An empirical analysis of Arms Exports and Economic Growth spillovers: The case of the United States

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Abstract

In this paper we study closely the relationship between arms exports, labor productivity and economic growth. Using a connectedness-measurement technology fundamentally grounded in modern network theory, we determine the size and direction of the spillover effects between these three variables. Our findings indicate that shocks from arms exports have direct spillovers over the labor productivity and GDP growth, whereas the reverse is not captured by our data. We also provide a dynamic analysis of the spillovers that confirm the direction of spillovers from arms exports to the other variables. The recent evolution of arms exports from the United States together with the changes in arms exports policy show the timeliness of studying the effects of this particular trade to the rest of the economy.

Keyword: arms exports; growth; spillovers; connectedness; variance decomposition
JEL: C22, F52, H56, O24, O51

1. Introduction

The relationship between exports of civil goods and economic growth has been widely analyzed in the literature. This paper takes a different approach focusing on the effects that the level of international trade in armaments may have on productivity, employment and growth.

There are two main reasons that make the case of arms exports interesting to analyzed. First, the main national military industries have enjoyed proactive state involvement and government–business cooperation worldwide (Hartley 2006). Accordingly, differences in defense research and development (R&D) budgets as well as institutional cooperation, or their absence, can explain the ability to develop competitive weaponry for international markets (Martí Sempere 2018). Second, arms development is becoming more R&D intensive and more expensive to develop and produce. Consequently, arms exports allow defense firms to take advantage of economies of scale. Additionally, arms transfers are expected to have a positive impact on the national industrial base, which include contributions to civil manufacturing and innovation as well (Ruttan 2006; Mazzucato 2015).

In the case of the United States (US), government's defense procurement has been considered a major driving force for the development of innovations with both defense-related and civilian applications (Mowery 2010). Moreover, Moretti, Steinwender, and Van Reenen (2021) show that increases in private R&D induced by increases in US public defense R&D have resulted in productivity gains. In the same line, Link and Scott (2013) show that public R&D subsidies awarded through the Department of Defense Small Business Innovation Research Program (SBIR) may have positive effects on employment growth as long as the investment results in additional private investment and successful development of new technology. Therefore, this government-sponsored R&D has affected the speed of innovation, and the development of new products has encouraged the creation of new markets and has stimulated the demand and employment which can favor exports as well (Guarascio and Pianta 2017).

Despite the relevance of the US sector in the global defense market and the potential effects on growth, the effect of arms exports on the US economy has been barely addressed in the literature as far as the authors are concerned.[1,2] This paper tries to make a contribution in this sense. Our objective is to determine the size and direction of the spillover effects (if any) between arms exports, labor productivity and economic growth. In particular, we build on Diebold-Yilmaz Connectedness Index methodology to investigate the joint structure of connectedness between arms exports and the US economy. There are at least two reasons that make this relationship worth analyzing. First, high-end arms systems, as the ones designed in the US, are characterized by complexity, integrating a large number of emerging technologies, being engineering intensive and having potential significant economic value (Dietrick 2006). Second, the growing global arms transfer market and the positive evolution of US arms exports in the last decade, making this sector more suitable to test the effects of exports on economic activity.

There could be at least two explanations for this type of trade flow to be under-researched, compared to trade in commercial goods. One could be associated to the additional consequences of such a trade. Arms exports may affect national security and international relations. Should arms exports go to political allies, there were scope for strategic substitution between domestic defense spending and arms trade which can have additional indirect effects on the economy as well (Pamp, Dendorfer, and Thurner 2018). Further, the few states that have the ability to manufacture and export advanced weapons

[1] US arms exports accounted for 7% of total US exports in 2016 (2018 World Military Expenditures and Arms Transfers report).

[2] See Yeung (2010) for an exception.

can use it to promote a variety of domestic political goals, international agreements as well as economic objectives (Caverley 2017). Interestingly, recent evidence shows that with the end of the Cold War the relevance of commercial aspects has increased in detriment of the security–based alignments (Thurner et al. 2019).

The second reason could be the lack of proper time series data. Arms transfers have been related to lack of transparency and corruption (Fish et al. 2015). The main international data source available to researchers is the Stockholm International Peace Research Institute (SIPRI) Arms Transfers Database, which contains yearly information on all transfers of major conventional weapons from 1950. The main series is the trend indicator values (TIV) which is based on the known unit production costs of a core set of weapons and is intended to represent the transfer of military resources rather than the financial value of the transfer. Therefore, although TIV is a useful tool for comparing trends in arms transfers by geography and period, the measure, as SIPRI points out, cannot be compared directly with gross domestic product (GDP) or defense expenditures.

Due to the nature of the arms transfer data available, we consider appropriate to use the Diebold-Yilmaz Connectedness Index (DYCI) (Diebold and Yilmaz 2009, 2012, 2014, 2015) which provides a measure of interdependence, or spillovers, among two sets of variables based on a generalized vector autoregressive framework. The DYCI methodology is a flexible, and straightforward-to-implement approach to study interconnectedness between the variables of interest. It has been extensively used to study both the structure of financial and macroeconomic connectedness separately (Uluceviz and Yilmaz 2018). The DYIC approach has the considerable advantage that it fully accounts for contemporaneous effects and it also directly measures not only the direction but also the strength of the linkages among the different variables (Greenwood-Nimmo, Nguyen, and Shin 2021). In addition, this framework is agnostic regarding how the interdependence among variables arises. Therefore, this method allows us to test the magnitude of the spillovers between arms exports and economic activity and to identify the precise direction of this effect.

Results from our analysis show that shocks arising from military exports have a clear spillover to US labor productivity and real economic growth. The dynamic analysis reveals that although the magnitude of the connectedness measure is not constant during the period analyzed, the direction maintains, showing that the shocks always go from military exports to economic growth and not in the opposite one. Further, our evidence suggests that the geopolitical strategic scenario seems to influence the corresponding upsurge/reduction in the connectedness of exports growth to the other economic variables, which would be coherent with the additional effects on security and strategic aspects associated to arms trade.

The rest of the paper is organized as follows. Section 2 introduces the theoretical background. Section 3 describes the methodology and data. Section 4 and 5 present the results and discussion respectively. Finally, section 6 concludes.

2. Theoretical Background

The economic analysis of the arms trade has primarily focused on new trade theory, industrial organization, and regulation theory, with the addition of security concerns and (home biased) procurement to examine how export and industrial policies affect national security, the defense industry as well as the consequences for importer countries (García-Alonso and Levine 2007). It is true that arms trade is very specific due to different strategic interests and security aspects affecting it (Pamp and Thurner 2017), but it is still surprising that such an element has been absent from the debate about the link between economic growth and foreign trade.

Proponents of the export-led growth hypothesis advocate that exports are an important driver of economic growth (Dreger and Herzer 2013; Siliverstovs and Herzer 2007). They discuss the main channels in which exports can affect productivity: cross border spillovers of knowledge (Grossman and Helpman 1991), R&D investment concentrated in the sectors which have comparative advantage (Kunst and Marin 1989), and externalities from export sector to non-export sector (Feder 1983). However, endogenous growth economists challenge the export-led growth hypothesis suggesting that the origin of economic growth lies within the countries themselves, see for example Lucas (1988) and Romer (1990). We argue that both hypotheses should be considered when analyzing arms exports.

Following the theoretical works of Feder (1983) or Ahumada and Sanguinetti (1995), an economy produces many different goods, some of them categorized as military goods. According to the export-led growth theory, military exports would allow defense contractors to capitalize on large orders from armed forces around the globe which help support defense-industrial development in activities where domestic demand may not be enough (Connolly and Sendstad 2017). The underlying assumption is that augmenting domestic production with foreign orders occurs while the defense contractor experiences increasing returns to scale, so that increasing production will result in a lower per-unit cost than without foreign orders. Provided learning occurs in the production process, the reduction in costs associated with larger cumulative production would be greater. This aspect is increasingly important as western countries' military budgets have reduced (Dunne and Smith 2016) and the costs of high-end weaponry have risen (Hartley 2006). The economic revenues of military exports can have additional positive effects on consumption and investment, reducing unemployment and increasing capital utilization and in turn the output (Yakovlev 2007).

Although the theory of export-led growth was formulated to explain variations in economic growth among developed countries, empirical testing was mostly directed to developing ones (Kamat, 2008). However, academic literature identified this strategy in developed countries, too. For example, Marin (1992), who focuses on four industrialized countries, United States, United Kingdom, Germany, and Japan, establishes that the causality relation from exports to growth cannot be rejected. In addition, Kónya (2006) and Konya (2004) conduct several analyses for OECD countries finding export-led growth indices for some of them, including the US. Pistoresi and Rinaldi (2012) analyze the case of Italy for different periods and find changing patterns over time. With respect to the case of military exports, procurement policy has often been used as a "lever of trade policy to promote national champions with an edge in international markets" (Weiss and Thurbon 2006). The US is a clear example and the ability to devote large budgets to weaponry puts the US in an advantageous position (Marti Sampere, 2018). Further, the renewal of the Conventional Arms Transfer (CAT) policy in 2018 to facilitate export and to actively increase the number of arms contracts shows the importance of the international arms market for the US.[3] As different US officials recognized, the primary motivation for easing CAT regulation aimed at fostering exports' deals that could affect positively the defense industry, employment, and American economy in general.[4,5] Then,

[3] Conventional Arms Transfer (CAT) Policy, was revised on July 16, 2018. The main focus of changes is on boosting American jobs and increasing national security. Among the targets: higher competitiveness of US defense firms, but also the care for human rights. Regarding the destinations of the exports, policy instructs not to sell arms where they might be used for human rights violation.

[4] Tina Kaidanow, head of the State Department's Bureau of Political-Military Affairs, said at a Capitol Hill event hosted by the Aerospace Industries Association that the new Arms Transfer Initiative not only 'bolsters our ability to protect the United States by being a force multiplier for the U.S. warfighter' but 'ultimately benefits U.S. industry by driving new innovation and creating high-quality American jobs.' In Bender B. and Palmeri T. 'Trump to unleash more global arms sales', Politico published on 9/29/2017 https://www.politico.com/story/2017/09/29/trump-global-arms-sales-243282.

[5] Peter Navarro, former director of the White House Office of Trade and Manufacturing, claimed during a meeting at the Center of Strategic and International Studies that 'The new Conventional Arms Transfer policy (CAT) works for economic security and national security. If we are able to sell defense systems to our allies and partners, it makes that partner stronger, it makes the region where that partner is more stable. and most important to me, (….) that's more jobs right here, good jobs at good wages.' Economic Security

arms exports may act as an externality, similarly as the one in capital in the model of Romer (1986).

The US is by far the world's largest defense spender and exporter. In 2019, US spending was 2.7 times higher than the second largest one, China (SIPRI 2020), and despite the increasing trend during the Trump administration, defense budget is still below the 4.5% of GDP, accounted in 2010 (3.1% in 2019).[6] Moreover, US investments in weapons procurement and R&D[7] alone were larger than China's total defense budget.[8] Actually, American defense R&D has accounted for 79% of total OECD defense R&D funding since 2009 (Sargent 2020). As Gilli and Gilli (2016) claim, designing, developing, and manufacturing advanced weapon systems require high investments as well as know-how and experience. This investment effort would relate clearly to the existence economies of scale and learning in the defense industrial sector and especially in the US case. As presented above, this is precisely one of the main arguments behind the export-led growth models. The increase in exports would lead to economies of scale, increase of employment and technological progress in export industries, thus, leading to a rise in productivity implying a fall in capital coefficient, ultimately resulting in a rise in natural rate of economic growth. Therefore, one of the proposed research hypotheses is the following:

H1a: According to the export-led growth theory there are direct spillovers from arms exports to the performance of the economy in all sectors, especially when domestic demand is shrinking.

as National Security: A Discussion with Dr. Peter Navarro, November 13, 2018 https://www.csis.org/analysis/economic-security-national-security-discussion-dr-peter-navarro.

[6] See Defense Budget Overview (Office of the Under Secretary of Defense (Comptroller) 2019).

[7] In 2017, the US devoted 43.5% of government R&D expenditures to defense (Sargent 2020).

[8] https://www.iiss.org/blogs/military-balance/2020/02/global-defence-spending

To assure the competitiveness of military goods, high quality, top technology products, and efficient management should be in place. The early models of endogenous growth (e.g., Romer 1990) predict that the growth rate of the economy is proportional to the effort that the economy allocates to research and development (scale effect). However, Dinopoulos and Thompson (1998) and Young (1998) describe an economy with two different types of R&D, to improve existing products and to develop new varieties. Therefore, R&D becomes progressively more complex over time and avoids the scale effects in the growth rate. As Hartley (2007) argues, each generation of weapons is more effective than their predecessors and have significantly higher R&D. As military R&D becomes more relevant to develop new generation weaponry, the defense sector would increase competition with the civilian sector for human capital, natural resources and technology which could crowd-out public and private investment and commercial R&D activities (Mylonidis 2008). Nevertheless, military R&D does not have to rule out research and development concerning the production of other goods. On the contrary, military R&D spending has resulted in the development of new technology (i.e. radar, jet engine, nuclear energy) that would spill over into the civilian (private) sector. Moreover, the recent technology evolution suggests that there would be increasing flows of know-how between civilian and military research achievements, (James, Molas-Gallart, and Stankiewicz 2019) that can affect overall output.[9] Further, proponents of military spending argue that some research projects will not be carried out in the private sector due to the high-risk environment and public-good characteristics of the final product. It is expected that the demand for workers capable of running such projects will increase as well. A shortcoming of such increase in R&D investments is that new weapons come

[9] For example, Cheben et al. (2018) describe metamaterials with exotic properties like negative permeability and permittivity, super-resolution, asymmetric transmission or invisibility. If they are to be the components of the next generation of optical communication, they will be certainly of interest in military applications.

at a higher cost for the taxpayer (Hartley 2007). To boost sales, defense ministries or departments should be ready to promote deals between countries to reduce average costs. Therefore, output (and productivity) is impacted directly through R&D and indirectly through exports. The better the technological development of arms, the higher positive technological externalities for the rest of the economy and as weapons are competitive in the global markets, there will be an indirect effect of exports to the economy. This alternative hypothesis is outlined below.

H1b: R&D investment allows productivity growth, making products better and more competitive causing economic growth and inducing spillovers on arms exports.

3. DYCI Methodology and Data

3.1 Measure of spillover effects

To measure the spillover effects from shocks to the annual military exports growth to the real GDP per capita growth and labor productivity growth (and vice versa) we apply the connectedness index methodology developed in a series of papers see Diebold and Yilmaz (2009, 2012, 2014, 2015), based on a forecast variance decomposition of vector autoregressive (VAR) processes. In particular, we follow Dielbold and Yilmaz (2012), so that our results do not depend on the ordering of the variables. One of the basic differences between the two papers by Dielbold and Yilmaz (2009, 2012) is the different procedures used to deal with the orthogonality of errors. Diebold and Yilmaz (2009) used an identification approach based on the Cholesky factorization which was not robust enough to a different ordering of the variables that are part of the VAR model. In 2012, they applied the generalized VAR framework from Koop et al. (1996) and Pesaran and Shin (1998) that allows for correlated shocks but they are appropriately weighted using the empirical observed distribution of errors.[10] The improved spillover index obtained is insensitive to variable ordering and takes into account not just the total spillover effects but also the direction of the spillovers.

The total connectedness index is the ratio of the sum of off-diagonal elements of the forecast error variance-covariance matrix to the sum of all elements of the same matrix.

To apply the methodology we take the variable Y_t , of dimension Nx1, and assume it follows a VAR(p) process

$$Y_t = \sum_{i=1}^{p} \phi_i Y_{t-i} + \varepsilon_{t,} \qquad t=1,2,....T \tag{1}$$

where $\varepsilon_t \sim N(0, \Omega)$ is white noise with variance matrix Ω. Variable Y_t is also considered to obey the moving-average process

$$Y_t = \sum_{i=0}^{\infty} A_i \varepsilon_{t-i} \tag{2}$$

with the following relationship between the two coefficients

$$A_i = \phi_1 A_{i-1} + \phi_2 A_{i-2} + ... + \phi_p A_{i-p} \tag{3}$$

where $A_0 = I_N$ and $A_i = 0$ for $i < 0$.

To be able to come up with connectedness measures, we first have to perform H-step ahead error variance decomposition of the VAR framework, $\theta_{i,j}^{g}(H)$, as suggested in Koop, Pesaran, and Potter (1996), Pesaran and Shin (1998) and Diebold and Yilmaz (2012),

$$\theta_{i,j}^{\ g}(H) = \frac{\sigma_{jj} \sum_{h=0}^{H-1} \left(e_i' A_h \Omega e_i\right)^2}{\sum_{h=0}^{H-1} \left(e_i' A_h \Omega A_h' e_i\right)^2} \tag{4}$$

[10] In this framework all variables in the system are subject to shocks simultaneously.

where σ_{jj} is the j^{th} diagonal element of Ω, H is the forecast horizon, and e_i is the selection vector with unity at its *i*th element and zero elsewhere. Additional property of these forecast error variance contributions is that their sum does not have to be unity, $\sum_{j=1}^{N} \theta_{i,j}^{g}(H) \neq 1$. Similarly to Diebold and Yilmaz (2012) we normalize each element in the variance decomposition matrix by the sum of each row

$$\overset{\approx}{\theta}{}_{i,j}^{g}(H) = \frac{\theta_{i,j}^{g}(H)}{\sum_{j=1}^{N} \theta_{i,j}^{g}(H)} \tag{5}$$

obtaining the items of the connectedness matrix *D*, $d_{ij} = \overset{\approx}{\theta}{}_{i,j}^{g}(H)$, depicted in the upper left corner of Table 1. Notice also that $\sum_{j=1}^{N} \overset{\approx}{\theta}{}_{i,j}^{g}(H) = 1$ and $\sum_{i,j=1}^{N} \overset{\approx}{\theta}{}_{i,j}^{g}(H) = N$.

[Table 1 near here]

Matrix *D* comprises of $N^2 - N$ pairwise directional values of connectedness from *j* to *i*

$$C_{i \leftarrow j} = d_{ij} = \overset{\approx}{\theta}{}_{i,j}^{g}(H). \tag{6}$$

Term $C_{i \leftarrow j}$ reflects the fraction of the *H*-step-ahead error variance in variable *i* due to shocks originating in variable *j*. In general, $C_{i \leftarrow j} \neq C_{j \leftarrow i}$, therefore, $\frac{N^2 - N}{2}$ net pairwise directional connectedness is expressed through

$$C_{ij} = C_{j \leftarrow i} - C_{i \leftarrow j} = d_{ji} - d_{ij} = \overset{\approx}{\theta}{}_{j,i}^{g}(H) - \overset{\approx}{\theta}{}_{i,j}^{g}(H). \tag{7}$$

The outcomes stated in the column 'From Others' and the row 'To Others', embody the total directional connectedness 'from others' to *i*

$$C_{i \leftarrow \blacksquare} = \Sigma_{i \neq j}^{N}{}^{j=1} d_{ij} = \Sigma_{j \neq i}^{N}{}^{j=1} \overset{\approx}{\theta}{}_{i,j}^{g}(H), \tag{8}$$

and the total directional connectedness from *j* 'to others'

$$C_{\blacksquare\leftarrow j} = \Sigma_{i\neq j}^{N}{}^{i=1}\, d_{ij} = \Sigma_{i\neq j}^{N}{}^{i=1}\theta_{i,j}^{\approx g}(H), \qquad (9)$$

respectively. Further, the difference between two such results for the same variable,

$$C_i = C_{\blacksquare\leftarrow i} - C_{i\leftarrow\blacksquare}, \qquad (10)$$

depicts the net total directional connectedness. Finally, the bottom right cell offers a measure of total connectedness,

$$C = \frac{\Sigma_{i\neq j}^{N}{}^{i,j=1}\theta_{i,j}^{\approx g}(H)}{N}, \qquad (11)$$

expressed as a percentage of total variation.

To sum up, the connectedness table shows how one can start from the most disaggregated connectedness (pairwise directional) and aggregate them in various ways to obtain macroeconomic total directional and total connectedness (Diebold and Yilmaz 2016).

Given the variables we are interested in, in our empirical application N = 3, namely $Y_t = [g_{GDPcap_t}, g_{LaborProd_t}, g_{ArmsExports_t}]$, where g_{GDPcap_t} is the annual growth rate of the US real gross domestic product per capita at time *t*, $g_{LaborProd_t}$ is the annual growth rate of the US labor productivity and $g_{ArmsExports_t}$ is the annual growth rate of US military exports. Further we use one period ahead forecast horizon (H = 1) and one period lag (p = 1), respectively.

3.1 Data

We use three data sets for the US from 1950 to 2017. The first set comprises annual data of the real gross domestic product (GDP) and the population. The data are retrieved from FRED, Federal Reserve Bank of St. Louis.[11] Following the economic growth literature we work with real GDP in per capita terms. The second data set comprises information

[11] Data retrieved from https://fred.stlouisfed.org/series/FYGDP.

on the annual growth of labor productivity that comes from Penn World Tables (PWT) 9.0, and military exports from Stockholm International Peace Research Institute (SIPRI) Arms Transfers database. As outlined above, export data are the trend indicator values (TIV) series based on unit production costs and represent the transfer of military resources rather than the financial value of the transfer.[12]

Our main goal is to assess the spillover effects between the military exports' growth and the real GDP per capita growth, as well as the labor productivity growth. Table 2, panel A reports the main summary statistics. The empirical implementation of DYCI relies on a covariance stationary VAR model, otherwise connectedness results can be unreliable. To test the order of integration of the series we consider the Philips and Perron test and the modified Dickey–Fuller *t* test (known as the DF-GLS test) proposed by Elliott, Rothenberg and Stock (1996).[13] The null hypothesis of the tests is that the series under study have unit root against the assumed alternative hypothesis that the series are stationary about a linear time trend. The number of lags, *k*, is selected using the Ng and Perron (1995) sequential t-test.[14] In all the cases, we reject the null hypothesis that a unit root exists suggesting they are all integrated of order zero *I(0)* (Table 2, panel B). In addition, we also test for the existence of cointegration relationships in the data, such that in the presence of cointegrating relations a vector error-correction specification for the

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[12]The US State Department prepares the World Military Expenditure and the Arms Trade (WMEAT) report with data on US arms exports that was also considered to use. However, the information, which is not always in yearly basis, is only available from 1964 to 2017. WMEAT contains value of transfers, therefore, taking account of prices actually paid, although it also includes services, trade orders and small arms trade. In addition, it presents some series discontinuities and different computations. Therefore, we consider TIV series more suitable.

[13] Essentially, the test is an augmented Dickey–Fuller test except that the time series are transformed via a generalized least squares regression before performing the test. Elliott, Rothenberg, and Stock (1996) have shown this test has significantly greater power than the previous versions of the augmented Dickey–Fuller test.

[14] Results are robust to the choice of the alternative methods for choosing which value of *k* to use, the minimum Schwarz information criterion or the Ng–Perron modified Akaike information criterion.

approximating model should be more appropriate (Diebold and Yilmaz 2016).[15] For that, we run the Engle and Granger test and the Johansen test where the null hypothesis is that there is no cointegration against the existence of cointegration. Results indicate that we can not reject the null hypothesis suggesting that no cointegration relationship exists in the data (Table 2, panel B).

[Table 2 near here]

4. Empirical results

In the following subsections, we describe the spillover effects found between the annual US military exports growth, the US real economic growth as well as the US labor productivity growth. We start by outlining the static, or unconditional, connectedness resulting from the generalized variance decomposition. Later on, we show rolling window estimation of the dynamic connectedness.

4.1 Unconditional patterns: The full-sample connectedness table

Full-sample analysis of military exports growth, real GDP per capita growth and labor productivity growth connectedness is carried out for the observation period (1950-2017). Estimated connectedness outcomes for these three variables are stated in Table 3. Compared to the generalized results in Table 1, Table 3 contains the net connectedness row (bottom row) which shows the difference between the corresponding 'To Others' and 'From Others' entries.

[Table 3 near here]

[15] The peculiarity of the series of arms exports, namely, they represent the transfer of military resources rather than the financial value of the transfer, leads us to consider that, despite the potential of relationships among the different variables, there are not theoretical reasons to be cointegrated in the long run and the proposed VAR analysis would be appropriate. However, we have tested for cointegration status of the data to clarify this aspect.

Careful reading of Table 3 implies that about 40% of the forecast error variance originates from connectedness or spillovers, C = 42.40% (bottom right cell, total connectedness index). On the other hand, the remaining 57.60% is explained by idiosyncratic shocks. We can thus conclude that connectedness, or spillovers, are influential on average in our case. To confirm this point, the connectedness 'To Others' row shows that the military exports growth, and GDP per capita growth have remarkable 'To' connectedness, above 50%. On the other hand, the labor productivity growth has a negligible 'To' connectedness close to 0%. Although endogenous growth models claim that the productivity growth is closely linked to GDP growth, the evidence found suggests that shocks would go only in one direction, namely, from GDP to labor productivity. In addition, labor productivity growth shows negative net directional connectedness and it is a net recipient of shocks from military exports. Further, the GDP per capita growth is a net shock transmitter as well.

In terms of the directional connectedness 'To Others' throughout the full sample, military export growth is the variable that contributed the most to other variables' forecast error variance. Military exports growth shows the highest 'To' connectedness, reaching a value of $C_{ArmsExports} = 67.54\%$. Shocks arising from $g_{ArmsExports}$ have a clear spillover to errors in the 1-year ahead forecast of g_{GDPcap} and $g_{LabourProd}$ (above 30% in both cases) but the reverse is not true. Interestingly, exports growth has almost 0% 'From' connectedness, implying that shocks from the real GDP per capita growth and the labor productivity growth have negligible unconditional impact on the military exports growth that depends on idiosyncratic factors. The real GDP per capita growth has also a remarkable 'To' connectedness, above 50%. On the other hand, the labor productivity growth has an insignificant 'To' connectedness close to 0%. This could be related to the fact that US productivity seems to be less pro-cyclical after the mid-1980s (McGrattan and Prescott 2012). In addition, the labor productivity growth shows negative net directional connectedness and it is a net recipient of shocks from the military exports' growth, and especially, from the real GDP per capita growth, that are net transmitters of shocks.

4.2. Conditional patterns: Connectedness dynamics

The above discussion sheds light on the 'average' connectedness of the US military exports growth, US real GDP per capita growth and US labor productivity growth in our sample. However, given that the business cycles and the intensity of military export activity also varies over the analyzed period, dynamic connectedness parameters are computed.

We plot the total military exports growth, real GDP growth per capita and labor productivity growth connectedness using 30-year rolling-sample windows in Figure 1 . The first attribute of the connectedness plot is the absence of a long-run trend. Therefore, there are periods during which shocks to the variables are notably transmitted to others, and other periods during which connectedness, although still important, seems to be less relevant. The total connectedness ranges between a minimum about 26% and a maximum about 46%. We can identify two periods that are characterized by a lower connectedness whose average is about 30%: the 1999-2002 period and the 2008-2011 period, linked to the burst of the technology stock market bubble and the subprime economic crisis, respectively. Conversely, there are two periods where shocks across variables are more notably transmitted. From 1980 to 1992 and from 2013 the average conditional connectedness is about 40%.

[Figure 1 near here]

In addition, we analyze directional connectedness plots (see Figures 2-4) to gain insight into military exports growth, real GDP per capita growth and, labor productivity growth connectedness.

These figures show that over the whole period the 'From' connectedness of the labor productivity growth is fairly stable, above 80%, and the 'To' connectedness is not relevant. Further on the one hand, the net connectedness of the labor productivity growth is clearly negative, as it is a net recipient of shocks from the real GDP per capita growth and the military exports growth and on the other hand, the net connectedness of the military exports' growth is positive over the whole sample, although the magnitude varies importantly, not showing any trend.

The net connectedness of the real GDP per capita growth is positive with some rare exceptions (1988-1992 period and 2013). Interestingly, there is some kind of complementarity between GDP and exports growths' net connectedness. When the arms exports connectedness is increasing, the net connectedness of the GDP per capita is declining, and vice versa. Further, the maximum arms exports connectedness coincides with the negative result in 1988-1992 and 2013 growth connectedness. Despite this, the shock size is different, being the 'net' connectedness of the total military exports growth average about 27% larger than the 'net' connectedness of the real GDP per capita growth average, suggesting that arms exports have greater influence on the variables analyzed.

[Figure 2 near here]

[Figure 3 near here]

[Figure 4 near here]

To gain additional understanding of the connectedness patterns described above, figure 5 shows the net pairwise connectedness. It can be easily seen that g_{GDPcap} transmits shocks to $g_{laborProd}$ but not to $g_{ArmsExports}$. In fact, the average connectedness between g_{GDPcap} and $g_{laborProd}$ is about 50%, showing cyclical variations. The minimum spillovers could be associated with two economic downturns, namely, the 1989-1991 recession, and the 2008 financial crisis.

[Figure 5 near here]

The connectedness between the real GDP per capita growth and military exports growth is always negative, suggesting that arms exports is a net shock transmitter, with an average connectedness of about -20%. Further, the average connectedness between the labor productivity growth and military exports growth is about -35%. Therefore, our empirical results show that military exports growth is a clear transmitter of shocks to the other variables.

Notably, higher arms exports' periods coincide with the highest connectivity from arms exports to the other variables, suggesting positive spillovers from arms exports to the rest of the economy (Figure 5 and Figure 6).

[Figure 6 near here]

Therefore, we find evidence of the influence of arms exports on the growth of the economy and productivity, as suggested by the export-led growth theory and in line with the hypothesis (H1a). Nevertheless, transmission of shocks from labor productivity and per capita GDP to the arms exports, which would support the endogenous growth model, is not verified (H1b has been falsified). This result is found both for the unconditional and conditional analysis.

Obviously, the connectedness found may depend on the forecast horizon H and VAR model. To assure the robustness of our analysis, we proceed with the variance decompositions of the estimated VAR and total connectedness index computation for different VAR model (p = 2) and the forecast horizon (H = 2). Figure 7 displays the results for H = 1, 2 and p = 1, 2 for comparison purposes. As it can be observed, the $g_{ArmsExports}$, g_{GDPcap} and $g_{LaborProd}$ connectedness using 30-year rolling-sample windows is not sensitive to the choice of the forecast horizon and/or the order of the VAR model since the total connectedness increases or decreases in tandem for different combinations of parameters. As an additional robustness exercise, different rolling windows are considered. Results for 28 and 32 -year rolling windows also displays the same pattern (figure 8). Therefore, the support for the hypothesis (H1a), export-led growth theory, is robust to the parameters chosen.

[Figure 7 near here]

[Figure 8 near here]

5. Discussion

As explained in the introductory section, arms export is a special flow because of its potential effects on national security and political goals. Traditionally, arms trade has been heavily regulated with export controls (and embargoes) and export subsidies often pursuing rather conflicting objectives such as the advancement of a domestic defense industry and the limitation of arms exports and/or their quality so as to ensure national security (García-Alonso and Levine 2007). In this sense, US has traditionally had strict norms that required that proposed transfers take into account the National Security to retain control over the technological advantage of the transferred weapons, preventing the diversion of sensitive technology to unauthorized end users (Clarke 1995).[16] Accordingly, countries may strategically choose to export more arms so as to be able to reduce their domestic defense burdens, provided national security increases (Pamp, Dendorfer, and

[16] See 1995 US Presidential Decision Directive/ NSC-34 and 2014 Presidential Policy Directive/PPD-27 for further details.

Thurner 2018). Further, military cooperation with other countries will affect national security and technology diffusion (Callado-Muñoz, Hromcová, and Utrero-González 2019). In this sense, the NATO enlargement together with the development of the partnership program, as well as the US bilateral agreements imply that most of US export destinations are ally countries which would suggest that national security is not an issue in American arms exports. In any case, along the period analyzed, international and political scenario has changed importantly. Provided US is the leading exporter, looking at this evolution can help explain the dynamics observed in the capacity to transmit shocks to the other economic variables.

Related to the arm export shocks to GDP growth, three different periods can be observed, pre 1986 period, 1986-2000 and 2001 onwards (with the 2014 exception). The central period would show the highest connectedness from arms exports growth to GDP growth. The first part of this period coincides with the Reagan Buildup, the end of the cold war, the collapse of the centrally controlled economic system as well as the first Gulf war. These events could partially explain the relevance of US military exports for at least two reasons. On the one hand, it has been shown that there is a positive relationship between domestic defense spending and arms exports (Blum 2019), which would be coherent with the more intense connectedness during high defense spending periods. On the other, the newborn countries in Eastern Europe were interested in forming part of the NATO, so were prompted to reform and renew their armies (Utrero-González, Hromcová, and Callado-Muñoz 2019). The other point in time with greatest spillovers is 2014, which concur with the military intervention of Russia in Ukraine that forced NATO to take extra reassurance measures for their allies. Related to it, the defense budget of former soviet republics increased as well.[17]

It is also remarkable that during the period 2000-2010 the shocks arising from military exports growth have less impact on the real economic growth per capita. This is especially true after the 9/11 terrorist attacks to the US and when the NATO started to counter the threat of international terrorism. However, the military spending reduced, compared to the Reagan Buildup (less than 5% of GDP compared to more than 6%).[18] In addition, the amount of military operations was lower than previous period up to the beginning of the Libyan crisis and the Arab spring in 2011. Further, the number of United Nations (UN) active mandatory arms embargoes in the 2000-2006 is the highest after the Second World War (Fruchart et al. 2007). However, data suggest that the US[19] supplied arms and ammunition to embargoed targets in violation of arms embargoes associated to conflicts, suggesting difficulties in UN enforcement capacity to reduce the flow of arms to embargoed targets (Fruchart et al. 2007).[20]

Looking at the shocks from arms exports to productivity, it can be observed a similar pattern to the shocks to GDP growth, although greater in magnitude. Interestingly, it seems that shocks to productivity are transmitted more rapidly than to GDP growth as the dynamics observed preceded the evolution in the GDP growth shocks. Therefore, although the results show robustly that arms exports transmit shocks to GDP and

[17] Lithuania, Latvia and Estonia intend to triple annual spending on arms and military equipment to $670 million by 2018 from 2014 due to fears of Russia following its annexation of Ukraine's Crimea region. Reuters, October 2016 retrieved from https://www.reuters.com/article/us-baltics-military/baltics-fearing-russia-to-triple-military-spending-by-2018-report-idUSKCN12J2S4

[18] SIPRI (2018).

[19] Together with China, Europe, Russia or the Soviet Union.

[20] It is worth noting that in cases related to Global Security rather than conflicts the USA made it clear that it was not willing to tolerate embargo violations and committed significant resources to a range of measures both within and outside the UN to improve monitoring and enforcement capacities.

productivity, as expected by export-led growth hypothesis, the dynamic analysis suggests that the magnitude may be affected by political agenda and environment.

6. Conclusion

This paper examines the connections between shocks in military exports, labor productivity and economic growth for the US, drawing on recent research on measures of connectedness and spillover effects (Diebold and Yilmaz 2009, 2012, 2014, 2015). We construct a spillover index that captures the link between these three variables. In doing so, we try to apprehend the relationships among them, and specially, the effect of the military exports on growth. Results confirm that shocks arising from military exports have a clear spillover to labor productivity and real GDP per capita growth, but the reverse is not true.

The dynamic analysis evidences the robustness of the results and shows that geopolitical strategic changes, such as international military tensions, could be affecting a corresponding upsurge/reduction in the connectedness of exports growth to the other economic variables, but does not seem to cancel the spillovers to GDP growth and productivity. Furthermore, higher US arms exports' periods coincide with the highest connectivity from US exports. These positive spillovers from US arms exports to US GDP and productivity growth would be in line with the export-led growth hypothesis. This result is not dependent on the forecast horizon, the order of the VAR model or the window width considered. Further, it has been shown that security and political scenarios still seem to affect the relationship between the three variables analyzed as suggested by Thurner et al. (2019). Our results show that economic aspects of arms exports should not be neglected, and that recent changes in US arms export policy could help US economy, together with military R&D process behind the technology diffusion.

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Table 1. Connectedness table.

	Y_1	Y_2	• •	Y_N	From Others
Y_1	$d_{11} = \overset{\approx}{\theta}{}^{g}_{1,1}(H)$		• •	$d_{1N} = \overset{\approx}{\theta}{}^{g}_{1,N}(H)$	$\sum_{j=1, j\neq 1}^{N} \overset{\approx}{\theta}{}^{g}_{1,j}(H)$
Y_2	$d_{21} = \overset{\approx}{\theta}{}^{g}_{2,1}(H)$	$d_{22} = \overset{\approx}{\theta}{}^{g}_{2,2}(H)$	• •	$d_{2N} = \overset{\approx}{\theta}{}^{g}_{2,N}(H)$	$\sum_{j=1, j\neq 2}^{N} \overset{\approx}{\theta}{}^{g}_{2,j}(H)$
•	•	•	•	•	•
•	•	•	•	•	•
Y_N	$d_{N1} = \overset{\approx}{\theta}{}^{g}_{N,1}(H)$	$d_{N2} = \overset{\approx}{\theta}{}^{g}_{N,2}(H)$	• •	$d_{NN} = \overset{\approx}{\theta}{}^{g}_{N,N}(H)$	$\sum_{j=1, j\neq N}^{N} \overset{\approx}{\theta}{}^{g}_{N,j}(H)$
To Others	$\sum_{i=1, i\neq 1}^{N} \overset{\approx}{\theta}{}^{g}_{i,1}(H)$	$\sum_{i=1, i\neq 2}^{N} \overset{\approx}{\theta}{}^{g}_{i,2}(H)$		$\sum_{i=1, i\neq N}^{N} \overset{\approx}{\theta}{}^{g}_{i,N}(H)$	$1/N \sum_{i,j=1, i\neq j}^{N} \overset{\approx}{\theta}{}^{g}_{i,j}(H)$

Schematic connectedness table: upper-left block matrix of dimension *Y*x*N* represents the 'variance decomposition matrix', $D = \left[d_{ij} = \theta_{i,j}^{\approx g}(H) \right]$, amplified with one column on the right where row sums are stated, and one row at the bottom containing column sums, and the bottom-right cell with the average of all previous results, in all cases for *i* different from *j*.

Table 2. Summary statistics and unit roots.

Panel A. Summary statistics.

	g_{GDPcap}	$g_{LabourProd}$	$g_{ArmsExports}$
Mean	3.35	1.85	2.32
Median	4.53	1.68	2.69
Std. deviation	9.67	1.39	24.45
Skewness	0.35	-0.28	0.16
Kurtosis	4.60	3.04	3.38

The table reports the main statistics for the US over the 1950-2017 observation period: g_{GDPcap} is the annual growth of the US real gross domestic product per capita, $g_{LabourProd}$ is the annual growth of US labour productivity, and $g_{ArmsExports}$ is our measure of annual growth of military exports.

Panel B. Unit root and cointegration tests.

Unit root	**Phillips-Perron**	**Dickey–Fuller**
g_{GDPcap}	-6.906^{***}	-7.32^{***}
$g_{LabourProd}$	-6.907^{***}	-4.50^{***}
$g_{ArmsExports}$	-8.476^{***}	-7.42^{***}
	Engle and Granger	**Johansen**
Cointegration	-2.989^{***}	30.40^{***}

The table reports the Philips Perron and the Dickey–Fuller test for unit roots, and the Engle-Granger and Johansen test for cointegration. Significance levels: *** at 1%, ** at 5% and * at 10%.

Table 3. Real GDP per capita growth, labor productivity growth, and military exports growth connectedness table.

	g_{GDPcap}	$g_{LabourProd}$	$g_{ArmsExports}$	From Others
g_{GDPcap}	64.32	0.57	35.10	35.67
$g_{LabourProd}$	58.54	9.02	32.44	90.98
$g_{ArmsExports}$	0.53	0.01	99.46	0.54
To Others	59.08	0.58	67.54	
Net	23.41	-90.40	67.00	42.40

Measure of the connectedness based on a vector autoregression of order 1 and a generalized variance decompositions of 1-year ahead forecast errors. Each cell reports the relative (in percentage terms) contribution of the column variable shocks to variance in the forecast error for the row variable.

Figure 1 . Total military exports growth, real GDP per capita growth and labor productivity growth connectedness for the US (30-year rolling-sample windows).

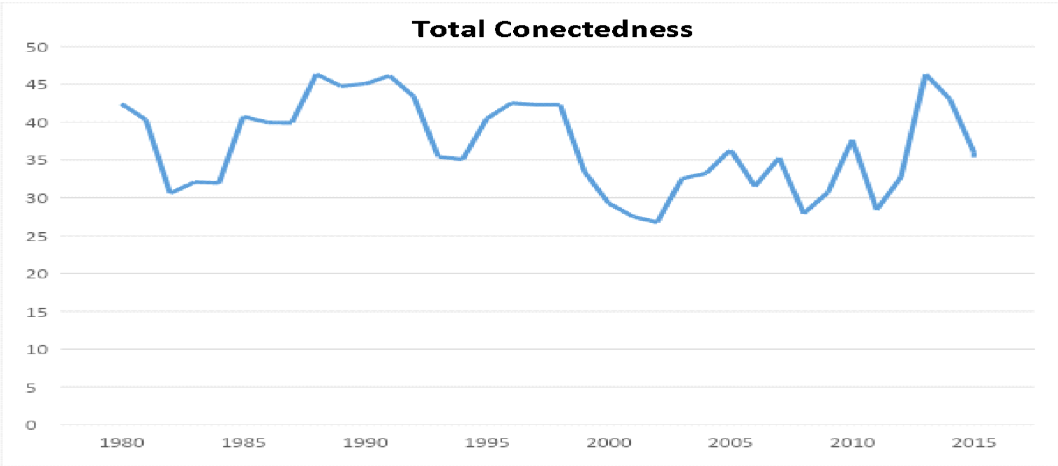
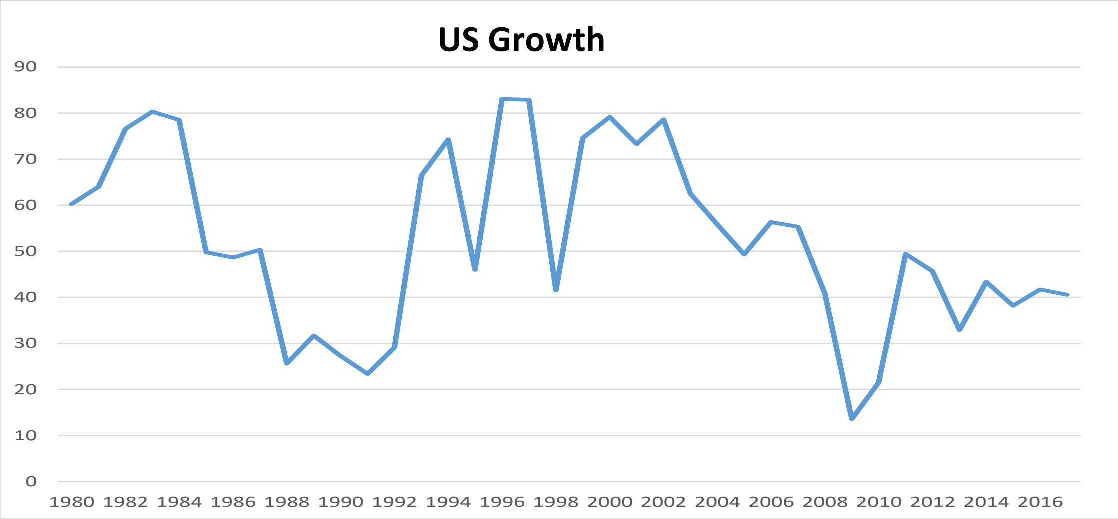


Figure 2 . 'To' connectedness Index (30-year rolling-sample windows)



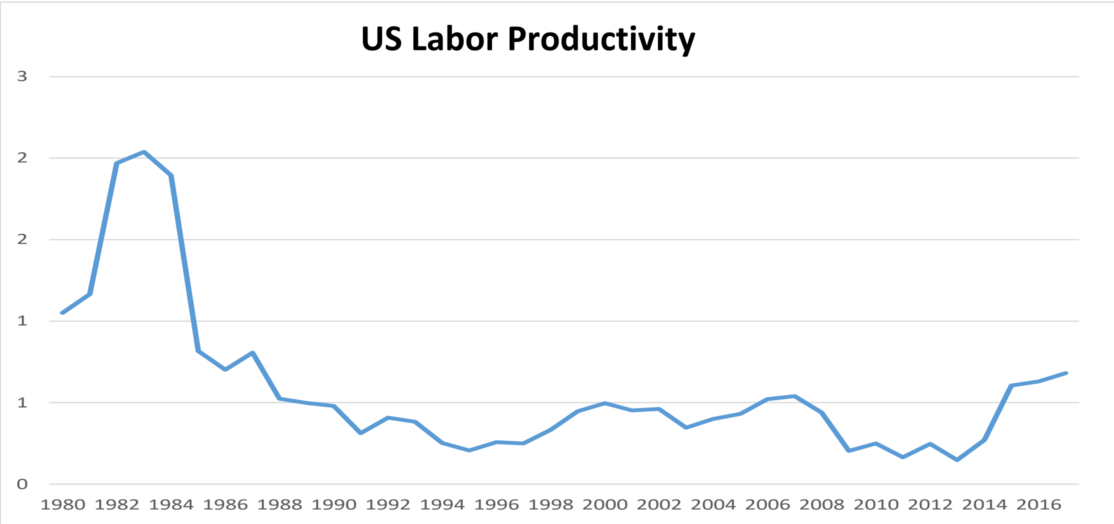


Figure 3 . 'From' connectedness Index (200-day rolling-sample windows).

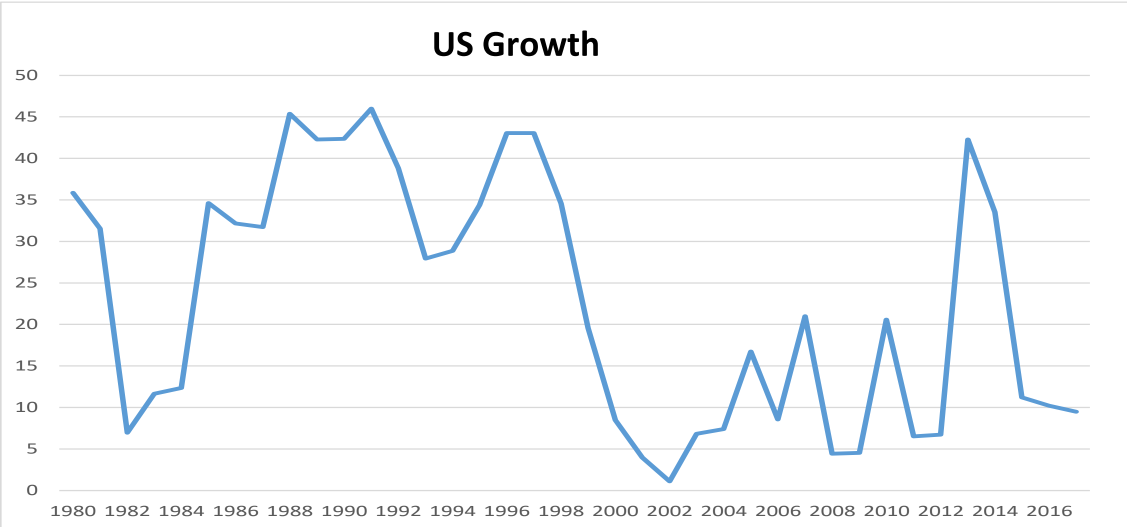


Figure 4 . Net connectedness Index (30-year rolling-sample windows).

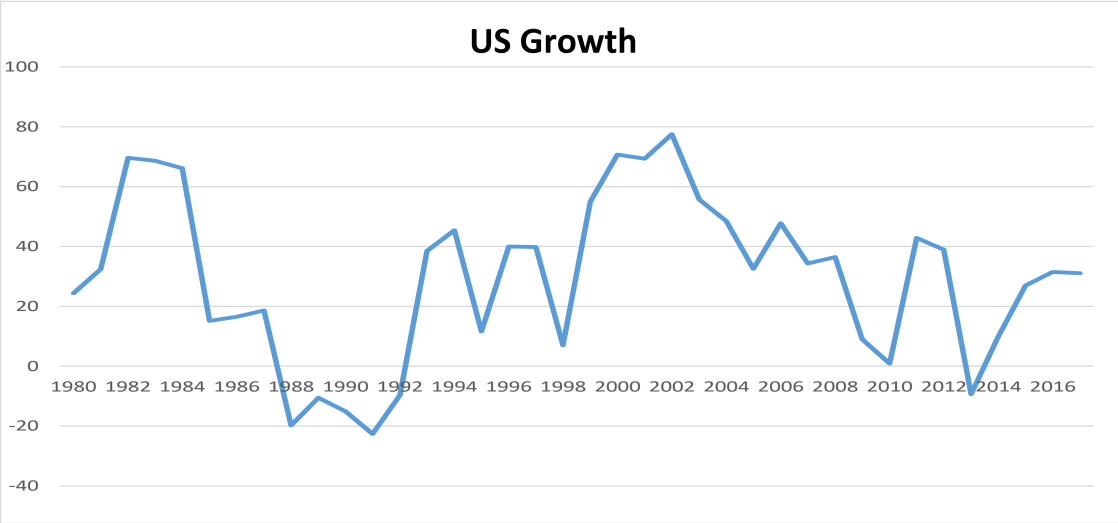


Figure 5 . Net pairwise connectedness Index (30-year rolling-sample windows).

Figure 6 . Evolution of the US Military Exports

Figure 7 . Robustness to the forecast horizon (H) and the lag choice (L): total military exports growth, real GDP per capita growth and labor productivity growth connectedness (30-year rolling-sample windows).

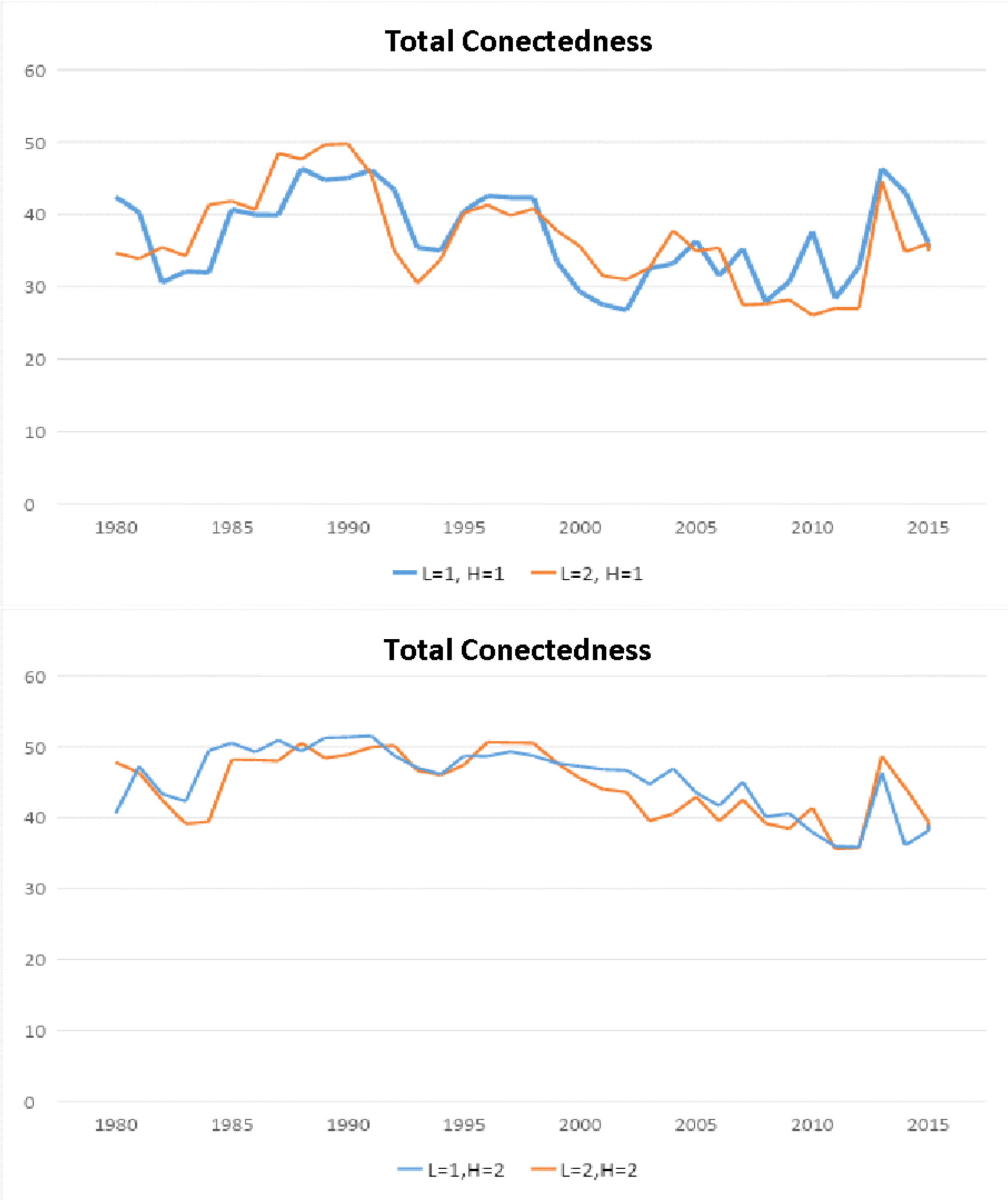


Figure 8. Robustness to different rolling windows: w=28 and w=32-year rolling windows.