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Sectoral Investment in Input-Output Frameworks, a Reply

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Abstract: This note responds to the comments by Garbellini (2026) on the treatment of demand shocks in the Input-Output model in Stamegna et al. (2024). We show that the increase in arms expenditure is correctly identified as an investment shock, while increases in public expenditure on environmental protection, education, and health services should be more appropriately interpreted as public consumption shocks. Once import shares consistent with this interpretation are applied, the central result of Stamegna et al. (2024) – namely, the higher employment effects of civilian expenditure relative to arms procurement – is further reinforced, with only minor changes in estimates. Furthermore, in Stamegna et al. (2024) the shares of arms imports are estimated using data for European countries and, even under a zero-import-share assumption, the main results are shown to be robust. Finally, we show that reducing the dimensionality of the Input-Output table yields results that are almost identical to those that we obtain here using the disaggregated tables.

Keywords: military expenditure; arms acquisition; input-output; economic impact; military jobs

Our article, Stamegna et al. (2024), investigates the economic impact of public expenditures on arms and civilian activities in Germany, Italy and Spain. We address here the issues raised in the note by Garbellini (2026); we clarify some definitions and

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interpretations, introduce minor adjustments to the calculations of the import shares, and we show that the main result of our article – namely, the higher employment effects of civilian expenditures compared to arms expenditure – is confirmed and strengthened.¹

1. The basic problem in the type of investigation we conducted is the lack of official data on the arms industry and on other relevant dimensions of its economic impact.

A well-established method for assessing the economic impact of public expenditures is Input-Output analysis, and the economic impact of defense spending in comparison with civilian alternatives has already been investigated decades ago (Leontief and Hoffenberg 1961; Leontief and Duchin 1983). Recent studies on the United States have used I-O tables that explicitly identify defense as a separate sector, with its own purchases of intermediate inputs from the rest of the economy, and document defense investment in equipment as a separate component of final demand. Using standard I-O multiplier methodology, these studies find that defense spending generates lower employment effects than civilian alternatives (Pollin and Garrett Peltier 2009; Peltier 2017; 2019; 2023).

For European countries, available I-O tables – OECD-ICIO – do not provide comparable information on purchases of intermediate inputs and capital goods by the defense sector. These tables aggregate public administration and defense into a single sector and do not distinguish between public investment in defense and in civilian activities among final-demand components. As a consequence, they do not allow for the identification of sectors supplying intermediate inputs and investment goods to the defense sector.

Moreover, in national accounts weapon systems are recorded as capital goods, although they have a different nature from that of machinery or equipment.

In order to investigate the economic impact of arms procurement, considering the limitation of European data, the approach we adopted is to assess the composition of investment in arms using US data, and extend this structure to European countries. In the article, we consider the three main industries involved in the production of weapon systems in the US and we assume that a similar European “arms sector” could be identified by the linear combination of such industries, with their Input-Output structures (see Table 1 in Stamegna et al. 2024: 405).²

¹ Data sources and replication files used in this note and in Stamegna et al. (2024) are available upon request.

² The relatively stable structure of arms production across major countries has been documented in the literature. Comparative surveys show that national arms industries tend to exhibit similarities in their sectoral composition, with leading firms typically concentrated in a common set of sectors – most notably aerospace, shipbuilding, motor vehicles and electronics – despite cross-country

In order to account for potential differences between the composition of the arms industry in the US and in the EU countries under investigation, in our article we have carried out a sensitivity analysis. We examined how variations in the weights assigned to each component sector affect our results. The sensitivity analysis shows that changes in the sectoral composition of the arms industry do not significantly alter our findings (Stamegna et al. 2024, Section 4.1 and Figure 4, pp. 410–412).

2. Estimates of the structure of the EU arms industry are particularly relevant as Europe is currently experiencing a major increase in military expenditure, with arms procurement growing faster than other components. This motivates our analysis on the economic impact of a public-expenditure shock in arms procurement that in national accounts is formally recorded as investment.

In a few passages of our article, we incorrectly refer to the component sectors involved in the production of weapon systems as “intermediate input suppliers of the arms industry”. We should refer to them as *the sectors producing capital goods for defense*.³ This terminological issue does not affect the construction of the demand shock, nor the resulting multiplier estimates. Indeed, our methodology consistently identifies the “sectoral structure of arms production” reported in Table 1 Stamegna et al. (2024: 405).

In order to implement the analysis, we first consider the extent to which the arms procurement shock in European economies is directed towards imports, leading to a leakage of demand (see below point 5 for methodology used). We then identify the multiplier effects generated by purchases of capital goods for defense, estimating their impact on domestic output and employment. More specifically, we estimated the output and employment effects generated by the activation of the sectors directly receiving the spending, their intermediate input suppliers, and the broader supply chain. Further details on the

differences in specialization and scale (Haveman et al. 1993; Kopac 2006; Dunne and Smith 2016; Evron and Bitzinger 2023). Moreover, the SIPRI methodology used to estimate arms transfer volumes across countries relies on production-cost measures based on predefined categories of weapon systems – such as aircraft, air defense systems, armoured vehicles, engines, sensors, and ships – which can be broadly mapped into the manufacturing sectors we identified as the main components of the arms industry (SIPRI 2025).

3 For terminological consistency, the following corrections should be introduced in Stamegna et al. (2024: 405) “suppliers of intermediate inputs” and “intermediate input suppliers” should be replaced with “component sectors”.

methodology used are provided in the article (Stamegna et al. 2024: 403, and in the Appendix).

3. The economic impact of arms procurement should be assessed in comparison with alternative uses of public expenditure. In our analysis, we considered expenditures on environmental protection, education, and health activities. Information on public expenditures in Europe is provided by the Eurostat COFOG database; in Figure 3 (Stamegna et al. 2024: 402) we have presented comparable data on investment in arms, environmental protection, education, and health.

When we move to the Input-Output analysis, we have to turn to the NACE Rev. Two classification adopted in OECD-ICIO tables, that includes the sectors “Water supply, sewerage, waste management, and remediation activities”, “Education”, and “Human health and social work activities”.⁴

I-O tables provide information on the flow of intermediate inputs activated by a final demand shock on such industries, but do not include information on investment undertaken by each sector; therefore, the economic impact of purchases of capital goods by these sectors cannot be explicitly modelled within this framework.

Public expenditure shocks for these sectors should therefore be more appropriately interpreted as public final consumption shocks. The aim of our analysis is to quantify the output and employment effects of public final consumption shocks directed to the “Water supply, sewerage, waste management, and remediation activities”, “Education”, and “Human health and social work activities” sectors.

In a few passages of the article, we incorrectly refer to the expenditures associated with increased demand for these sectors as capital-account expenditures. We should instead refer to *public final consumption expenditures*.⁵

⁴ These NACE sectors do not coincide exactly with the COFOG divisions “Environmental protection”, “Education”, and “Health”, which classify public spending functions (Eurostat 2019; 2022). The focus of our analysis is exclusively on the NACE sectors.

⁵ For terminological consistency, the following corrections should be introduced in Stamegna et al. (2024).

- pp. 403, 413: “public capital expenditure in” should be replaced with “public final consumption expenditure on”;
- bottom of p. 405, 406, 410 (last line), 411: the term “investment” should be removed;
- pp. 407, 408, 410, 412, footnote 13, 413, 414: the term “investment” should be replaced by “expenditure”;
- p. 414: the term “investing” should be replaced by “expenditure”.

There is, of course, an asymmetry between the capital good classification of arms procurement, on the one hand, and the focus on consumption expenditures in environmental protection, education, and health activities, on the other. However, this asymmetry is justified not simply by data limitations, but also by the dominance of consumption expenditures in the three civilian areas, that largely shape their overall economic impact.

4. In the article, the import shares associated with expenditures on environmental protection, education, and health were calculated from Input-Output tables by measuring, for each sector, the share of investment demand for the goods it produces that is met by imports. For consistency with the consumption-expenditure approach adopted in the analysis, *import shares should be calculated referring to government final consumption demand* for environmental protection, education, and health services.⁶

Table 1 below replaces Table 2 in Stamegna et al. (2024), showing that import shares for the three sectors (column 2) are even lower than in the original version. The resulting output and employment effects are presented in Table 2, that replaces Table 3 in Stamegna et al. (2024). The import shares based on government final consumption are lower than those calculated on investment demand and *the multipliers for the civilian sectors are therefore higher*. Finally, Table 3 replaces Table 4 in Stamegna et al. (2024) and reports the employment impact of the cumulative increase in arms expenditure over the period 2013–2023, together with the potential employment impact if the same amount had been devoted to civilian alternatives, expressed in terms of jobs/year.⁷

Since the import shares based on government final consumption are lower than those calculated on investment demand, this correction further strengthens

⁶ For terminological consistency, the following corrections should be introduced in Stamegna et al. (2024).

- p. 406: the term “final capital goods” should be replaced with “final goods”;
- p. 407: the term “ratio of investment demand”, should be replaced with “ratio of public consumption demand”,
- p. 410: the term “final investment demand” should be replaced with “final public consumption demand”.

⁷ Figure 4 updated with the revised data is almost identical to that presented in the paper. Results for arms do not change; for environmental protection, education, and health services, the employment effects – due to the very low import propensity of final demand for such industries – are always very close to the results of Scenario C, where imports are assumed to be zero. The updated figure is available upon request.

Table 1: Output multipliers for arms, environment, education, and health.

Germany			
	Multiplier of final demand (domestic + final imports)	Share of imports (%)	Multiplier of final demand for the national economy
Arms	1.62	24.21	1.23
Environment	1.77	0.68	1.76
Education	1.27	0.05	1.27
Health	1.38	0.02	1.38
Italy			
	Multiplier of final demand (domestic + final imports)	Share of imports (%)	Multiplier of final demand for the national economy
Arms	1.82	59.28	0.74
Environment	1.91	0.06	1.91
Education	1.26	0.02	1.26
Health	1.56	0.00	1.56
Spain			
	Multiplier of final demand (domestic + final imports)	Share of imports (%)	Multiplier of final demand for the national economy
Arms	1.65	22.30	1.28
Environment	1.83	0.03	1.83
Education	1.19	0.01	1.19
Health	1.39	0.01	1.39

our results, with very modest changes in the estimates. Our findings – namely, that arms procurement generates lower output and employment effects than the civilian alternatives considered – not only remain valid but are, if anything, reinforced.

5. The claims that we relied on US BEA tables to estimate European arms import shares and that our results are “driven almost entirely by the assumed import shares rather than by the underlying input-output structure” (Garbellini 2026) are incorrect.

As clearly stated in Stamegna et al. (2024, Section 3.2, p.406), the shares of arms imports in total arms procurement are calculated using WMEAT and NATO data as the ratio of “Imports of arms (goods & services)” to “Defence expenditure in equipment”, using data for Germany, Italy, and Spain. Since WMEAT data on imports are available only up to 2019, values for the period 2020–2023 were obtained through

Table 2: Output and employment effects of 1,000€ million expenditures for arms, environment, education, and health.

Germany						
	Domestic output effects (millions €)			Employment requirements (FTE) per million euros of direct output	Domestic employment (FTE) effects (thousands employees)	
	Direct (1)	Indirect (2)	Total (3) = (1) + (2)		Direct (1)	Indirect (2)
Arms	831.24	399.34	1,230.58	2.45	2.01	1.83
Environment	1,186.73	568.87	1,755.60	3.15	3.74	2.57
Education	1,092.28	177.47	1,269.75	9.60	10.48	0.82
Health	1,043.52	339.75	1,383.27	11.57	12.08	1.54
Italy						
	Domestic output effects (millions €)			Employment requirements (FTE) per million euros of direct output	Domestic employment (FTE) effects (thousands employees)	
	Direct (1)	Indirect (2)	Total (3) = (1) + (2)		Direct (1)	Indirect (2)
Arms	440.17	301.47	741.64	3.29	1.44	1.47
Environment	1,126.40	782.91	1,909.32	4.81	5.42	3.79
Education	1,013.89	242.04	1,255.93	11.43	11.59	1.20
Health	1,096.06	467.33	1,563.39	8.26	9.06	2.26
Spain						
	Domestic output effects (millions €)			Employment requirements (FTE) per million euros of direct output	Domestic employment (FTE) effects (thousands employees)	
	Direct (1)	Indirect (2)	Total (3) = (1) + (2)		Direct (1)	Indirect (2)
Arms	837.74	446.87	1,284.61	3.50	2.88	3.11
Environment	1,268.96	565.10	1,834.05	5.49	6.97	3.89
Education	1,002.45	192.08	1,194.54	13.64	13.67	1.31
Health	1,057.58	329.04	1,386.62	11.06	11.69	2.24

Table 3: Additional new jobs resulting from the cumulative increase in expenditure (2013–2023).

	Germany	Italy	Spain
Cumulative increase in arms expenditure relative to 2013 (billions €)	22.46	16.34	10.57
Additional annual jobs resulting from increased expenditure in 2013–2023 (thousands employees)			
Arms	86.27	47.55	63.32
Environment	141.88	150.49	114.82
Education	253.81	209.04	158.43
Health	305.81	184.97	147.35

linear interpolation and linear projection using SIPRI data on arms transfers for the respective countries (Stamegna et al. 2024, Appendix, p. 417). The resulting import shares are high but fully consistent with available official reports and policy documents at the EU and national levels.⁸

In Stamegna et al. (2024, columns 1 in Table 2 and Figure 4, Scenario C), we showed the results under the assumption of zero final import shares, when both military and civilian demand is entirely satisfied by domestic production. The output multiplier is highest for environmental protection, followed by arms expenditure; *the employment effects in all civilian activities are greater than those of arms*. Our main results are therefore not affected by the consideration of import shares.

6. A further comment from Garbellini (2026) concerns the use of a 7×7 Input-Output table, in which all sectors other than those under examination are aggregated into a single residual category called “Other sectors”. It is certainly true that this aggregation reduces the level of detail available for assessing the supply-chain effects operating through other industries. However, its impact on the results is negligible, since the bulk of the effects of increased expenditure is concentrated in the industries directly receiving the demand shock.

Tables 4 and 5 report the same estimated results as Tables 1 and 2, using the original 45×45 Input-Output table.

The results are almost identical to those reported in Tables 1 and 2.

7. In conclusion, we can argue that:

⁸ For instance, the Draghi Report calculates that between June 2022 and June 2023, 78 % of the increase in defense investment by EU Member States has been directed to non-EU producers (Draghi 2024). In the case of Italy, policy simulations on the impact of defense spending conducted by the Parliamentary Budget Office assumes that 60 % of additional defense investment demand is met by imports (UPB 2025) – an assumption that is almost identical to our own estimate (59.28 %).

Table 4: Output multipliers for arms, environment, education, and health (45×45 I-O table).

Germany			
	Multiplier of final demand (domestic + final imports)	Share of imports (%)	Multiplier of final demand for the national economy
Arms	1.63	24.21	1.24
Environment	1.76	0.68	1.75
Education	1.27	0.05	1.27
Health	1.38	0.02	1.38
Italy			
	Multiplier of final demand (domestic + final imports)	Share of imports (%)	Multiplier of final demand for the national economy
Arms	1.85	59.28	0.75
Environment	1.93	0.06	1.93
Education	1.26	0.02	1.26
Health	1.57	0.00	1.57
Spain			
	Multiplier of final demand (domestic + final imports)	Share of imports (%)	Multiplier of final demand for the national economy
Arms	1.68	22.30	1.30
Environment	1.85	0.03	1.85
Education	1.20	0.01	1.20
Health	1.39	0.01	1.39

- In the case of arms expenditure, we focused on the sectors producing capital goods for defense. This is the correct way for assessing the impact of a shock in the demand for arms.
- In the case of civilian activities, most expenditure is public final consumption and we focus on the impact of such an expenditure shock. We had mistakenly referred to them as capital expenditures, and we have provided here the relevant correction.
- The assessment of the demand effects on the domestic economy has to consider the relevance of imports, that are shown in Table 1. For both arms and civilian expenditures, import shares are calculated using data for Germany, Italy, and Spain. Even in our Scenario C in Figure 4, where imports are not considered, the employment effects of all civilian activities are greater than those of arms. Our results are therefore robust.

Table 5: Output and employment effects of 1,000€ million expenditures for arms, environment, education, and health (45 × 45 I-O table).

Germany						
	Domestic output effects (millions €)			Employment requirements (FTE) per million euros of direct output	Domestic employment (FTE) effects (thousands employees)	
	Direct (1)	Indirect (2)	Total (3) = (1) + (2)		Direct (1)	Indirect (2) Total (3) = (1) + (2)
Arms	831.48	405.26	1,236.74	2.45	2.01	1.92 3.94
Environment	1,185.52	565.29	1,750.81	3.15	3.74	2.58 6.32
Education	1,092.31	177.13	1,269.44	9.60	10.48	0.81 11.29
Health	1,043.48	341.15	1,384.64	11.57	12.07	1.58 13.65
Italy						
	Domestic output effects (millions €)			Employment requirements (FTE) per million euros of direct output	Domestic employment (FTE) effects (thousands employees)	
	Direct (1)	Indirect (2)	Total (3) = (1) + (2)		Direct (1)	Indirect (2) Total (3) = (1) + (2)
Arms	440.76	312.74	753.51	3.29	1.44	1.39 2.83
Environment	1,127.41	800.51	1,927.93	4.81	5.43	3.90 9.33
Education	1,013.93	241.41	1,255.34	11.43	11.59	1.17 12.76
Health	1,096.65	472.75	1,569.40	8.26	9.06	2.11 11.17
Spain						
	Domestic output effects (millions €)			Employment requirements (FTE) per million euros of direct output	Domestic employment (FTE) effects (thousands employees)	
	Direct (1)	Indirect (2)	Total (3) = (1) + (2)		Direct (1)	Indirect (2) Total (3) = (1) + (2)
Arms	838.66	465.13	1,303.79	3.50	2.88	3.18 6.07
Environment	1,269.69	577.86	1,847.55	5.49	6.97	3.81 10.78
Education	1,002.52	196.61	1,199.13	13.64	13.67	1.34 15.01
Health	1,057.78	334.06	1,391.85	11.06	11.70	2.31 14.00

- d. Considering the lack of information on defense investment in the Input-Output Tables for European countries, we had to assume that arms producing industry has a structure similar to the US. In order to test the robustness, we carried out a sensitivity analysis and our findings are not significantly altered by variations in the weights assigned to each component sector (Stamegna et al. 2024, Section 4.1 and Figure 4, pp. 410–412).
- e. Using the full 45×45 Input-Output table or a compact 7×7 Input-Output table – where sectors outside the investigation are aggregated into a single one – yields almost identical results, as shown in the comparison of Tables 4 and 5 with Tables 1 and 2.

In short, the results presented in Stamegna et al. (2024) – namely, the higher employment effects of expenditures in environmental protection, education, and health, compared to arms expenditure – are robust. When civilian expenditure shocks are correctly interpreted, and import shares for these activities are appropriately calculated on government final consumption demand, the results are further reinforced, with minimal changes in the estimates of the effects on output and employment.

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