levels. Following the standard Engle-Granger approach, we performed four tests in each case. This is because it is possible that one of the variables enters the co-integrating relationship with a statistically insignificant coefficient. We do not know, a priori, whether or not this will happen. If it does happen, however, a test that uses such a variable as the endogenous variable will not pick up the cointegration. Therefore, a different variable is endogenous in each of the four tests. We apply the ADF t-test to the residuals from the regressions of each variable on the remaining variables. This makes a total of 24 tests for each sector. In all of the tests, the optimal lag is chosen using the BIC, and a deterministic component and dummies for periods of the two CSF programs are included when they are statistically significant.

At the aggregate level, the values of the t-statistics are larger than the 5% or, at least, the 1% critical values. Thus, the ADF tests cannot reject the null hypothesis of a random walk, and we cannot reject that the variables are not cointegrated. At the industry level, for nine industries the values of the t-statistics are also larger than the 1% critical values for all of the four cases. For six industries, the values of the t-statistics are larger than the 1% critical values in three of the four cases considered. For the remaining three industries, the values of the t-statistics are larger than the 1% critical values in two of the four cases considered. These results strongly suggest that, also at the industry level, co-integration among variables can be rejected. This is consistent with the view that it is rather unlikely to find co-integration when combining more disaggregated private sector variables with aggregate measure of public investment when no cointegration was found at the aggregate level. The absence of cointegration is consistent with results in the relevant literature [see, for example, Pereira (2000) and Pereira and Andraz (2003) for the US case and Pereira and Andraz (2005) for the Portuguese case]. Furthermore, in the case of economies in a transition stage of their development, as it is the case of the Portuguese economy, not finding in the data evidence of convergence to the so-called great ratios among the aggregate variables in the economy is hardly surprising.

3.3. Model Specification

We have now determined that all variables are stationary of first order and that they are not cointegrated. Accordingly, we follow the standard procedure in the econometrics literature and determine the specifications of the VAR models in growth rates. We consider a VAR model for the aggregate economy as well as for each industry, for a total of nineteen models. All models include the relevant output, employment and private investment variables. In addition, each of the nineteen VAR models includes the aggregate measure of public investment. This means that, consistently with our conceptual arguments, the public investment variable is allowed to be an endogenous variable throughout the estimation procedure. Furthermore, the same aggregate measure of public investment is used both in the aggregate model and the eighteen industry-specific models. This is consistent with the view that public investment is a non-exclusionary good, which has the potential of affecting all economic activities simultaneously.

The VAR specification has two dimensions, which were determined jointly using the BIC criterion - the specification of the deterministic components and the consideration of the possibility of structural breaks. In all cases, first order specifications were selected. A higher order was not considered due to relative small size of sample. In terms of the deterministic components, the BIC selects a specification with constant for the aggregate model. For 9 of the 18 models, the BIC tests select a specification with a constant and a trend. For one case, the Other Manufacturing (S9), the selected specification does not include any deterministic components. For the remaining 8 industries, the BIC tests suggests a specification with a constant but no trend.

In order to consider the possibility of structural changes due to the two CSF programs, three alternative VAR specifications are considered. The first allows for no structural break. The second allows for one structural break/one dummy distinguishing the periods before and after the CSF programs. The third allows for two structural breaks/two dummies reflecting the possibility of the three different periods, one before the CSF programs and one for each of the two CSF programs. We find that the BIC criterion leads to the selection of the VAR specification with two structural breaks for all nineteen models. This suggests that in addition to considering the differences before and after the EU structural programs, there are important structural changes associated with each of the two CSF programs.

3.4. Identifying and Measuring the Effects of Public Investment

We use the impulse-response functions associated with the estimated VAR models to examine the effects of one-percentage point, one-time shocks in the rate of growth of public investment. Clearly and by their very nature, these one-time shocks in the growth rates translate into permanent shocks in levels.

Table 3. Long-term Accumulated Elasticities of Private Sector Variables with Respect to Public Investment

Industries		Output	Employment	Private Investment
Agriculture (S1)	central case	0.11856	-0.02010	1.79462
	range of varation	[0.119;0.174]	[-0.033;-0.006]	[1.221;1.795]
Mining (S2)	central case	1.44383	0.47928	-3.56416
	range of varation	[0.152;1.494]	[0.212;0.491]	[-5.869;-1.696]
Food (S3)	central case	0.09976	-0.06550	0.91688
	range of varation	[-0.053;0.111]	[-0.076;0.102]	[0.254;1.007]
Textiles (S4)	central case	-0.16394	-0.04050	1.22091
	range of varation	[-0.287;0.049]	[-0.153;0.093]	[0.384;1.379]
Paper (S5)	central case	-0.16211	0.08860	1.16808
	range of varation	[-0.301;0.488]	[0.089;0.406]	[0.184;1.291]
Chemicals (S6)	central case	-0.00125	0.44430	1.14509
	range of varation	[-0.070;0.258]	[0.375;0.558]	[0.918;1.237]
Non-Metal Products (S7)	central case	0.36656	0.27550	1.93367
	range of varation	[-0.484;0.367]	[-0.346;0.276]	[0.676;1.969]
Metal Products (S8)	central case	0.37450	0.44901	0.92069
	range of varation	[-0.028;0.375]	[0.136;0.496]	[0.208;0.996]
Other Manufacturing (S9)	central case	-0.29733	-0.19773	1.10558
	range of varation	[-0.297;0.066]	[-0.198;-0.042]	[-1.106;1.210]
Utilities (S10)	central case	0.35726	0.07285	-0.45306
	range of varation	[0.356;0.617]	[0.062;0.112]	[-3.846;0.657]
Construction (S11)	central case	0.66934	0.36240	1.99280
	range of varation	[0.321;0.679]	[0.123;0.362]	[1.118;2.322]
Trade (S12)	central case	0.01793	0.07934	1.11524
	range of varation	[0.009;0.031]	[0.074;0.086]	[0.966;1.124]
Restaurants (S13)	central case	0.54647	0.07214	2.30059
	range of varation	[0.127;0.548]	[-0.036;0.072]	[1.705;2.934]
Transportation (S14)	central case	0.02675	0.35499	1.25416
	range of varation	[0.019;0.078]	[0.158;0.385]	[-0.067;2.317]
Communications (S15)	central case	-0.05453	0.07235	0.69859
	range of varation	[-0.080;-0.051]	[0.028;0.076]	[0.531;0.791]
Finance (S16)	central case	0.47878	0.24611	0.49017
	range of varation	[-0.098;0.479]	[0.116;0.266]	[0.490;0.777]
Real Estate (S17)	central case	0.23177	-0.07734	0.47676
	range of varation	[-0.074;0.674]	[-0.806;1.381]	[-0.064;0.517]
Services (S18)	central case	0.13804	0.02625	0.68995
	range of varation	[0.030;0.241]	[0.001;0.030]	[0.148;0.709]
Portugal	central case	0.15360	0.07870	0.82944
	range of varation	[0.122;0.154]	[0.062;0.080]	[0.471;0.832]

NB: In parenthesis are the ranges of variation across all Choleski orthogonalization alternatives.

In this context, our methodology allows dynamic feedbacks among the different variables to play a critical role, both in the identification of the innovations and in the measurement of the effects of such innovations.

The central issue for the determination of effects of public investment is the identification of innovations that are truly exogenous. This means that we need to identify shocks to public investment that are not contemporaneously correlated with shocks in the remaining variables. These exogenous shocks are not subject to the contemporaneous reverse causation problem. In dealing with this issue, we draw from the approach followed in the literature on the effects of monetary policy [see, for example, Christiano, Eichenbaum and Evans (1996), and Rudebush (1998).]. This approach was adopted in the context of the analysis of the effects of public infrastructures by Pereira (2000) and the details about its application at the industry level may be found in Pereira and Andraz (2003).

In measuring the effects of the innovations in public investment, we report the long-term accumulated elasticities of the private-sector variables with respect to public investment (see Table 3 for details). Long-term is defined as the time horizon over which the growth effects of innovations disappear. These elasticities represent the total percentage point change in the private-sector variable for a long-term accumulated percentage point change in public investment, accounting for all the dynamic feedback effects among the different variables. We also report the long-term accumulated marginal products of public investment (see Tables 4, 5, and 6 for details). These figures measure the change in the private-sector variables per each accumulated million euro long-term change in public investment. We obtain each figure by multiplying the ratio of each private variable to public investment for the last ten years, by the elasticity of each private variable with respect to public investment. The choice of the ratios for the ten last years is designed to reflect the relative scarcity of public investment at the margin of the sample period without letting these ratios be overly affected by business cycle factors.

Finally, it should be noted that, since we are considering the effects of accumulated changes in public investment we are actually analyzing the effects of permanent changes in the stock of infrastructure capital. Nevertheless, for the sake of consistency with the stationary data used in the VAR estimates, all variables including public investment being stationary in growth rates, we will refer to these as the effects of public investment.

4. THE AGGREGATE EFFECTS OF PUBLIC INVESTMENT

Although that is not the focus of our discussion, we start with the analysis of the aggregate results to bring a general perspective to the industry-level results that follow. The aggregate results are reported in the bottom section of Tables 4, 5, and 6, for private employment, investment and output, respectively.

4.1. The Aggregate Effects of Public Investment

The elasticity of private employment with respect to public investment is 0.079. In terms of job creation, this means that one million euros in public investment generate, in the long-term, 231 new private sector jobs. In turn, the elasticity of private investment with respect to public investment is 0.829. This implies that one million euros in public investment induce, in the long-term, an accumulated increase of 9.4 million euros in private investment. Therefore, at the aggregate level, public investment crowds in both private employment and private investment.

We also find that public investment has a positive impact on private output. The elasticity of private output with respect to public investment is 0.154, which implies that one million euros in public investment leads to an accumulated increase in output of 8.01 million euros. Assuming a life horizon of twenty years and a depreciation rate of 5%, this implies a rate of return of 15%, a rate well above the range one would expect for the rate of return on private investment. From this perspective, the reliance on public investment in transportation infrastructures as the cornerstone of a development strategy in Portugal seems to have been justified.

4.2. The Relationship Between the Aggregate and Industry-level Results

The ultimate objective in this paper is to identify the decomposition at the industry level of the aggregate effects of public investment. Before we do so, however, we need to compare the results from the aggregate model with the sum of the results obtained from the industry-specific models. Indeed, for the industry disaggregation to be credible one would want the sum of the effects estimated with the eighteen industry-specific models to be discussed below, to be in line with the effects just presented and which were obtained with the aggregate model.

The relationship between the aggregate results and the sum of the industry-specific results requires some reflection. Since public infrastructures are a public good, when public investment occurs, the new infrastructures become available, simultaneously, to all industries. From this standpoint, the sum of the marginal products of public investment across industries should be equal to the marginal products obtained at the aggregate level. It is plausible, however, to expect the sum of the industry-specific marginal products to somewhat differ from the aggregate effects. This is due to the possible existence of general equilibrium effects that are not captured at the industry level. For example, when public infrastructures are installed, more inputs are desired, simultaneously, by all industries. This simultaneous increase in demand, however, is limited by resource constraints in the economy. Therefore, part of the increased demand induces higher input prices and a downward adjustment of the industry-specific input demands. Thus, it is possible that the sum of the industry-specific marginal products may somewhat exceed the aggregate effects. In the same vein, an increase in output for each industry individually would not affect substantially aggregate output prices, i.e., it is as if each industry has a horizontal output supply schedule. At the aggregate level, however, we would expect the simultaneous increase in output in most industries to lead to a reduction in the equilibrium output price and to smaller aggregate output effects.

According to our empirical results, the sum across the different industries of the effects of public investment represents 107.8%, 97.1% and 115.2% of the values obtained with the aggregate model for employment, private investment, and output, respectively. This means that the results from the eighteen industry-specific models are remarkably in line with the results from the aggregate model, which gives great credibility to our effort to find the industry patterns behind the aggregate results. Moreover, general equilibrium effects seem to be somewhat relevant in the case of employment and output, but less so in the case of private investment.

5. THE EFFECTS OF PUBLIC INVESTMENT AT THE INDUSTRY LEVEL

We consider now the effects of public investment on transportation infrastructures on private sector variables at the industry level. The main estimation results for private employment, investment, and output, are reported in Tables 4, 5, and 6, respectively.

5.1. The Effects of Public Investment on Private Employment

Estimation results suggest that the positive elasticity of employment with respect to public investment at the aggregate level hides a certain disparity of effects at the industry level. In fact, we find positive elasticities in thirteen of the eighteen industries and negative elasticities in the remaining five. The elasticities span a relatively short range from -0.198 for Other Manufacturing (S9) to 0.479 for Mining (S2). The largest positive elasticities occur for Mining (S2), Chemicals (S6), Metal Products (S8), Construction (S11), and Transportation (S14), while the negative elasticities occur in Agriculture (S1), Food (S3), Textiles (S4), Other Manufacturing (S9), and Real Estate (S17).

Table 4. Effects of Public Investment on Private Employment

Industries	% of Private Employment	Elasticities	Number of Jobs (per million euros)	Shares of Benefits (%)
Agriculture (S1)	12.77	-0.02010	-8	----
Mining (S2)	0.28	0.47928	4	1.32
Food (S3)	3.02	-0.06550	-6	----
Textiles (S4)	8.82	-0.04050	-11	----
Paper (S5)	1.44	0.08860	4	1.32
Chemicals (S6)	1.07	0.44430	15	4.95
Non-Metal Products (S7)	1.04	0.27550	9	2.97
Metal Products (S8)	4.37	0.44901	59	19.47
Other Manufacturing (S9)	3.72	-0.19773	-21	----
Utilities (S10)	0.68	0.07285	1	0.33
Construction (S11)	9.44	0.36240	101	33.33
Trade (S12)	13.77	0.07934	32	10.56
Restaurants (S13)	4.27	0.07214	9	2.97
Transportation (S14)	3.07	0.35499	33	10.89
Communications (S15)	0.97	0.07235	2	0.66
Finance (S16)	1.96	0.24611	14	4.62
Real Estate (S17)	3.94	-0.07734	-8	----
Services (S18)	25.39	0.02625	20	6.60
Sum across Industries	100.00		249	
Portugal		0.07870	231	

A better idea of the impact in absolute terms of public investment on employment is obtained by focusing on its marginal product. Our estimates at the industry level suggest that one million euros in public infrastructures generate, in the long-term, a total of 303 jobs. Of these, 249 are new jobs, while the remaining 54 correspond to jobs shifted across industries. The industries that benefit the most are Metal Products (S8), Construction (S11), Trade (S12), Transportation (S14), and Services (S18) with 59, 101, 32, 33, and 20 new jobs, respectively. These five industries account for 80.9% of the total gains in employment. In turn, Textiles (S4) and Other Manufacturing (S9) are the industries that lose more jobs, 11 and 21, respectively.

In turn, a better idea of the impact in relative terms of public investment on employment is obtained by comparing the share of new jobs created per industry and the employment share of the industry. Of the five industries that concentrate most of the benefits in terms of job creation, we see that Metal Products (S8), Construction (S11) and Transportation (S14) benefit in a way that is greatly disproportionate to their shares of private employment. Other industries, such as Mining (S2), Chemicals (S6) Non-Metal (S7), and Finance (S16), while showing less significant gains in absolute terms, still benefit in relative terms more than proportionally to their share of private employment. Overall, the seven industries with significant gains in relative terms correspond to 21.2% of total employment and capture 77.6% of the benefits. Therefore, public investment has contributed markedly to the concentration of employment in these industries. Finally, the biggest losers in relative terms are Utilities (S10), Restaurants (S13), and Services (S18), which benefit from public investment in a way that is disproportionately lower than their share of private employment. This is, naturally, in addition to the industries that actually lost jobs, i.e., Agriculture (S1), Food (S3), Textiles (S4), Other Manufacturing (S9), and Real Estate (S17).

5.2. The Effects of Public Investment on Private Investment

In terms of the effects of public investment on private investment, the aggregate positive effect is also present for most industries. Indeed, the elasticities of private investment with respect to public investment are positive in sixteen of the eighteen industries, the exceptions being Mining (S2) and Utilities (S10). The elasticities of private investment tend to be relatively high in absolute value, ranging from -3.56 for Mining (S2) to 2.30 for Restaurants (S13). The largest positive elasticities are for Agriculture (S10), Non-Metal Products (S7), Construction (S11), and Restaurants (S13).

In terms of the impact of public investment on private investment in absolute terms, our estimates suggest that one million euros in public investment generate, in the long-term, an increase in private investment of 9.78 million euros. This figure corresponds to a net increase of 9.18 million and to a negligible transfer of private investment of 0.60 million euros across industries. The industries that benefit the most are Construction (S11), Trade (S12), Transportation (S14), Real Estate (S17) and Services (S18) with marginal products of 1.16, 0.88, 0.82, 1.50, and 1.63 million euros, respectively. These five industries capture 61.4% of the total benefits of public investment on private investment.

In terms of the gains relative to the industry shares of private investment, among the industries with the greatest benefits in absolute value, Construction (S11), Trade (S12), and Transportation (S14) are now the big winners. Among the other industries, Agriculture (S1), Textiles (S4), Paper (S5), Non-Metal Products (S7), Other Manufacturing (S9) and Restaurants (S13), also show benefits that are disproportionately large compared to their share of private investment. Overall, these nine industries correspond to 31.2% of total private investment in the country and capture 53.1% of the benefits in terms of private investment. Therefore, public investment has contributed markedly to the concentration of private investment in these industries. In turn, the big losers in relative terms are Mining (S2) and Utilities (S10) which see an absolute decline in private investment and Communication (S15), Finance (S16), Real Estate (S17) and Services (S18) which benefit less than proportionally to their shares of private investment.

Table 5. Effects of Public Investment on Private Investment

Industries	% of Private Investment	Elasticities	Marginal Products	Shares of Benefits (%)
Agriculture (S1)	2.73	1.79460	0.58	5.93
Mining (S2)	1.23	-3.56420	-0.50	----
Food (S3)	3.69	0.91688	0.39	3.99
Textiles (S4)	3.60	1.22091	0.52	5.32
Paper (S5)	2.40	1.16808	0.33	3.37
Chemicals (S6)	1.11	1.14509	0.14	1.43
Non-Metal Products (S7)	0.43	1.93367	0.10	1.02
Metal Products (S8)	3.99	0.92069	0.41	4.19
Other Manufacturing (S9)	2.67	1.10558	0.34	3.48
Utilities (S10)	2.01	-0.45306	-0.10	----
Construction (S11)	5.07	1.99280	1.16	11.86
Trade (S12)	6.91	1.11524	0.88	9.00
Restaurants (S13)	1.75	2.30059	0.46	4.70
Transportation (S14)	5.63	1.25416	0.82	8.38
Communications (S15)	3.57	0.69859	0.29	2.97
Finance (S16)	4.25	0.49017	0.23	2.35
Real Estate (S17)	27.86	0.47676	1.50	15.34
Services (S18)	21.09	0.68995	1.63	16.67
Sum across Industries	100.00		9.18	
Portugal		0.82944	9.45	

5.3. The Effects of Public Investment on Private Output

The positive aggregate effects of public investment on private output hide a variety of effects at the industry level. Indeed, our empirical results suggest that public investment has positive effects on private output for thirteen of the eighteen industries and negative effects in the remaining five. Overall, the elasticities range from -0.312 for Utilities (S10) to 1.444 for Mining (S2), still, most of the elasticities fall in a relatively narrow range since the elasticity for Mining (S2) is clearly an outlier. The largest positive elasticities are for Mining (S2), Construction (S11), Restaurants (S13), and Finance (S16) while the industries with negative elasticities are Textiles (S4), Paper (S5), Chemicals (S6), Other Manufacturing (S9), and Communications (S15).

In terms of the marginal product of public investment, the overall net gain is 9.23 million euros in long-term output per one million euros in public investment. This figure reflects a total gain of 10.48 million euros of which 1.25 million euros corresponds to a shift in output across industries.

Table 6. Effects of Public Investment on Private Output

Industries	% of Private Output	Elasticities	Marginal Products	Shares of Benefits (%)
Agriculture (S1)	6.17	0.11856	0.40	3.81
Mining (S2)	0.69	1.44380	0.55	5.25
Food (S3)	4.70	0.09976	0.25	2.39
Textiles (S4)	5.82	-0.16394	-0.51	----
Paper (S5)	2.13	-0.16211	-0.18	----
Chemicals (S6)	2.08	-0.00125	0.00	0.00
Non-Metal Products (S7)	1.35	0.36656	0.28	2.67
Metal Products (S8)	4.19	0.37450	0.83	7.92
Other Manufacturing (S9)	3.21	-0.29733	-0.49	----
Utilities (S10)	3.82	0.35726	0.72	6.87
Construction (S11)	6.75	0.66934	2.37	22.61
Trade (S12)	15.62	0.01793	0.15	1.43
Restaurants (S13)	3.25	0.54647	0.93	8.87
Transportation (S14)	4.14	0.02675	0.06	0.57
Communications (S15)	2.53	-0.05453	-0.07	----
Finance (S16)	6.25	0.47878	1.58	15.08
Real Estate (S17)	9.17	0.23177	1.07	10.21
Services (S18)	18.13	0.13804	1.29	12.31
Sum across Industries	100.00		9.23	
Portugal		0.15360	8.01	

The industries with the largest marginal products are Construction (S11), Restaurants (S13), Finance (S16), Real Estate (S17), and Services (S18) with marginal products of 2.37, 0.93, 1.58, 1.07, and 1.29, respectively. Overall these five industries concentrate 69.1% of the benefits.

In terms of the impact of public investment on the industry composition of private output it is particularly informative to compare the size of benefits relative to the size of the industries. In fact, of the thirteen industries that benefit from public investment only seven do so in a way that is disproportionately greater than their shares of private output. These industries are Mining (S2), Non-Metal Products (S7), Metal Products (S8), Utilities (S10), Construction (S11), Restaurants (S13), and Finance (S16). Overall, these seven industries correspond to 26.3% of total output in the country but capture 69.3% of the benefits in terms of output. Therefore, public investment has contributed markedly to the concentration of output in these industries. As a corollary, public investment tends to shift the industry mix of output away from the remaining eleven industries. Of these, particularly affected are five industries which are negatively affected by public investment, Chemicals (S6) which is unaffected, and Trade (S12) and Transportation (S14) which benefit substantially less than proportionately to their share of private output.

At this stage it is important to note that the nature of the effects of public investment on output at the industry level highlights the importance of considering the indirect effects of public investment on output, i.e., the effects generated through the changes in private inputs. This is, of course, in addition to considering the direct effects of public investment on private output as a production externality. In fact, eight of the thirteen industries with positive elasticities of private output have also positive elasticities for both private inputs. The direct and indirect effects work in the same direction. For other three industries, Agriculture (S1), Food (S3) and Real Estate (S17), the elasticities of employment are negative but the elasticities of private investment are positive. Accordingly, for these industries, the direct and indirect private investment effects dominate the negative effect on employment. In turn, Mining (S2) and Utilities (S10) display negative elasticities of private investment, but positive employment elasticities. Accordingly, for these industries, the direct and employment effects dominate the negative effect on private investment. Finally, among the five industries with negative elasticities of output, Textiles (S4) and Other Manufacturing (S9), display positive elasticities of private investment and positive elasticities of employment. Accordingly, for these industries the positive private investment effect is dominated by the negative employment effect. However, Paper (S5), Chemicals (S6) and Communications (S15) present negative elasticities of output while at the same time display positive elasticities for both inputs. For these industries, the negative direct effect dominates the positive indirect effects.

5.4. The Effects on Capital Intensity and Labor Productivity

Our results allow us to identify the effects of public investment on the capital intensity, i.e., the capital-labor ratio, as well as on labor productivity, i.e., the output-labor ratio, at both the aggregate and the industry levels. The relevant information can be obtained as the difference between the elasticities of investment and employment, and the difference between the elasticities of output and employment, respectively. These results are presented in Table 7.

Our estimates at the aggregate level suggest that public investment affects employment with an elasticity of 0.079 and private investment with an elasticity of 0.829. This implies that public investment affects private investment proportionately more than employment and, therefore, affects the capital-labor ratio positively. The analysis of the industry specific results confirms that this finding holds for all but two industries, Mining (S2) and Utilities (S10).

In turn, our results at the aggregate level suggest that public investment affects employment with an elasticity of 0.079 and output with an elasticity of 0.154.

Table 7. Effects on Capital Intensity and Labor Productivity

Industries	Capital Intensity	Labor Productivity
Agriculture (S1)	1.81470	0.13866
Mining (S2)	-4.04348	0.96452
Food (S3)	0.98238	0.16526
Textiles (S4)	1.26141	-0.12344
Paper (S5)	1.07948	-0.25071
Chemicals (S6)	0.70079	-0.44555
Non-Metal Products (S7)	1.65817	0.09106
Metal Products (S8)	0.47168	-0.07451
Other Manufacturing (S9)	1.30331	-0.09960
Utilities (S10)	-0.52591	0.28441
Construction (S11)	1.63040	0.30694
Trade (S12)	1.03590	-0.06141
Restaurants (S13)	2.22845	0.47433
Transportation (S14)	0.89917	-0.32824
Communications (S15)	0.62624	-0.12688
Finance (S16)	0.24406	0.23267
Real Estate (S17)	0.55410	0.30911
Services (S18)	0.66370	0.11179
Portugal	0.75074	0.13866

This implies that public investment affects output proportionately more than employment and, therefore, affects labor productivity positively. The analysis at the industry level confirms this finding for ten of the eighteen industries, namely, Agriculture (S1), Mining (S2), Food (S3), Non-Metal Products (S7), Utilities (S10), Construction (S11), Restaurants (S13), Finance (S16), Real Estate (S17), and Services (S18).

6. SUMMARY AND CONCLUDING REMARKS

This paper presents estimates for the Portuguese case of the aggregate effects of public investment in transportation infrastructures on private employment, investment, and output, as well as the decomposition of such effects at the industry level. In doing so, we attempt to uncover the diversity behind the aggregate results and to identify the effects of public investment on the industry mix.

Empirical results at the aggregate level indicate that public investment affects positively employment, investment, and output. The positive aggregte effect of public investment on employment masks a wide disparity of results at the industry level as public investment affects employment positively in only thirteen of the eighteen industries. Our results suggest that public investment tends to shift the industry composition of employment toward Mining (S2), Chemicals (S6), Non-Metal Products (S7), Metal Products (S8), Construction (S11), Transportation (S14), and Finance (S16). In fact, these seven industries represent just 21.2% of aggregate employment and capture 77.6% of the benefits. In turn, the positive aggregate effect on investment is present in almost all industries. In fact, public investment affects private investment positively in sixteen of the eighteen industries. Nevertheless, these effects are distributed in an unbalanced manner among industries and tend to shift the composition of private investment towards Agriculture (S1), Textiles (S4), Paper (S5), Non-Metal Products (S7), Other Manufacturing (S9), Construction (S11), Trade (S12), Restaurants (S13), and Transportation (S14). These nine industries represent 31.2% of private investment and capture 53.1% of the benefits. As to output, the aggregate pattern of positive results is present in also thirteen of the eighteen industries. Comparing the size of the benefits to the size of the sector it becomes clear that public investment tends to shift the composition of output toward Mining (S2), Non-Metal Products (S7), Metal Products (S8), Utilities (S10), Construction (S11), Restaurants (S13), and Finance (S16). These industries concentrate just 26.3% of the GDP and capture 69.3% of the effects of public investment on output.

The results in this paper have important policy implications. First, our results suggest that public investment has contributed to the increase in labor productivity and, thereby, to the catching up to EU standards of GDP per capita in purchasing power parity. Despite some progress, however, Portugal is still far from such EU standards. Therefore, the case can be made that there is a need for further EU and/or domestic resources to be allocated to public investment. With the eastward EU expansion, however, EU financing has been markedly reduced, while at the same time, Portugal faces great budgetary constraints in the context of the Stability and Growth Programs associated with the participation in the Economic and Monetary Union. In this context, our results suggest that the tendency for achieving budgetary consolidation through reduction in public investment spending is a mistake from the standpoint of long-term growth.

Second, our results suggest that the catching up at the aggregate level induce by public investment has been achieved in a way that is rather unbalanced across industries and that leads to significant shifts in industry composition. The persistent of a significant lag in standards of living and the expected scarcity of both domestic public financing and external transfers for future public investment projects, brings our attention to the relative benefits across industries of public investment and to the need for much more fine-tuned domestic policies. Industrial policies, for example, should recognize that the prevailing policies geared towards real convergence have a significant impact on the industry mix. In addition, fiscal policies and the design of the ever-present tax incentives to the private sector should explicitly consider the industry effects of public investment spending. Fine-tuning these policies could neutralize some of the undesirable effects at the industry level of public investment policies and at the same time enhance its aggregate benefits.

Finally, it should be pointed out that although this paper focuses on the Portuguese case, its interest is far from parochial. This is because the Portuguese development strategy based on EU structural programs has a lot in common with the Greek, Irish and Spanish experiences. These countries have also in common a current policy context of diminished expectations as to future EU funding and tight domestic public budgetary policies. Moreover, most of the recent EU entrants have levels of development, industrial environment and infrastructure scarcities that are not unlike the Portuguese case by the end of the 1980s and they are expected to benefit from large EU structural transfers, much like Greece, Ireland, Portugal, and Spain currently do.

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