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Can buying weapons from your friends make you better off? Evidence from NATO[☆]

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ABSTRACT

In this paper we analyse the effect of multilateral defence alliances and arms trade on economic growth of allies. Previous literature shows that military alliances may improve institutional development and efficiency in defence budget allocation, with consequent enhancement of economic performance. We postulate that importing advanced weapons from allies can bring about technology diffusion. This conjecture is developed theoretically assessing the effect of arms imports on domestic military technology and output. The model is tested for the countries that have a partnership relationship with the North Atlantic Treaty Organization for years 1990 to 2019. We confirm empirically the theoretical suggestion of military technology spillovers, namely, that imports of frontier technology arms from allies, have positive effects on output and productivity through a diffusion of foreign knowledge. Our findings imply that policy makers should have in mind that foreign policy issues, security matters in this case, can interact with economic goals.

1. Introduction

In this paper, we analyse the effect of multilateral defence alliances and arms trade on the economic growth of allies. Arms exported to aligned partners could exhibit higher technology levels than those to non-allies, thus acting as a channel for technology diffusion and spillovers. We explore this hypothesis first at the theoretical level. We then test our model implications for the case of the North Atlantic Treaty Organization (NATO) enlargement process and partnership strategy that started after the end of the Cold war.

Understanding the defence spending-growth nexus is one of the focuses of the defence economics literature. On the one hand, previous results often exhibit negative effects of defence expenditures on growth, among many Chang et al. (2011), Kollias and Paleologou (2013) or D'Agostino et al. (2017). On the other hand, a positive relationship between defence spending and growth may be driven by capital accumulation or trade openness, as reported by Shahbaz et al. (2013). Frequently, defence spending data are not disentangled to account for productive and/or non-productive spending, as is the case for non-military public spending.[1] To avoid this shortcoming, we thus concentrate on arms trade and explore how frontier technology transfers (embedded in the traded goods) between countries might influence the growth rate. Arms trade is interesting because it is where economic and foreign policy issues interact (Smith and Tasiran, 2005). One should consider that cutting-edge military technologies are more likely to be interchanged among allies or countries with shared interests (Gowa and Mansfield, 2004; Rodman, 2007, or Pamp et al., 2018). Previous literature finds benefits of arms trade within military alliances (Jones, 1988; Pearson, 1989; Callado-Muñoz et al., 2019; Kinsella, 2000, or Schmid et al., 2017). It suggests that technology diffusion through arms imports may be of interest. Nevertheless, whether the dissemination of military technology within military alliances affects economic growth remains unexplored to our knowledge.

This paper adds the impact of arms imports between defence allies to the military spending-growth nexus debate. We first present a theoretical analysis building on the idea of spillovers within an international organisation (Callado-Muñoz et al., 2014). We incorporate the technology diffusion mechanism into a Barro (1990) style growth model, following, in particular, Ghosh and Roy (2002), and Shieh

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[1] An example of one exception is Malizard (2015).

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et al. (2002). In our economy, government revenues are converted into non-productive government purchases and productive investments into civilian and military projects. Military projects consist of purchases of frontier technology weapons developed elsewhere. Once a country starts importing arms from a military ally, the technology level of the existing stock of arms improves, converges to the military technological edge, and consequently, the output is affected. This happens because a military investment in the form of imports of advanced weapons is, in fact, a pipeline allowing the flow of external research and development, through technological externalities, into the domestic economy. We show that once this flow is established, it can be tailored to superior performance by a design of the pace at which the military capital is accumulated. In other words, a government facing challenges in the form of trade-offs between allocating resources to different kinds of investments can adapt the revenues and their distribution to magnify the technology diffusion impact.

The model is tested using an unbalanced panel data set from countries with a partnership relationship with the North Atlantic Treaty Organization for the years 1990 to 2019. Our empirical evidence confirms the model results of economic benefits associated with importing advanced military technology from NATO allies and deepening NATO partnership relations. In particular, we find a positive effect on growth and productivity and show the existence of a positive military-international spillover effect. These results validate our hypothesis about the armament trade within a military alliance acting as a channel for technology diffusion through the technology embedded in the weapons acquired. Based on these results and concerning public policy, we conclude that even governments interested primarily in national security should be open to multi-dimensional international military collaborations. The recent Defence Innovation Accelerator for the North Atlantic (DIANA) and NATO Innovation Fund – launched as part of the NATO 2030 initiative to invest in emerging and disruptive technologies in critical areas to improve Allied security and to boost cooperation and interoperability – show the timeliness of the analysis.

The paper links to the literature on trade, technology diffusion and international institutions (for example Grossman and Helpman, 1991; McGrattan and Prescott, 2009; Schiff and Wang, 2003). Although different in approach, it also relates to the analysis of international research and development (R&D) spillovers (Coe and Helpman, 1995; Madsen, 2007; Coe et al., 2009 or Ghosh and Parab, 2021, for country-level studies, and Eberhardt et al., 2013, or Bournakis et al., 2018, for industry level analysis). Our starting point is complementary to the former papers and distinct from the latter. We focus on economic growth rather than productivity. We add to the literature by analysing whether the effects associated with technology diffusion embedded in the civilian sector are also present in the military sphere. The paper also connects to the NATO analysis literature that has shown that alliance partnership strategy has positively affected institutional development (Melnykovska and Schweickert, 2011) and that membership helps to improve efficiency in defence budget allocation (Utrero-González et al., 2019).

The remainder of the paper is organised as follows. Section 2 presents the theoretical model. Section 3 describes the data and the empirical strategy. In Section 4, we discuss the results. Section 5 includes a robustness analysis. Conclusions can be found in Section 6.

2. Model

In the construction of the model, we build on Barro (1990), Ghosh and Roy (2002), Shieh et al. (2002) and Pieroni (2009). This stream of literature assumes a part of government revenues is converted into productive factors. We incorporate a technology and security spillover mechanism similar to Callado-Muñoz et al. (2014). This allows us to study the effects of an attachment to an international organisation, in particular the arms trade within a military alliance, on the performance of arms importers. Some allied countries are military technology developers whose research and development efforts allow to reach the military technology frontier (Yakovlev, 2007).

Households Let us consider an economy populated by infinitely lived identical households. Households maximise their discounted utility function over the stream of consumption c_t, government purchases a_t, and national security s_t

$$\sum_{t=0}^{\infty} \beta^t \left[(1-\psi)\, \frac{\left(c_t^{\nu} a_t^{1-\nu}\right)^{1-\theta} - 1}{1-\theta} + \psi S(s_t) \right] \tag{1}$$

where $0 < \beta < 1$ is the discount factor, $\theta > 0$ is the inverse of the elasticity of intertemporal substitution, ψ is the weight agents assign to national security in their utility (and consequently $1-\psi$ is the weight assigned to private or public consumption which is weighted by a factor $0 < \nu < 1$) and the function $S(\cdot)$ is increasing in security.

Government finances three different items: (i) non-productive government purchases, (ii) investment into productive civilian projects, and (iii) import of arms.[2] Two of them, civilian projects, or non-military public capital, n_t, and arms import, or military public capital, m_t, are assumed to be productive, similar to Shieh et al. (2002) and Pieroni (2009). Military capital m_t is necessary for national security and military technology, and affects the output through technology diffusion. Both publicly financed capitals are accumulated over time, as in Fugatami et al. (1993), Ghosh and Roy (2002), Shieh et al. (2002) or Economides et al. (2011).[3]

We follow the literature and assume the production function to have the Cobb–Douglass form

$$y_t = A_t k_t^{1-\sigma-\varepsilon} n_t^{\sigma} m_t^{\varepsilon} \tag{2}$$

where y_t is output per capita at time t, A_t is the productivity level at time t, and k_t is the private physical capital per capita. The elasticity of output with respect to private physical, non-military and military capital is $1-\sigma-\varepsilon$, σ and ε, respectively, where $0 < \sigma, \varepsilon < 1$. Total productivity level A_t is given by the weighted average of the existing civilian, A_{civil_t}, and military technology, A_{mil_t}. We consider that

$$A_t = A_{civil_t}^{\mu} \, A_{mil_t}^{1-\mu} \tag{3}$$

with $0 < \mu < 1$. Civilian level of technology depends on the domestic characteristics. Military technology depends on the source of military capital.

Households income is taxed at a rate τ_t in each period. Disposable income is used for consumption, c_t, and investment into physical capital, i_{k_t},

$$c_t + i_{k_t} = \left(1-\tau_t\right) A_t k_t^{1-\sigma-\varepsilon} n_t^{\sigma} m_t^{\varepsilon}. \tag{4}$$

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[2] As mentioned above, we focus on countries that capture military technology and know-how through military imports and cooperation as opposed to devoting resources to their own research and development. Therefore, in the model, we assume that all arms and related military improvements will be imported. They will in turn export the equivalent value of goods and services abroad so the trade is balanced.

[3] Ghosh and Roy (2002) generalise the productive public sector idea, so that for a given set of values of parameters one can obtain the original Barro (1990) model (with productive government spending), and for another set of parameters the productive public capital is in place, as in Fugatami et al. (1993). None of the aforementioned models disentangles military spending, though. Shieh et al. (2002) model deals with military capital and it is in fact the most similar one to our setup. We can highlight two main differences: (1) we introduce non-productive government spending which allows us to obtain a realistic feature that some public resources are deviated from production with an accompanied negative impact on the growth rate, (2) we introduce the convergence mechanism that allows us to study the technology diffusion in a context of a military alliance.

Physical capital evolves in a usual way

$$k_{t+1} = i_{k_t} + \left(1 - \delta_k\right) k_t \tag{5}$$

where $0 < \delta_k < 1$ is its depreciation rate.

Government Government taxes output at a rate τ_t and uses the revenues to finance g_t, total government spending.[4] We can write the government budget constraint as

$$g_t = \tau_t \; A_t k_t^{1-\sigma-\varepsilon} n_t^{\sigma} m_t^{\varepsilon}. \tag{6}$$

Government spends the revenues on government purchases, military and non-military investments, a_t, i_{m_t} and i_{n_t}, respectively

$$a_t + i_{m_t} + i_{n_t} = g_t. \tag{7}$$

Particularity of the investment into military capital is that it corresponds to the imports of military weaponry. Otherwise, both public capitals evolve in a standard fashion

$$m_{t+1} \;=\; i_{m_t} + \left(1 - \delta_m\right) m_t, \tag{8}$$

$$n_{t+1} \;=\; i_{n_t} + \left(1 - \delta_n\right) n_t \tag{9}$$

where $0 < \delta_m < 1$ and $0 < \delta_n < 1$ are the corresponding depreciation rates. Military capital thus comes from abroad and the military technology depends on the quality of the imported arms. We assume that the security depends on the military capital and technology as follows

$$s_t = \varsigma \; A_{mil_t} m_t \tag{10}$$

where ς is the efficiency at which the military capital is turned into national security.[5]

Government must also decide what fraction of its revenues is dedicated to each spending

$$a_t \;=\; \chi_t g_t, \tag{11}$$

$$i_{m_t} \;=\; \rho_t g_t, \tag{12}$$

$$i_{n_t} \;=\; \left(1 - \rho_t - \chi_t\right) g_t \tag{13}$$

with $0 < \rho_t < 1$, $0 < \chi_t < 1$.

Military technology We assume that there exists a military technology frontier, $A_{m\text{frontier}}$. A country i has a technology level $\eta_i A_{m\text{frontier}}$, with $0 < \eta_i \leq 1$. Alliance arms exporters (or developers) have $\eta_{\text{frontier}} = 1$.

Following the result from (Callado-Muñoz et al., 2019), once a country becomes a partner in a military alliance, say at time T, it starts to import arms from allies so that technologically more advanced weapons are now available. This implies that at all times before T, when $t < T$, the country's military technology is below the frontier, $0 < \eta_i < 1$.[6]

Until time T, the domestic economy owns arms with the technology level below the frontier. This capital will depreciate at a rate δ_m in each period. Thus, at time T the level of the military capital with non-edge technology is

$$\left(1 - \delta_m\right) m_T.$$

Starting from the period T, for all $t \geq T$, imported technology is of the highest available quality, and the remains of the old technology capital at time $T + j$, $j \geq 0$, can be expressed as

$$\left(1 - \delta_m\right)^{j+1} m_T.$$

Any new capital bought afterwards, at $T + j$, $j \geq 0$, is on the technology frontier, thus the stock of military capital that embodies the new technology is

$$m_{T+1+j} - \left(1 - \delta_m\right)^{j+1} m_T, \; j \geq 0. \tag{14}$$

Over time, as the old arms with non-edge technology are discarded, the military technology level converges to the frontier as the alliance innovation and organisation are diffused among participating members and productivity increases. The total military technology level j periods after starting the imports from alliance exporters can be expressed as the weighted average of capital on the frontier and the one below it

$$A_{mil_{T+j}} = A_{m\text{frontier}} \frac{m_{T+1+j} - \left(1 - \delta_m\right)^{j+1} m_T}{m_{T+1+j}} + \eta_i A_{m\text{frontier}} \frac{\left(1 - \delta_m\right)^{j+1} m_T}{m_{T+1+j}}. \tag{15}$$

All arms importers will thus converge to the same military technology frontier $A_{m\text{frontier}}$. Notice that it is of interest to all partners sharing the innovations embedded in the frontier military technology because it allows the adoption of new practices that ease the cooperation among members and strengthens security of the whole alliance, as well as it provides incentives for more R&D from the side of the arms developers. In other words, buying arms from partners means that they will eventually work on a common platform, which improves the military cooperation. According to Eq. (10) security is strengthened because the military technology is better. Also, if countries can import arms and they do not have to devote resources to their development, they might be able to accumulate higher stock of military capital which again increases the security. Consequently, arms trade that enhances security is an incentive to develop innovation-trading channel within the alliance, even if the innovation is not directly comprehended in the model. The fraction of the total military capital that is on the military technology frontier can be used to represent a measure of cooperation penetration.

Equilibrium In equilibrium, households maximise their utility (1) subject to the budget constraint (4) and physical capital accumulation constraint (5), choosing how to distribute their disposable income between consumption $\left\{c_t\right\}_{t=1}^{\infty}$ and investment into physical capital $\left\{k_{t+1}\right\}_{t=1}^{\infty}$, and the government chooses the stream of tax rates $\left\{\tau_t\right\}_{t=1}^{\infty}$ and the stream of shares of revenues devoted to each public target, $\left\{\rho_t\right\}_{t=1}^{\infty}$ and $\left\{\chi_t\right\}_{t=1}^{\infty}$. First order conditions can be collapsed into the following single equation

$$\left(\frac{c_{t+1}}{c_t}\right)^{1-\nu(1-\theta)} \left(\frac{a_{t+1}}{a_t}\right)^{(\nu-1)(1-\theta)} = \left\{\beta\left[\left(1-\sigma-\varepsilon\right)\left(1-\tau_{t+1}\right) A_{t+1} \left(\frac{n_{t+1}}{k_{t+1}}\right)^{\sigma} \left(\frac{m_{t+1}}{k_{t+1}}\right)^{\varepsilon} + \left(1-\delta_k\right)\right]\right\}^{\frac{1}{\theta}}. \tag{16}$$

Balanced growth path Let us explore the balanced growth path (BGP) behaviour of this model. As in similar models, when the tax rate and the fraction of government revenues devoted to military and non-military capitals are set constant, $\tau_t = \tau$, $\rho_t = \rho$, $\chi_t = \chi$, and the civilian and military technology levels are also constant, $A_{civil_t} = A_{civil}$, $A_{mil_t} = A_{mil}$ in the long run all variables, c_t, k_t, a_t, m_t, n_t, g_t, y_t, will grow at the same rate.[7] For the existence of the balanced growth path

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[4] One could consider also a version of the model with progressive tax, as in Lai and Liao (2012). Such a model would deliver analogous properties as in our setup with lower balanced growth rate under higher tax progresssivity.

[5] Security may increase even more if one considers that a country integrated into a military alliance should be backed by its allies in case of a conflict, as is the case of NATO, for example (Utrero-González et al., 2019). Then we could write

$$s_t = \varsigma \; A_{mil_t} \mathcal{M}_t$$

where $\mathcal{M}_t$ is the military capital of all allies per inhabitant of the analysed economy. We can imagine it as arms per capita deployed in an action of collective defence.

[6] There may exist more arms exporters from which our studied economy imports. Consequently, the military technology level may differ when they start to import from alliance partners. Additionally, we work with a simplifying assumption in the model that all arms imports after T come from an alliance partner who has frontier military technology.

If the imported arms do not exhibit the frontier technology but are technologically more developed than the ones previously imported, the spillover effect, nonetheless weaker, remains.

[7] See equation couples (4) and (5), (8) and (12), (9) and (13).

both public capitals must depreciate at the same rate, i.e.

$$\delta_m = \delta_n.$$

The ratio between non-military public and physical private capital on the BGP is obtained from (8), (9), using (6), (12) and (13)

$$\left(\frac{m}{k}\right)_{BGP} = \left[\frac{\tau A^{\mu}_{civil}\left(\eta_i A_{m\text{frontier}}\right)^{1-\mu}\rho^{1-\sigma}\left(1-\chi-\rho\right)^{\sigma}}{\gamma_{BGP}-\left(1-\delta_m\right)}\right]^{\frac{1}{1-\sigma-\varepsilon}} \tag{17}$$

where γ_{BGP} is the BGP growth rate of the economy. Further, the equations for the accumulation of both public capitals, (8) and (9) imply

$$\left(\frac{n}{k}\right)_{BGP} = \left(\frac{m}{k}\right)_{BGP}\left(\frac{1-\chi-\rho}{\rho}\right). \tag{18}$$

Balanced growth path growth rate γ_{BGP} can be then written as

$$\gamma_{BGP} = \left\{\beta\left[\left(1-\sigma-\varepsilon\right)\left(1-\tau\right)A^{\mu}_{civil}\left(\eta_i A_{m\text{frontier}}\right)^{1-\mu} \times \left(\frac{m}{k}\right)^{\sigma+\varepsilon}_{BGP}\rho^{-\sigma}\left(1-\chi-\rho\right)^{\sigma}+\left(1-\delta_k\right)\right]\right\}^{\frac{1}{\theta}} \tag{19}$$

that combines (16), (17) and (18).[8] Our model on the BGP is analogous to Pieroni (2009), and thus the results with respect to the behaviour of the growth rate. The tax rate that maximises the growth rate is

$$\tau^* = \sigma + \varepsilon, \tag{20}$$

i.e.

$$\frac{d\gamma_{BGP}}{d\tau} > 0 \text{ for } \tau < \sigma+\varepsilon, \text{ and } \frac{d\gamma_{BGP}}{d\tau} < 0 \text{ for } \tau \geq \sigma+\varepsilon.$$

This is the result obtained in the models with productive public sector, as described first by Barro (1990). The trade-off between the return on private capital and the resources available on public activities implies the maximum growth rate for a given size of the public sector, see equation (20). Productive public capital distribution between military and non-military purposes that leads to maximise the growth rate is also given by the respective shares of each capital in the production function, similar to Pieroni (2009). Once the fraction of government spending devoted to non-productive purposes, χ, is chosen, fraction of the public budget destined to arms import, ρ, that maximises the growth rate is

$$\rho^* = \frac{\varepsilon\left(1-\chi\right)}{\sigma+\varepsilon}, \tag{21}$$

i.e.

$$\frac{d\gamma_{BGP}}{d\rho} > 0 \text{ for } \rho < \frac{\varepsilon\left(1-\chi\right)}{\sigma+\varepsilon}, \text{ and } \frac{d\gamma_{BGP}}{d\rho} < 0 \text{ for } \rho \geq \frac{\varepsilon\left(1-\chi\right)}{\sigma+\varepsilon}.$$

Nevertheless, the distribution of the tax revenues that maximises the utility may be different from the growth rate maximising one as the military government spending improves security and may contribute to higher welfare of households. Besides, despite increasing the utility, higher non-productive government spending a_t decreases the growth rate and the optimal fraction of public resources dedicated to arms import and productive civilian activities.

Transition towards the balanced growth path As developed in Fugatami et al. (1993), if the initial ratio of public and private capitals does not correspond to its BGP value, say $\frac{n_0}{k_0} < \left(\frac{n}{k}\right)_{BGP}$, along the transition non-military capital has to grow faster than physical capital, $\gamma_{n_{t+1}} > \gamma_{k_{t+1}}$. Simultaneously consumption will outgrow physical capital, $\gamma_{c_{t+1}} > \gamma_{k_{t+1}}$, for $\theta+\sigma+\varepsilon > 1$, and $\gamma_{k_{t+1}} > \gamma_{c_{t+1}}$ for $\theta+\sigma+\varepsilon < 1$.

Additionally, a country with lower original military technology, $\eta_{\text{country 1}} < \eta_{\text{country 2}}$, will grow faster after imports from an alliance take place, and will benefit more from the know-how embedded in the frontier technology military imports, the usual convergence effect, implied by (15) in this case. Resulting better economic conditions will then allow the benefiting countries to bolster the endurance of the alliance.

Notice, however, that an economy with higher fraction of military spending in total government spending, higher ρ, will converge faster, as illustrated by Eq. (15): starting from the same initial condition before arms import from developers takes place, higher ρ means more military capital, Eq. (8), higher military technology in the next period $A_{mil_{t+1}}$, hence higher temporary growth rate. Therefore, higher military spenders will benefit from faster growth rate in the transition.

Effects of Technology Diffusion on the Balanced Growth Path Growth Rate Let us analyse, in what follows, the characteristics that influence the effects of technology diffusion on the BGP growth rate. The purpose of this exercise is to highlight properties of the model and relate them to the empirical results, which are considered the main contribution of our work.

We present numerical results targeting the averages in the sample of all analysed countries, depicted in Table A.1 in the appendix. Additionally, we assume that the tax rate is set to maximise the growth rate, as indicated in Eq. (20). Consequently, the sum of the government consumption and defence expenditures to GDP (average) ratios, $0.2227 + 0.0225$, is used to set the tax rate, $\tau^* = \sigma + \varepsilon = 0.25$. The Eq. (20) then implies that the share of physical capital in the production function will be $1 - \varepsilon - \sigma = 0.75$. Growth friendly public expenditures are evaluated by Cepparulo and Mourne (2020) at the level of about 35%. We use this findings to set the unproductive government spending share to about 65%. This indicates, taking into account (21), that for $\rho^* = 0.1$ (value necessary to generate defence expenditures to GDP ratio $\rho\tau = 0.025$), the share of military capital in the production function is $\varepsilon = 0.07$. Implied share of the public nonmilitary capital in the production is then $\sigma = 0.18$ and $\chi = 0.643$. According to ECB (2006) total capital stock has an average lifetime of 20 years, meaning the depreciation rate is about 5%, whereas metal products, machinery and transport equipment depreciate faster, at about 15%. We assign the former general value to the private capital depreciation, $\delta_k = 0.05$, and the latter one to the military capital, $\delta_m = 0.15$. The inverse of the elasticity of intertemporal substitution θ is accepted to be higher than unity and we set it to be $\theta = 2$. Discount factor $\beta = 0.95$. Finally, to obtain the average growth rate of around 2.5% as found in the data, $A_{civil} = A_{m\text{frontier}} = 0.53$. To assess the technology diffusion we take the initial technology level of military capital to be 20% below the military technology frontier, thus $\eta = 0.8$, and set the weight of both technologies to be equal, i.e. $\mu = 0.5$.[9]

We perform three different exercises with respect to the effect of a change in military investment on the technology diffusion. In the first case, case (1), tax rate is set to maximise the growth rate, τ^*, and it is then assumed that an increase in the fraction of public resources devoted to arms import, ρ, is compensated by a decrease in unproductive utility enhancing spending, χ, as implied by Eq. (21) — when this happens, $1-\chi-\rho$ increases as ρ increases and χ decreases. We

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[8] Notice that the ratio $\left(\frac{m}{k}\right)_{BGP}$ depends in turn on the BGP growth rate γ_{BGP}. It can be solved analytically for the particular case of $\theta = 1$ and $\delta_k = \delta_m = \delta_n = \delta$. In such a case

$$\gamma_{BGP} = \beta\left[\left(1-\sigma-\varepsilon\right)\left(1-\tau\right)\tau^{\frac{\sigma+\varepsilon}{1-\sigma-\varepsilon}}A^{\frac{1}{1-\sigma-\varepsilon}}\rho^{\frac{\varepsilon}{1-\sigma-\varepsilon}}\left(1-\chi-\rho\right)^{\frac{\sigma}{1-\sigma-\varepsilon}}+\left(1-\delta\right)\right].$$

[9] Given that the technology level is assumed to be

$$A_t = A^{\mu}_{civil_t}A^{1-\mu}_{mil_t}$$

and the value of A_{civil} and A_{mil} is lower than unity, $\mu > 0.5$ makes the military technology more important, meanwhile $\mu < 0.5$ causes civilian technology to be more crucial.

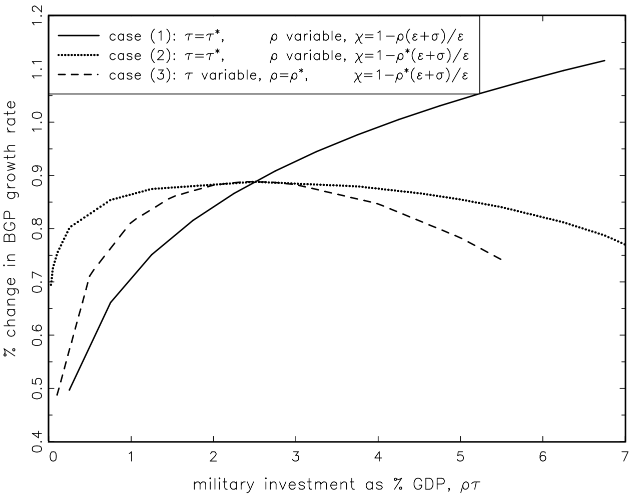

Fig. 1. Change of the balanced growth path growth rate due to arms imports from alliance members, $\left(\frac{\gamma_{BGP}(A_{m\text{frontier}})}{\gamma_{BGP}(\eta A_{m\text{frontier}})}-1\right)\times 100$, as a function of the public military budget, in percentage of GDP, $\rho\tau$; case (1): $\tau = \tau^* = 0.25$, ρ is variable, $\chi = 1 - \frac{\rho(\sigma+\varepsilon)}{\varepsilon}$, case (2): $\tau = \tau^* = 0.25$, ρ is variable, and $\chi = 1 - \frac{\rho^*(\sigma+\varepsilon)}{\varepsilon} = 0.643$, case (3): τ is variable, $\rho = \rho^* = 0.1$, $\chi = 1 - \frac{\rho^*(\sigma+\varepsilon)}{\varepsilon} = 0.643$.

find that under such conditions higher military investment measured in % of GDP, $\rho\tau$, brings about higher change of the balanced growth path growth rate due to technology diffusion. In the second case, case (2), tax rate is again set to maximise the growth rate, τ^*. However, an increase in arms import, ρ, is now not accompanied by a decrease in the share of tax revenues destined to the utility enhancing nonproductive spending, and $\chi = 0.643$ for different levels of ρ. Consequently, Eq. (21) only holds for one particular combination of ρ and χ, for which the technology diffusion, as well as the balanced growth path growth rate, achieve their maxima. The third case, case (3), presents a situation in which $\rho = \rho^*$ and $\chi = 1 - \frac{\rho^*(\sigma+\varepsilon)}{\varepsilon}$, and it is now the tax rate that is variable and not necessarily set to its BGP growth rate maximising value. Tax rate variation is thus used to change the military spending as % of GDP, $\rho\tau$. Fig. 1 provides an illustration of how the frontier technology embedded in arms imports from alliance members affects the change in the long run growth rate of the economy for these three cases. From Fig. 1 we can conclude that higher military spending is associated with higher benefit of technology diffusion from arms imports when an increase in the military spending goes together with a decrease in funding of the utility enhancing, but growth conflicting, public activities. When the policy does not target explicitly the distribution of public resources which maximises the growth rate, all kinds of outcomes may arise when higher military spending as % of GDP is employed. We can therefore conclude that it is the execution of the policy that will influence the observed outcome.

With regard to the weight of each kind of technology in the production function, higher weight of military technology in the total technology level, lower μ in this case as $A_{mil} < 1$, implies a higher military technology gap to close, thus higher benefit of technology diffusion from arms imports. In other words, $\eta^{1-\mu}$ is an increasing function of μ.

Using Eqs. (15) and (19), we can write the growth rate as a function of total government spending to GDP $\left(\frac{g_t}{y_t} \sim \tau_t\right)$, military spending to GDP $\left(\frac{m_t}{y_t} \sim \rho_t \tau_t\right)$, technology level and alliance partnership $\left(A_t, \eta\right)$, and structural parameters

$$\gamma_t = \frac{y_t}{y_{t-1}} = f\left(\frac{g_t}{y_t}, \frac{m_t}{y_t}, A_t, \eta; \beta, \delta_k, \delta_m, \delta_n, \theta\right).$$

Our model suggests that the growth rate will be negatively affected by public spending, in case of non-optimal allocation of government resources to public activities by hindering the accumulation of private capital. Technology diffusion process is a force that disseminates innovation and organisation along the alliance members, and it is stronger for the ones that present lower initial technological achievements, i.e. the further is a given economy from the technology frontier, the stronger will be the alliance push. Additionally, the higher is the importance of the military technology in the production function of a given country, the more benefit is expected to come from arms imports and technology diffusion. The model likewise predicts that the alliance's influence is stronger for higher military spenders who compensate the increase in military spending by decreasing the resources dedicated to non-productive utility enhancing actions, or in some cases, do not target growth maximising allocation of public funding. Under such conditions, countries can speed up the technology diffusion by accumulating more military capital (higher imports) and in turn increase national (and common) security, see (10) and the related note.

3. Background, data and empirical strategy

3.1. NATO enlargement and partnership process

NATO post-Cold War transformation has been led by alliance's continued enlargement with countries to the east (German, 2017). This process ended up in 2020 when New Macedonia became the 30th member.[10] At the same time NATO has developed a partnership program and strategy which have resulted in a dynamic and extensive security network. In 1994 the Partnership for Peace program (PfP) and the Mediterranean Dialogue (MD) were established.[11] Partnerships in the post-September 11th encouraged stability beyond Europe and focused on establishing links with countries or institutions that would offer resources to contribute to crisis management (Moore, 2007). In 2004 the settlement of the Istanbul Cooperation Initiative (ICI) broadened the geographical scope of NATO's partnerships. Later on, by defining cooperative security as one of NATO's core tasks, the 2010 Strategic Concept gave greater prominence to partnerships (Tardy, 2021) and partner relations around the globe. The review of NATO's partnerships policy in April 2011 implied that all partnerships, dialogues, councils and special relationships were treated as general instruments to contribute to security through increased flexibility. This has allowed to build deeper and more tailor-made cooperation programs. Further, participation in different activities and programs (over 1200 education, training and consultation events offered in the Partnership Cooperation Menu) are opened to all partners on a voluntary and case-by-case basis to pursue a high level of cooperation with NATO.[12]

Many partnership tools are introduced to focus on the important priorities of interoperability and building capabilities, and supporting defence and security-related reform. For instance, standardization agreements (STANAG) play an important role enhancing the Alliance's operational effectiveness by promoting a more efficient use of resources (NATO, 2015).[13] In this sense, from a strategic point of view, weapon

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[10] https://www.nato.int/cps/en/natohq/news_174589.htm

[11] The PfP enabled participants to develop an individual relationship with NATO, choosing their own priorities for cooperation, and the level and pace of progress. In 1995 the PfP Planning and Review Process (PARP) was launched to enhance interoperability and capabilities of partner forces. Later on, individual Partnership Action Plans (IPAPs) were open to countries that have the political will and ability to deepen their relationship with NATO. Partners periodically reviewed their IPAPs and eventually moved from this mechanism to the Membership Action Plan (MAP) through the development of Annual National Program.

[12] https://www.nato.int/cps/en/natohq/topics_84336.htm

[13] NATO standardisation agreements allow the development and implementation of concepts, doctrines and procedures to achieve and maintain the required levels of compatibility, interchangeability or commonality needed to achieve interoperability. Standardisation affects the operational, procedural, material and administrative fields.

developers' members can be interested in the transfer of technology in an effort to increase interoperability and the aggregate strength of the alliance. It is easier logistically, and in terms of doctrine, to build a capable coalition if the participants are operating the same kind of equipment. The establishment of NATO procurement support program agency (NSPA), the Connected Forces Initiative and the NATO Response Force have been designed to reinforce the explicit encouragement of economic collaboration between members, to develop interoperability through exercises, training and education and to expose partners to the cutting edge of NATO's military developments.

Altogether, this evolution illustrates an increasing access to advanced technology as partnerships deepen as well as adopting common procedures and it shows the suitability of NATO recent evolution to test the results of the model. We take into account all the countries that have started a long-standing partnership relation with NATO for the period 1990 to 2019. The final sample consists of 49 countries' unbalanced panel data.[14]

3.2. Empirical strategy and variable definition

Using Eqs. (15) and (19) of the model, we can write the growth rate as a function of total government spending to GDP, military spending to GDP, technology level and alliance partnership. Taking this into account in a Barro-style growth regression, we estimate the following equation:

$$\begin{aligned}\Delta Y_{it} = {} & \alpha_1 Y_{it-1} + \alpha_2\ Inv\_GDP_{it} + \alpha_3\ Def\_GDP_{it} + \alpha_4\ Con\_GDP_{it} \\ & + \alpha_5\ ArmsIMPORTS_{it} + \alpha_6\ StratREL_{it} + \omega_i + \xi_{it}\end{aligned} \tag{22}$$

where for country i and period t, ΔY_{it} is the log difference of real GDP per capita, Y_{it-1} is the log of real per capita GDP (LGDPcap).[15] Similarly to previous papers on the defence economic growth nexus, Inv_GDP_{it}, Def_GDP_{it} and Con_GDP_{it} account for gross-fixed capital formation, defence expenditure and government consumption over GDP, respectively. In addition, in the baseline specification (22), variables $ArmsIMPORTS_{it}$ and $StratREL_{it}$ are introduced to account for the military capital imported (arms imports over GDP) and the existence of a strategic relationship with NATO. Variable ω_i denotes an unobserved country-specific effect and ξ_{it} is the error term.

Three different measures of $StratREL_{it}$ are used. Two dummy variables to control whether the country is a NATO partner or has been granted membership are introduced, $PARTNER$ and $NATO$, respectively. Furthermore, we construct the $PARTNERSHIP\_STATUS$ variable based on Utrero-González et al. (2019) analysis of NATO enlargement process. In particular, the metric is updated to include the information of the new partners and recent changes in relations with NATO. It has the lowest values in early stages of relationship (former Dialogue) and the highest value when membership is granted, ranging from 0 to 1. This variable reflects that the countries' partnership with NATO has evolved at a different pace. Some countries have maintained active engagement to NATO activity and operations, others have remained military neutral while cooperating and sharing values with the alliance, other countries have been granted membership along the period.

In addition, for the variable $ArmsIMPORTS_{it}$, we distinguish between arms imports coming from NATO members, $NATO\_ArmsIMPORTS$, and arms imports coming from other exporters, $NONATO\_ArmsIMPORTS$. In a second step, a set of control variables is introduced: population growth or average years of schooling, as well as number of conflicts. Further, three measures of institutional development that have been also used in the analysis of the economic growth-defence expenditure nexus are used, namely, corruption control, regulation quality and political stability.[16]

We merge data from different sources. Data on GDP, gross-fixed capital formation and government consumption come from Penn World Tables (10.0 edition). Defence expenditures and arms import of major conventional weapons come from the Stockholm International Peace Research Institute (SIPRI) Military expenditure and Arms Transfers databases, respectively. The information of countries' relations with NATO comes from the NATO itself. For the control variables, number of conflicts come from the Uppsala Conflict Data Program (UCDP)/ Peace Research Institute Oslo (PRIO) Armed Conflict Dataset (version 21.1). Data on population growth, education and institutional development come from the World Development Indicators (WDI) and World Governance Indicators from the World Bank. In addition, some of the countries in the sample are members of NATO and the European Union (EU) at the same time. Since there is an intense debate of the relationships between NATO and EU, the different military capability development plans and the EU efforts to promote European Arm Industry, a variable accounting for EU membership is also constructed and introduced. Table 1 presents summary statistics of the data used.

Equation (22) can be considered dynamic in the sense that it can be rewritten in terms of income levels with lagged income as a right hand side variable (Bleaney et al., 2001). That means that endogeneity issues can arise provided individual effects are correlated with the lagged dependent variable. This source of endogeneity bias has been addressed in the literature through the Generalised Method of Moments (GMM). In particular, in this analysis we employ the system GMM dynamic panel data estimator, developed by Blundell and Bond (1998), which has been used in previous papers on the relationship between defence expenditure and growth, see Yakovlev (2007), D'Agostino et al. (2012), Musayev (2016) and Compton and Paterson (2016), among others. This approach has the advantage to address the issues of potential biases induced by country specific effects, and of joint endogeneity of all explanatory variables. One potential drawback of system-GMM is the proliferation of instruments that can overfit instrumented variables, failing to expunge their endogenous components and biasing coefficient estimates (Roodman, 2009). To control for this, we restrict the number of instruments up to a maximum of three lags and collapse the instrument matrix as proposed by Kiviet (2020). Another potential flaw of this technique is that gaps in unbalanced panels can be magnified (Roodman, 2009). Arellano and Bover (1995) propose a second transformation "orthogonal deviations" that minimises data loss and since lagged observations do not enter the formula, they are valid as instruments. Therefore, we decide to use this technique. Finally, to account for global shocks we introduce time dummies in the equation.[17]

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[14] Russia, Tajikistan, Turkmenistan and Uzbekistan are not included for alteration of the relations with NATO during the period and data availability, respectively. The list of countries included in the final sample can be found in Table A.1 in Appendix.

[15] As Aizenman and Glick (2006) and Mylonidis (2008) among others, our *à la Barro* style growth regression does not include all variables in natural logs.

[16] Control of Corruption captures perceptions of the extent to which public power is exercised for private gain. Regulatory Quality captures perceptions of the ability of the government to formulate and implement sound policies and regulations that permit and promote private sector development. Political Stability and Absence of Violence/Terrorism measures perceptions of the likelihood of political instability and/or politically motivated violence, including terrorism. Percentile rank indicates the country's rank among all countries covered by the aggregate indicator, with 0 corresponding to lowest rank, and 100 to highest rank. Percentile ranks have been adjusted to correct for changes over time in the composition of the countries covered by the World Governance Indicators.

[17] In particular, we introduce five dummy variables to account for the changes of the international strategic scenario that has shaped NATO evolution and doctrine since 1990. These events correspond to: NATO development of partnerships with former adversaries (1991), Bosnia–Herzegovina crisis (1995), terrorist attacks in New York and Washington (2001), NATO command of International Security Assistant Force in Afghanistan (2003), NATO adoption of "Active Engagement, Modern Defence" (2010). Source: www.nato.int.

Table 1
Summary statistics.

Variable	Definition	Obs	Mean	Std. Dev.
ΔY	Per Capita GDP Growth Rate	1,450	0.0243	0.1054
LGDPcap	Per Capita GDP (log)	1,500	9.6214	0.9137
Inv_GDP	Gross Capital formation over GDP	1,500	0.2255	0.0856
Con_GDP	Government consumption over GDP	1,500	0.2227	0.0987
Def_GDP	Defence expenditure over GDP	1,348	0.0255	0.0400
ArmsIMPORTS	Total arms imports over GDP (percentage)	1,500	0.0818	0.2123
NATO_ArmsIMPORTS	NATO arms imports over GDP (percentage)	1,500	0.0554	0.1889
NONATO_ArmsIMPORTS	Non NATO arms imports over GDP (percentage)	1,500	0.0264	0.0939
NATO	NATO membership (dummy)	1,470	0.1361	0.3429
PARTNER	Partnership with NATO (dummy)	1,469	0.7204	0.4489
PARTNERSHIP_STATUS	Evolution of partnership status	1,469	0.3458	0.3451
POP_GROWTH	Population growth	1,480	0.0091	0.0216
EDUCATION	Years of schooling (log)	1,427	2.2009	0.3526
EU	European Union Membership (dummy)	1,470	0.1918	0.3939
CONFLICTS	Number of conflicts	1,470	0.2248	0.6813
CORRUPTION_CONTROL	Corruption control	1070	54.7288	28.0442
REG_QUALITY	Regulation quality	1065	60.5449	26.4573
POL_STABILITY	Political Stability	1,064	52.8005	28.6195

These time dummy variables contrary to the other regressors, which are considered endogenous, are treated as exogenous. Along with coefficient estimates obtained using GMM system estimator, the tables also report four tests of the validity of identifying assumptions they entail: Arellano and Bond (1991) AR(1) and AR(2) tests in first differences. Hansens' test of over-identification and exogeneity of instruments.

From the time series analysis point of view, provided data may be non-stationary, that would give rise to co-integration analysis and specification of an error-correction model. To test the order of integration of the series we consider a battery of panel unit root tests for the main variables. Table A.2 in the Appendix collects the results. In all the cases, we reject the null hypothesis that a unit root exists. Thus, we do not find evidence of non-stationarity in our sample.

4. Empirical results

As explained above, Eq. (22) has been first estimated without the set of control variables. Results are presented in Table 2. It can be observed that the gross capital and the government consumption coefficients are significant and have the expected signs. Namely, capital formation (investment) affects positively economic growth while government consumption hinders it, as it is commonly found in the literature (D'Agostino et al., 2016). However, either the lagged value of GDP or the defence expenditure coefficient is not significant. This mild evidence is similar to previous empirical papers using GMM techniques, see for example Utrero-González et al. (2019) for the lagged value of GDP or Yakovlev (2007) for the defence spending. The model suggests that if the defence expenditure is set at about the level that maximises the growth rate, insignificant, positive, or negative effect on growth rate can be expected. Therefore, the evidence found is coherent with model predictions, although some recent papers tend to show a negative relation (D'Agostino et al., 2017).

Columns 1 to 3 analyse the effects of arms imports without distinguishing between exporters. In this case the coefficient is positive and significant indicating that the military technology imported has positive effects on economic growth. The variables that account for the alliance relationship are all positive as expected, but only NATO membership dummy and the partnership status are significant. The message would be that organisation innovation through new practices and alliance activities associated to partnership deepening and membership have positive effects on growth. However, columns 1 to 3 present poor overidentification test so these results, should be taken cautiously.

The effects of arms import coming from NATO and non-NATO countries are analysed separately in columns 4 to 6. It can be seen that the arms coming from NATO countries, that is, arms closer to the technology frontier, are the ones that have a positive influence on growth while the other military imports present a negative but not significant coefficient. Looking at the NATO relationship effect, again all three proxies are positive but only partnership status variable has a significant coefficient, suggesting that the changes in military organisation linked to NATO partnership evolution are the most relevant for growth. This evidence is in line with Utrero-González et al. (2019) that find a positive effect on economic growth of belonging to NATO institutional arrangements and enjoying the possibility of collective defence action. Additionally, it is also in line with Schmid et al. (2017) who find a positive effect of the military alliance with the United States. Furthermore, diagnosis tests, when we differentiate arms imports' origin, show that the specification chosen is supported. The test of autocorrelation AR(2), the null hypothesis (of no autocorrelation) is accepted at 5% for all runs.

We include the aforementioned set of controls in Table 3, taking column 6 of Table 2 as baseline. As it can be observed, the results associated to the variable of interest, arms imports coming from NATO, replicate those just commented. Independently of the controls introduced, there is a positive and significant effect on growth when countries import arms from NATO allies, while importing arms from non-NATO countries does not have any significant effect. However, the effect of the partnership status variable is only significant in the first three columns. When the other institutional variables are introduced the significance disappears. Further, results for the control variables are mild. Only population growth affects economic growth significantly and presents the expected sign. The rest of the control variables: EU dummy variable, number of conflicts and institutional variables are not significant. Therefore, EU membership and national institutional environment are not so relevant for NATO partners during the period considered. The general message of Table 3 is then in line with the model predictions, namely, imports of advanced military technology foster economic growth.

According to the model, the effects of arms imports should be influenced by the level of initial technology and defence expenditure. Then, we repeat the analysis for different sub-samples of countries. Since the technology level of a country is related to economic development, we split the sample into developed and developing countries (Table 4). Results are pretty different for developed and developing countries. Imports of more sophisticated weaponry allow developing countries to improve the technology level and have a significant effect on growth. Better military organisation associated to deeper partnership and membership with NATO also reinforces growth. The coefficients for developed countries have the same sign but are not significant. This evidence is in line with model predictions, which suggests first the existence of non-linear effects of sophisticated arms imports, and second, more benefit from the know-how embedded in the frontier technology for countries with lower military technology.

Table 2
Estimation results. Baseline specifications.

	(1)	(2)	(3)	(4)	(5)	(6)
LGDPcap (lagged)	0.0021	0.0006	0.0003	0.0006	−0.0006	−0.0010
	(0.0037)	(0.0037)	(0.0036)	(0.0035)	(0.0036)	(0.0035)
Inv_GDP	0.2683**	0.2699**	0.2594**	0.2661***	0.2714***	0.2534***
	(0.1193)	(0.1221)	(0.1173)	(0.1003)	(0.1009)	(0.0982)
Con_GDP	−0.4375***	−0.3873***	−0.3071***	−0.4034***	−0.3548***	−0.2757**
	(0.1112)	(0.1099)	(0.1164)	(0.1132)	(0.1145)	(0.1181)
Def_GDP	−0.1447	−0.2104	−0.3009	0.1730	0.0934	0.0058
	(0.3028)	(0.3040)	(0.2938)	(0.2744)	(0.2613)	(0.2556)
ArmsIMPORTS	0.2596**	0.2526**	0.2343**			
	(0.1114)	(0.1129)	(0.1154)			
NATO_ArmsIMPORTS				0.2657*	0.2578**	0.2408**
				(0.1033)	(0.1059)	(0.1073)
NONATO_ArmsIMPORTS				−0.0273	−0.0253	−0.0430
				(0.2403)	(0.2342)	(0.2238)
PARTNER	0.0166			0.0234		
	(0.0139)			(0.0150)		
NATO		0.0120*			0.0082	
		(0.0071)			(0.0072)	
PARTNERSHIP_STATUS			0.0559***			0.0573***
			(0.0203)			(0.0196)
Observations	1314	1314	1314	1314	1314	1314
AR(1)	**−3.18**	**−3.26**	**−3.32**	**−3.67**	**−3.69**	**−3.75**
AR(2)	−0.24	−0.53	0.19	−1.26	−1.65	−0.69
Hansen tests:						
Overid restrictions:	**25.11**	**25.90**	**30.84**	23.92	24.47	32.26
Exogeneity	7.16	6.94	9.02	14.13	13.56	15.30

Notes. The dependent variable is the growth rate of per capita GDP. Labels of variables are defined in Table 1. All specifications include time effects (NATO key events) as defined by NATO. Heteroskedasticity and autocorrelation robust standard errors are reported. The asterisks stand for the *p*-value significance levels (* $p < 0.1$; ** $p < 0.05$; *** $p < 0.01$). At the bottom of the table, diagnostic test statistics are reported. Bold numbers indicate significance at least at 0.05.

Table 3
Estimation results. Control variables.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
LGDPcap (lagged)	−0.0004	0.0080	0.0087	0.0106	0.0098	0.00877	0.00831
	(0.0036)	(0.0069)	(0.0068)	(0.0068)	(0.0060)	(0.0059)	(0.0064)
Inv_GDP	0.3512***	0.3062***	0.2731***	0.2828***	0.2036***	0.204***	0.217***
	(0.1073)	(0.1021)	(0.0953)	(0.1081)	(0.0629)	(0.0587)	(0.0594)
Con_GDP	−0.3259***	−0.3353***	−0.3432***	−0.3325***	−0.0242	−0.0332	−0.0375
	(0.1110)	(0.1298)	(0.1249)	(0.1228)	(0.1027)	(0.1063)	(0.1053)
Def_GDP	−0.0382	−0.0353	−0.0188	−0.0670	−0.08825	−0.00507	−0.0406
	(0.2578)	(0.2780)	(0.2675)	(0.2590)	(0.5630)	(0.5544)	(0.6370)
NATO_ArmsIMPORTS	0.2026**	0.1994**	0.2149**	0.2197**	0.1086*	0.1037	0.1070*
	(0.0912)	(0.0925)	(0.9027)	(0.0892)	(0.0604)	(0.0636)	(0.0627)
NONATO_ArmsIMPORTS	−0.0484	−0.0271	−0.0197	0.0902	0.0860	0.0924	0.01083
	(0.20360)	(0.1997)	(0.1948)	(0.1825)	(0.0834)	(0.0782)	(0.0782)
PARTNERSHIP_STATUS	0.0302*	0.0303**	0.0348*	0.0218	−0.0257	−0.0221	−0.0233
	(0.0182)	(0.0153)	(0.0183)	(0.0198)	(0.0209)	(0.0219)	(0.0221)
POP_GROWTH	−1.2887***	−1.3552***	−1.3353***	−1.4330***	−0.7985***	−0.780***	−0.795***
	(0.3468)	(0.3814)	(0.3741)	(0.3787)	(0.2092)	(0.2028)	(0.2059)
EDUCATION		−0.0253	−0.0253	−0.0324	−0.0021	0.00265	0.00435
		(0.0396)	(0.0384)	(0.0401)	(0.0229)	(0.0225)	(0.0228)
EU			−0.0179	−0.0227*	0.0048	0.00383	0.000441
			(0.0114)	(0.0127)	(0.0105)	(0.0096)	(0.0114)
CONFLICTS				−0.0320	−0.0141	−0.0147	−0.0140
				(0.0226)	(0.0121)	(0.0131)	(0.0132)
CORRUPTION_CONTROL					−0.0009*	−0.000268	−0.000416
					(0.0003)	(0.0005)	(0.0006)
REG_QUALITY						−0.000612	−0.000562
						(0.0005)	(0.0005)
POL_STABILITY							0.000171
							(0.0006)
Observations	1314	1300	1300	1300	990	990	989
AR(1)	**−3.75**	**−3.69**	**−3.68**	**−3.75**	**−3.38**	**−3.41**	**−3.41**
AR(2)	−1.08	−1.37	−1.49	−1.73	0.34	0.40	0.54
Hansen tests:							
Overid restrictions:	30.60	35.84	35.52	37.70	43.01	42.50	44.01
Exogeneity	23.71	25.41	25.71	26.20	33.28	37.53	40.37

Notes. The dependent variable is the growth rate of per capita GDP. Labels of variables are defined in Table 1. All specifications include time effects (NATO key events) as defined by NATO. Heteroskedasticity and autocorrelation robust standard errors are reported. The asterisks stand for the *p-value* significance levels (* $p < 0.1$; ** $p < 0.05$; *** $p < 0.01$). At the bottom of the table, diagnostic test statistics are reported. Bold numbers indicate significance at least at 0.05.

Table 4
Estimation results. Developed and developing countries.

	Developed countries			Developing countries		
	(1)	(2)	(3)	(4)	(5)	(6)
LGDPcap(lagged)	−0.0058	−0.0043	−0.0058	0.0054	0.0083**	0.0053
	(0.0055)	(0.0049)	(0.0055)	(0.0040)	(0.0037)	(0.0040)
Inv_GDP	0.1168	0.1307	0.1170	0.0498	0.1015	0.0474
	(0.1290)	(0.0992)	(0.1287)	(0.1178)	(0.1122)	(0.1181)
Con_GDP	0.1734	0.0478	0.1736	−0.4220***	−0.4708***	−0.4218***
	(0.1444)	(0.1671)	(0.1443)	(0.1057)	(0.1009)	(0.1057)
Def_GDP	0.5109	0.4472	0.5106	0.1155	−0.1379	0.1359
	(0.8221)	(0.7399)	(0.8219)	(0.5351)	(0.6217)	(0.5402)
NATO_ArmsIMPORTS	0.1462	0.1806	0.1462	0.1559***	0.1549**	0.1550***
	(0.1246)	(0.1205)	(0.1246)	(0.0545)	(0.0625)	(0.0549)
NONATO_ArmsIMPORTS	−0.8356	−0.6650	−0.8355	0.0438	0.1360	0.0422
	(0.5960)	(0.5504)	(0.5961)	(0.1168)	(0.1152)	(0.1166)
NATO	0.0112			0.0850***		
	(0.0186)			(0.0299)		
PARTNER		−0.0084			−0.0192	
		(0.0148)			(0.0309)	
PARTNERSHIP_STATUS			0.0112			0.0868***
			(0.0186)			(0.0299)
Observations	679	679	679	635	635	635
AR(1)	**−3.24**	**−3.28**	**−3.24**	**−2.74**	**−2.81**	**−2.74**
AR(2)	−1.42	**−2.00**	−1.42	−0.82	−1.31	−0.81
Hansen tests:						
Overid restrictions:	24.37	25.77	24.37	21.40	21.66	19.50
Exogeneity	23.56	**24.39**	23.57	18.89	18.59	18.96

Notes. The dependent variable is the growth rate of per capita GDP. Labels of variables are defined in Table 1. All specifications include time effects (NATO key events) as defined by NATO. Heteroskedasticity and autocorrelation robust standard errors are reported. The asterisks stand for the *p-value* significance levels (* $p < 0.1$; ** $p < 0.05$; *** $p < 0.01$). At the bottom of the table, diagnostic test statistics are reported. Bold numbers indicate significance at least at 0.05.

In a similar vein, Table 5 presents the results for those countries with high and low defence expenditure, respectively. Results for the subsamples of countries with high and low defence expenditure are mixed. As it can be seen, the effects of arms imports are stronger for high defence spenders' countries as they can accumulate more military capital via arms imports as suggested by the model. However, effects associated to NATO partnership are positive as expected, but not significant for high spenders, being more relevant for countries with lower defence spending.

5. Robustness analysis

In this section we conduct several robustness analyses. First, it can be argued that the results presented can be caused by reverse causality. In order to rule out this issue, a new panel dataset is used. Mainly, starting from the original sample, we construct non-overlapping three year intervals. We compute the average real GDP per capita growth over each interval and treat it as the new dependent variable. All independent correlates are measured at the beginning of each three-year period. The new panel data then consists of 49 countries and 10 non-overlapping periods. This approach reduces biases stemming from reverse causation (Beck, 2008) and can filter out short-run cyclical fluctuations as well (Aghion et al., 2009). Moreover, Yakovlev (2007), Compton and Paterson (2016), Musayev (2016) or Utrero-González et al. (2019) among others have used this procedure with five and three year-intervals, respectively. Results are collected in Table 6.

Results for the new panel confirm the previous evidence, letting us to discard the potential reverse causality issue. Furthermore, they suggest that arms imports coming from NATO countries, and engaging in an intense partnership with NATO can have a positive and significant effect on growth not only in the short, but also in the medium run.

Second, one potential flaw of the results just presented is that our outcome measure, GDP growth, which is coherent with the theoretical model and it is the traditional variable in comparative studies on economic growth, is not fully capturing productivity improvements.[18] Actually, the positive effect reported could be due to increasing security rather than technology diffusion and productivity improvements. To exclude this possibility, we re-estimate our regression with total factor productivity (TFP) as the dependent variable.[19,20] Results are presented in Table 7.

The new coefficients for arms imports replicate the ones obtained with GDP growth as dependent variable in terms of sign and significance. Therefore, incorporating advanced technology via arms imports has a positive effect on productivity growth.

Related to this fact, it could be the case that arms imports may stimulate growth through increased security in the economy and not exactly productivity growth, especially in countries with more conflicts. In order to clarify this point, we classify countries as "conflictive", if they have had historically more conflicts and still have, and those which have not. Table 8 presents a summary of results. As it can be seen, the differences are associated to the "conflictive" nature of the country but not the dependent variable used. NATO arms imports affect positively and significantly economic and productivity growth in more conflictive countries while they do not in less conflictive countries. Therefore, it is true that the effect of arms imports is more relevant in more conflicting countries, but the evidence suggests not only the existence of a "security effect" but also a "productivity improving effect".[21]

Finally, the literature on international spillovers has highlighted not only the relevance of imports but also the importance of domestic and international R&D capital stock to explaining total factor productivity (Coe et al., 2009). Although our paper objective is to add to the defence-growth nexus debate, the increasing interest in the technology diffusion mechanism makes appropriate to explore the impact of R&D

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[18] Thanks to an anonymous referee for making us aware of this point.

[19] Data for TFP is taken from the Penn World Tables (10.0 edition).

[20] Summary statistics of the new variables used in this section and their stationarity analysis is presented in Table A.3 in the Appendix.

[21] We are thankful to an anonymous referee for bringing our attention to the issues of security and conflicts.

Table 5
Estimation results. Large and low military spending countries.

	Large spending			Low spending		
	(1)	(2)	(3)	(4)	(5)	(6)
LGDPcap (lagged)	−0.0049	−0.0038	−0.0041	0.0016	0.0002	0.0011
	(0.0056)	(0.0054)	(0.0053)	(0.0056)	(0.0059)	(0.0062)
Inv_GDP	0.3010**	0.3109**	0.2695**	0.1371	0.1831	0.1260
	(0.1267)	(0.1287)	(0.1201)	(0.1192)	(0.1261)	(0.1474)
Con_GDP	−0.1636	−0.2004	−0.0934	−0.3279***	−0.3208***	−0.3091***
	(0.3089)	(0.3124)	(0.2872)	(0.1001)	(0.1073)	(0.1137)
Def_GDP	0.0150	0.0740	−0.0467	1.1833	1.1542	0.8803
	(0.4153)	(0.4340)	(0.4148)	(0.8358)	(0.7467)	(0.6707)
NATO_ArmsIMPORTS	0.2525**	0.2528**	0.2405**	−0.2267	−0.2206	−0.2346
	(0.1045)	(0.1026)	(0.1032)	(0.2959)	(0.2797)	(0.3005)
NONATO_ArmsIMPORTS	−0.1978	−0.2077	−0.2218	−0.0675	−0.0603	−0.0762
	(0.2401)	(0.2370)	(0.2149)	(0.2493)	(0.2483)	(0.2661)
NATO	0.0064			0.0053		
	(0.0138)			(0.0074)		
PARTNER		0.0240			0.0175	
		(0.0163)			(0.0175)	
PARTNERSHIP_STATUS			0.0672			0.0521***
			(0.0464)			(0.0186)
obs	648	648	648	666	666	666
AR(1)	**−3.43**	**−3.45**	**−3.48**	**−2.76**	**−2.76**	**−2.83**
AR(2)	−1.76	−0.98	−0.28	−0.98	−0.79	−0.58
Hansen tests:						
Overid restrictions:	25.91	24.96	27.16	27.10	27.03	29.16
Exogeneity	9.26	8.62	12.83	17.17	16.55	21.41

Notes. The dependent variable is the growth rate of per capita GDP. Labels of variables are defined in Table 1. All specifications include time effects (NATO key events) as defined by NATO. Heteroskedasticity and autocorrelation robust standard errors are reported. The asterisks stand for the *p-value* significance levels (* $p < 0.1$; ** $p < 0.05$; *** $p < 0.01$). At the bottom of the table, diagnostic test statistics are reported. Bold numbers indicate significance at least at 0.05.

Table 6
Estimation results. Three-year average growth rate.

	(1)	(2)	(3)	(4)	(5)	(6)
LGDPcap (lagged)	−0.0025	−0.0057	−0.0065	−0.0004	−0.0043	−0.0040
	(0.0056)	(0.0060)	(0.0049)	(0.0046)	(0.0045)	(0.0040)
Inv_GDP	0.3499**	0.3953**	0.3548**	0.2379*	0.3067**	0.2639*
	(0.1744)	(0.1839)	(0.1606)	(0.1303)	(0.1428)	(0.1364)
Con_GDP	−0.1607	−0.1270	−0.0645	−0.1394	−0.1025	−0.0598
	(0.1222)	(0.1217)	(0.1140)	(0.1366)	(0.1342)	(0.1207)
Def_GDP	−0.5362	−0.2096	−0.1918	−0.3662	−0.0470	−0.1527
	(0.5512)	(0.4953)	(0.4925)	(0.4510)	(0.3616)	(0.5111)
ArmsIMPORTS	0.1278*	0.1134	0.0970			
	(0.0767)	(0.0831)	(0.0737)			
NATO_ArmsIMPORTS				0.1314**	0.1121*	0.1161*
				(0.0579)	(0.0612)	(0.0604)
NONATO_ArmsIMPORTS				−0.0443	−0.0307	−0.0918
				(0.1917)	(0.2007)	(0.1884)
PARTNER	−0.0014			−0.0011		
	(0.0075)			(0.0066)		
NATO		0.0100			0.0104	
		(0.0117)			(0.0118)	
PARTNERSHIP_STATUS			0.0424**			0.0373**
			(0.0188)			(0.0190)
Observations	455	455	454	455	455	454
AR(1)	**−2.83**	**−2.94**	**−2.76**	**−2.76**	**−2.86**	**−2.78**
AR(2)	−1.86	1.85	1.38	1.92	1.95	1.58
Hansen tests:						
Overid restrictions:	22.49	17.45	24.38	19.67	20.60	28.38
	12.72	12.10	17.04	15.17	14.02	19.17

Notes. The dependent variable is the three-year average growth rate of per capita GDP. Labels of variables are defined in Table 1. All specifications include time effects (NATO key events) as defined by NATO. Heteroskedasticity and autocorrelation robust standard errors are reported. The asterisks stand for the *p-value* significance levels (* $p < 0.1$; ** $p < 0.05$; *** $p < 0.01$). At the bottom of the table, diagnostic test statistics are reported. Bold numbers indicate significance at least at 0.05.

and the effects (if any) of military international spillovers on productivity.[22] Accordingly, we define $Domestic\_R\&D$ and $NATO\_R\&D$ to account for the R&D stock of each individual country, and NATO average R&D stock, respectively.[23] Regarding the spillover effect, we are concious about the ongoing debate on how to measure appropriate

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[22] We thank the editor for bringing our attention to this issue.

[23] R&D stock is in log of per capita terms and is computed assuming a depreciation rate of 15%. Data comes from the World Bank data on Research and development expenditure.

Table 7
Estimation results. Estimation with TFP.

	(1)	(2)	(3)	(4)	(5)	(6)
LTFP (lagged)	−0.0350	−0.0323	−0.0358	−0.0257	−0.0250	−0.0325
	(0.0398)	(0.0410)	(0.0393)	(0.0390)	(0.0408)	(0.0359)
Inv_GDP	0.1202	0.1090	0.1117	0.0494	0.0453	0.0594
	(0.0958)	(0.0971)	(0.0970)	(0.1071)	(0.1046)	(0.1091)
Con_GDP	−0.3002***	−0.2726***	−0.25219**	−0.2244**	−0.2005**	−0.1490*
	(0.0965)	(0.0807)	(0.0801)	(0.0998)	(0.0843)	(0.0762)
Def_GDP	−0.3640	−0.3938*	−0.4130*	0.1177	0.0890	0.0342
	(0.2362)	(0.2295)	(0.2266)	(0.4157)	(0.3937)	(0.3889)
ArmsIMPORTS	0.2235**	0.2181**	0.2104*			
	(0.1099)	(0.1094)	(0.1105)			
NATO_ArmsIMPORTS				0.2076**	0.2020**	0.1817*
				(0.0964)	(0.0962)	(0.0100)
NONATO_ArmsIMPORTS				−0.1978	−0.2028	−0.2185
				(0.3113)	(0.3115)	(0.3005)
PARTNER	0.0121			0.0136		
	(0.0091)			(0.0095)		
NATO		0.0049			0.0013	
		(0.0064)			(0.0062)	
PARTNER						
PARTNERSHIP_STATUS			0.0247**			0.0185
			(0.0102)			(0.0140)
Observations	1043	1043	1043	1314	1043	1314
AR(1)	**−3.44**	**−3.47**	**−3.44**	**−3.58**	**−3.59**	**−3.58**
AR(2)	−0.33	−0.36	−0.19	−0.62	−0.69	−0.44
Hansen tests:						
Overid restrictions:	**25.22**	**25.32**	**25.18**	24.75	25.25	30.74
Exogeneity	8.72	8.30	8.68	8.87	8.82	4.56

Notes. The dependent variable is the growth rate of total factor productivity (TFP). LTFP is the logarithm of total factor productivity. Labels of the rest of variables are defined in Table 1. All specifications include time effects (NATO key events) as defined by NATO. Heteroskedasticity and autocorrelation robust standard errors are reported. The asterisks stand for the *p-value* significance levels (* $p < 0.1$; ** $p < 0.05$; *** $p < 0.01$). At the bottom of the table, diagnostic test statistics are reported. Bold numbers indicate significance at least at 0.05.

Table 8
Main results for countries with more and less conflicts.

	Low probability of conflict		High probability of conflict	
	GDP growth	TFP growth	GDP growth	TFP growth
Def_GDP				+
NATO_ArmsIMPORTS			+	+
NONATO_ArmsIMPORTS			−	−
NATO	+			
PARTNER				
PARTNERSHIP_STATUS	+	+	+	

Notes: Main results of estimations for countries with more and less conflicts separately. The dependent variables are the growth rate of GDP and TFP. The +/−signs stands for positive or negative significant relationship with economic growth.

pools of international knowledge spillovers and if all knowledge embedded in imports are transferred to the importing country. Although the incorporation of industry data has permitted the construction of finer measures of international spillovers (see Bournakis et al., 2018), due to data availability, we construct an import-ratio weighting scheme in the spirit of Coe and Helpman (1995), Madsen et al. (2010) and Ghosh and Parab (2021).[24] Accordingly, we define the spillover effect as

$$NATO\_Spillover_{it} = \sum_{j=1}^{N} \frac{NATO\_ArmsIMPORTS_{jit}}{ArmsIMPORTS_{it}}\ Exporter\_R\&D_{jit}$$

where $NATO\_Spillover_{it}$ is the total spillover effect in country i at time t, N is the number of arms import partners of country i, $NATO\_ArmsIMPORTS_{jit}$ is the arms import from NATO country j to country i at time t, $ArmsIMPORTS_{it}$ is total arms imports from all the countries to country i at time t, and $Exporter\_R\&D_{jit}$ is the stock of domestic R&D of NATO country j from which country i imports in period t.

Results are presented in Table 9. As it can be observed, domestic R&D coefficient is not significant. On the contrary, R&D stock of NATO coefficient is positive and significant. In addition, the introduction of R&D variables does not change the result for NATO arms imports, being the coefficient positive and significant as well. Columns 4 to 6 include the NATO spillover effect. The estimated coefficient is positive and significant. The knowledge spillover elasticity lies between 2.5% and 2.8% depending on the institutional relationship with NATO and is similar to the result of Coe and Helpman (1995). This result suggests that military international knowledge spillovers exist and imports of advanced weaponry in the technology frontier are relevant mechanisms for diffusion of foreign knowledge.

6. Conclusions

We use an endogenous growth model with defence sector to study technology diffusion within a military alliance. Resources invested in military capital aiming at increasing security can generate technological externalities through arms trade. Allies and partners of the alliance who are granted the access to advanced technological weapon systems

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[24] We are conscious that as Bournakis et al. (2018) note this approach is assuming that the knowledge embodied in foreign R&D stock is considered a public good and that this assumption could be too strong. However, data availability at country level for our sample and period restrict our choices and makes us consider this measure appropriate.

Table 9
Estimation results. Estimation with R&D and Spillover.

	(1)	(2)	(3)	(4)	(5)	(6)
LTFP (lagged)	−0.0123	−0.0099	−0.0128	−0.1365*	−0.1321	−0.1320*
	(0.0338)	(0.0326)	(0.0327)	(0.0779)	(0.0768)	(0.0721)
Inv_GDP	−0.0335	−0.0241	−0.0380	0.0177	0.0512	0.0929
	(0.0708)	(0.0666)	(0.0676)	(0.2157)	(0.2070)	(0.1791)
Con_GDP	−0.2622***	−0.2675***	−0.2780***	−0.3257**	−0.2900*	−0.2925**
	(0.0715)	(0.0859)	(0.0779)	(0.1564)	(0.1626)	(0.1400)
Def_GDP	1.7802***	1.8600***	1.8661***	2.4208***	2.3903***	2.4330***
	(0.5591)	(0.5373)	(0.5307)	(0.3600)	(0.3403)	(0.3179)
Domestic_R&D	−0.0086	−0.0065	−0.0089	−0.0166	−0.0157	−0.0157
	(0.0069)	(0.0059)	(0.0068)	(0.0107)	(0.0102)	(0.0098)
NATO_R&D	0.0176*	0.0149*	0.0171*			
	(0.0095)	(0.0088)	(0.0096)			
NATO_ArmsIMPORTS	0.1230*	0.1086*	0.1170*			
	(0.0667)	(0.0610)	(0.0640)			
NATO_Spillover				0.0283*	0.0274*	0.0257*
				(0.0153)	(0.0148)	(0.0138)
NATO	0.0052			−0.0154		
	(0.0077)			(0.0350)		
PARTNER		−0.0087			−0.0096	
		(0.0206)			(0.0367)	
PARTNERSHIP_STATUS			0.0219			0.0325
			(0.0134)			(0.0446)
Observations	1042	1042	1042	1042	1042	1042
AR(1)	**−3.86**	**−3.95**	**−3.86**	**−2.31**	**−2.37**	**−2.45**
AR(2)	0.19	−0.25	0.18	−0.61	−0.63	−0.53
Hansen tests:						
Overid restrictions:	22.52	24.15	22.07	2.73	2.62	4.39
Exogeneity	10.59	12.54	10.59	0.84	1.14	1.16

Notes. The dependent variable is the growth rate of TFP. LTFP is the logarithm of total factor productivity. Domestic_R&D, NATO_R&D and NATO_Spillover that stand for domestic R&D stock, Alliance R&D stock and the total spillover effect, respectively. Labels of the rest of variables are defined in Table 1. All specifications include time effects (NATO key events) as defined by NATO. Heteroskedasticity and autocorrelation robust standard errors are reported. The asterisks stand for the *p-value* significance levels (* $p < 0.1$; ** $p < 0.05$; *** $p < 0.01$). At the bottom of the table, diagnostic test statistics are stated. Bold numbers indicate significance at least at 0.05.

Table A.1
List of countries in the sample 1990–2019.

Partner countries (as of 2019)

- Algeria
- Armenia
- Australia
- Austria
- Azerbaijan
- Bahrain
- Belarus
- Bosnia-Herzegovina
- Egypt
- Colombia
- Finland
- Georgia
- Iraq
- Ireland
- Israel
- Japan
- Jordan
- Kazakhstan
- Korea (Rep.)
- Kuwait
- Kyrgyzstan
- Malta
- Moldova
- Mauritania
- Mongolia
- Morocco
- New Zealand
- North Macedonia (2020)
- Pakistan
- Qatar
- Serbia
- Sweden
- Switzerland
- Tunisia
- United Arab Emirates
- Ukraine

Former partners that are fully NATO members as of 2019*

- Albania (2009)
- Bulgaria (2004)
- Croatia (2009)
- Czech Republic (1999)
- Estonia (2004)
- Hungary (1999)
- Latvia (2004)
- Lithuania (2004)
- Montenegro (2017)
- Poland (1999)
- Romania (2004)
- Slovakia (2004)
- Slovenia (2004)

*Year when membership was granted in parenthesis.

Table A.2
Unit root tests.

	IPS	ADF-Fisher	PP
Inv_GDP	−2.1204***	7.8032***	4.9017***
Con_GDP	−2.0556***	11.508***	5.7049***
Def_GDP	−2.7126***	9.4182***	9.348***
NATO_ArmsIMPORTS	−3.2324***	15.9598***	45.2978***
NONATO_ArmsIMPORTS	−3.5144***	7.886***	64.172***

Notes: IPS is the Im, Pesaran and Shin test, ADF is the Augmented Dickey–Fuller test and PP is the Phillips–Perron test. Significance levels: *** at 1%, ** at 5% and * at 10%.

are the ones that can enjoy those extra benefits, i.e. improved technology level of the existing stock of arms of importers can positively affect the level of output. The implications of the model have been tested using an unbalanced panel data set from NATO member and partner

Table A.3
Summary statistics and unit root tests of robust analysis.

Variable	Definition	Obs	Mean	Std. Dev.
LTFP	Total factor productivity Growth Rate (log)	1042	0.0048	0.0756
Domestic_R&D	Own R&D stock (log)	1042	9.4470	4.9385
NATO_R&D	NATO R&D stock (log)	1042	11.8354	3.9813
NATO_Spillover	Spillover effect (log)	1042	8.1968	6.5863

	IPS	ADF-Fisher	PP
Domestic_R&D	−11.8538***	1.9247***	45.5251***
NATO_R&D	−9.0241***	17.9002***	69.3241***
NATO_Spillover	−10.7997***	7.0774***	20.5220***

Notes: IPS is the Im, Pesaran and Shin test, ADF is the Augmented Dickey–Fuller test and PP is the Phillips–Perron test. Significance levels: *** at 1%, ** at 5% and * at 10%.

countries during the 1990–2019 period. Results from the econometric analysis are in line with theoretical predictions.

We show that NATO arms imports and strategic partnership with NATO have positive effects on growth. Further, it is shown that importing advanced NATO weaponry has positive effects on productivity and there exists a positive military international spillover effect. This result implies that armament trade within military alliance not only improves security and alliance endurance, but it can also act as a channel for technology diffusion through the technology embedded in the weapons acquired, and the practices and know-how associated to them. Hence, this evidence indicates that even governments interested primarily in national security should be opened to multi-dimensional international military collaborations. As it is exhibited in this paper, trade of advanced weaponry between military allies has economic benefits, analogously to what happens with free trade agreements and commercial products. Policymakers should thus have in mind military technology spillovers as an additional mechanism to promote economic growth.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

Appendix

See Tables A.1–A.3

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