Are space industries getting "normal"? Investigating current trends in the world space economy

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Abstract. This article investigates the evolution of space industries during the last decade (2000-2013). Building on descriptive statistics regarding the volumes of spacecraft launched by major space Nations (United-States, Russia, Europe, China, Japan and India), it provides evidence that the asymmetry between government (e.g., space agencies and military organisations) and non-government customers (e.g., universities, research laboratories and private companies) decreased before getting stable. However, it also demonstrates that the shift toward a (more) balanced market structure between public and private, commercial and non-commercial, government and non-government customers of space assets is not homogeneous among space Nations.

JEL Codes. O3, O33, O38.

1. Introduction

The role played by institutional and military customers in shaping the development of the space industry has long been acknowledged by scholars (e.g., McDougall 1982). From the very beginning of the space era, government agencies (e.g. NASA, Roskomos, CNES or ESA) and military organisations (e.g., Ministries of Defence, Air Forces, Defence Acquisition Agencies) provided direct support for the construction of space infrastructures, including ground stations, launchers and satellites facilities, and for the development and diffusion of space-related knowledge and capabilities. By expressing original needs and motives (e.g., defence and security, political prestige, science and technology development), government customers had a profound influence on the structure and dynamics of space industries. However, the past two decades revealed a significant decrease in military orders together with a growing importance of commercial and non-government demands for space technology. Investigating current trends in the U.S. space commerce activities in the middle of the 2000's, Shove (2005) stressed that "an interesting metamorphism is evolving in the space industry as many firms begin to evolve from government-only customers to mixed customers and finally to totally private customers" (Shove 2005, p. 191). This "gradual shift towards increased commercial activities" as Peeters (2004, p. 199) put it, would be in contradiction with the long term evolution of space industries, the latter being historically shaped by government customers and non-commercial applications.

The foregoing raises important issues regarding how space industries currently evolve. Are space industries on the path towards getting "normal"? What does it mean for an industry that delivers quasi-public infrastructure to become "normal"? Is this transformation homogeneous among major space Nations? Or does it take different form depending on national circumstances?

To address the above research questions, this article collected and analysed data on 1593 payloads launched by major space Nations from 2000 to 2013. Using descriptive statistics analysis, it aims at discussing whether or not the asymmetries between commercial *versus* non-commercial applications, and government *versus* non-government customers tended to reduce, at least for the satellites and transportation sub-markets[1]. Within this framework, two variables deserved particular attention: the relative shares of commercial *versus* non-commercial applications, and the distribution of payloads per types of customer. Another sign of the transformation of space businesses towards getting "normal" is related to (what we shall call) the level of "openness" of space industries. The civilianisation and privatisation of space activities, together with an increasing internationalisation of transactions, are considered as major clues of what it means for space economies to "open up". In order to evaluate the level of openness of space industrial and market structures, it is needed to estimate how domestic *versus* non domestic payloads launched evolve through time. The relative weights of civil payloads (i.e., private and non-government launches) *versus* military and government orders are also relevant variables to focus upon.

It is therefore contended in this contribution that if space industries are on the path towards becoming "normal", then they should –to some extent- exhibit three stylised facts: (i) a balanced distribution of payloads ordered by government *versus* non-government customers, (ii) a significant share of commercial *versus* non-commercial applications, and (iii) a positive level of openness of space market structures (i.e., civilianisation of demand and supply forces, and internationalisation of transactions).

[1] This contribution does not investigate the dynamics affecting ground stations' and launchers' market segments of the space economy.

Section 2 briefly describes the database (including data sources and analysis) and the categories used in this article. Section 3 describes what it means for space industries to become "normal". Section 4 explores how space industries evolve within major space Nations, namely those that possess domestic launch facilities (i.e., the United-States of America, the People's Republic of China, the Federation of Russia, the European Union, India, and Japan). Other Nations that also have domestic launch facilities such as Israel, Iran, North Korea or South Korea have been documented in the database but not studied at length. Considering total payloads launched from 2000 to 2013, it is argued that space industries are globally and progressively transforming towards a more balanced market structure, an increasing level of openness and a growing weight of commercial *versus* non-commercial applications. However, significant differences remain between space national space economies' dynamics and structure. Clearly, there no such thing as a unique transformational path followed by space industries at a national level, each Nation following its own path. The last sections draw on the main implications of the case study, and give final comments regarding future research agenda.

2. Data sources and analysis

This contribution builds on a database elaborated by the author[2] that contains exhaustive data on all spacecraft launched worldwide between January 2000 and December 2013. A particular attention has been paid to four major space Nations: the United-States of America, the Russian Federation, the European Union, and the People's Republic of China. Altogether, these four Nations account for 88% of total spacecraft launched during the 2000-2013 period (cf. Figure 1).

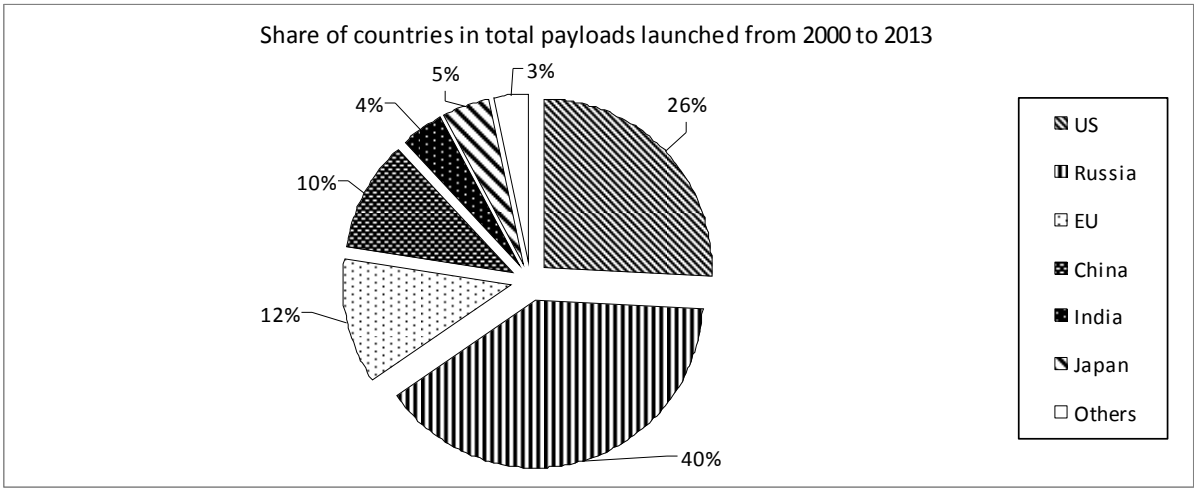


Figure 1. Payloads launched per space Nations (2000-2013)

Collected data are concerned with launched *payloads*, including space probes, capsules, spaceships and artificial satellites. Data on ground stations and launch vehicles have been excluded from the present contribution. Data sources include a variety of amateurs' (e.g., www.skyrocket.de) and institutional websites (e.g., NASA, ESA, Roskosmos) that keep records of any publicised spacecraft launched anywhere in the world. The above sources of data have been completed by consulting professional (e.g., Jane's Defence weekly) as well as academic publications (e.g., Space policy) on space technology and industry. For the purpose of this study, we collected data on over 1593 spacecraft launched between 2000 and 2013 (including failed launches) (cf. Figure 2).

[2] The author would like to thank Camille Bougerol, Florent Burgos and Nicolas Chinbaud (French Air Force Academy) for their support in collecting and structuring the original database.

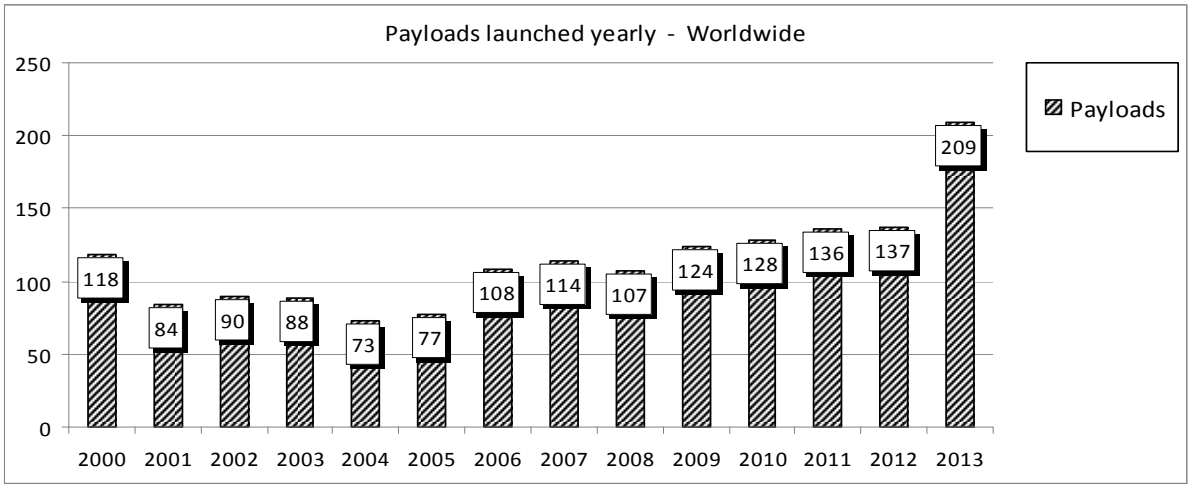


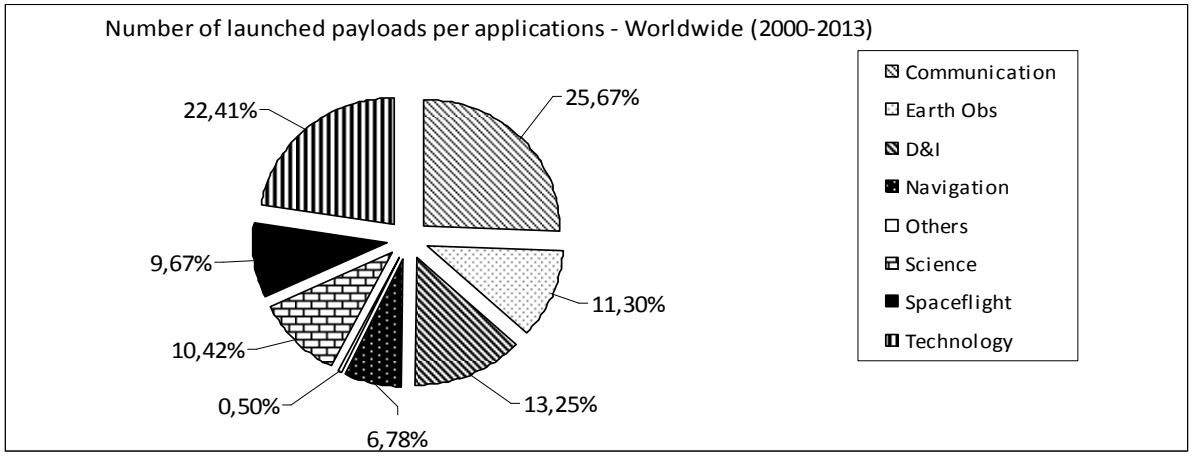
Figure 2. World-wide total launches (2000-2013).

We first classified data according to two variables: (i) customers and (ii) applications. Basically, the space industry is dominated by three types of customers: Military, Institutional and Commercial (McDougall 1982). A customer's type refers to its legal identity as a "consumer" of space technology. Military customers correspond to Departments of Defence, Defence Acquisition Agencies, military services, and military education and research laboratories. Institutional customers can be separated into two groups: government (e.g. space agencies, public research laboratories) and non-government (e.g., amateurs, private universities). Commercial customers mainly designate private companies (e.g., telecommunication firms) and privatised multinational cooperative organisations (e.g., INTELSAT and EUTELSAT). Since customers have unique motivations, missions, competences and industrial facilities, it follows that they are likely to demand for different applications of space technology. Seven distinctive applications have been considered in this contribution[3]: Transportation, Communication, Science, Technology, Navigation, Earth observation, and Defence and Intelligence (cf. Figure 3).

1. Transportation applications include manned and unmanned spaceflights, including cargo and crew transports, in particular for the purpose of resupplying the International Space Station (ISS). ISS cargo resupplying missions account for 9.67% of total spacecraft launched from 2000 to 2013. However, the opportunities openned by the transportation of civil passengers at Low-Earth Orbits (LEO) is likely to foster the development of this application in the short run.
2. Communication applications designate any kind of spacecraft, notably artificial satellites, that enable the transmission of data and information on a variety of supports; they notably contribute to the development of information and communciation technologies (ICT), media and broadcasting industries. Communication applications constitute major parts of all commercial space activities, and account for 25.67% of total payloads during the 2000-2013 period. After the burst of the "dot.com" bubble in the early 2000's, communication applications' development slew down, before recovery happened in the mid-2000's.
3. Science applications refer to any spacecraft launched for the purpose of supporting the development of scientific knowledge; examples of scientific activities include outer-space explorations (Peter et Stoffl 2009), but also non-space activities like biotechnology or agronomy (Chengzhi 2011). They represent 10.42% of total payloads launched between 2000 and 2013.

[3] Hiriart et al. (2010) identified 17 categories of spacecraft which they classified into three major applications: Defence and Intelligence (including Navigation, Intelligence, Weapon systems etc.), Science (including Earth Observation), and Communication.

4. Technology applications correspond to any spacecraft launched for the purpose of experimenting with novel space technology (e.g., robotics and automated systems). They account for 22.41% of total payloads launched from 2000 to 2013. Parts of technology applications are profit-oriented and privately funded, but the majority of technology-related space activities is non-commercial and operated by government organisations (e.g., national space agencies).
5. Navigation applications aims at providing geo-spatial positioning services (Positioning, Navigation and Timing, PNT) for the purpose of locating a broad range of moving objects such as aircraft, boats, and cars (e.g., Global Positioning System, GPS). Navigation payloads include both commercial (e.g., Location-Based Services such as smartphones; Personal Navigation Devices) and non commercial applications (e.g., military Intelligence, Surveillance and Reconnaisance services, included in the D&I application). Civil navigation payloads account for 6.78% of total payloads launched during the past decade[4], but grow at a faster pace than the global space economy.
6. Earth observation applications mainly designate remote sensing capabilities and distant, on-orbit, earth surveillance, in particular for the purpose of meteorological forecasting (Lodgson 2011; Morel 2013). Globally, earth observation market segments encompass commercial (e.g., urban, mining, insurance, traffic management, agriculture, fleet management) as well as non-commercial applications (e.g., disater management, meteorology, military remote sensing). They account for 11.3% of total payloads launched from 2000 to 2013. Earth observation commercial markets evolve jointly with communication and navigation applications to provide decision-makers from a variety of businesses (e.g., agriculture, fisheries, energy, transport and communication infrastructure, insurance, news and media) with critical information. Alike navigation and communication segments, earth observation applications are expected to grow at faster pace than the rest of the space economy in the next future.
7. Defence and Intelligence (D&I) applications are supportive of defence and security policies (Buckerfield de la Roche 2011). D&I applications include intelligence capabilities (i.e., electronics intelligence, imagery intelligence, radar intelligence), communication (i.e., command and control, C^2), earth observation (i.e., remote sensing), navigation (i.e. tracking and targetting), and aerospace ballistic missiles (ABM). They represent 13.25% of total payloads launched between 2000 and 2013. With the exception of few payloads (e.g., Israeli private/military partnership for producing and operating military satellites), D&I payloads are ordered and funded by government-only military customers (i.e., armed forces, ministries of defence, defence acquisition agencies, research and education Defence organisations).



[4] Military navigation payloads have been classified into the D&I category.

Figure 3. Distribution of payloads per applications – Worldwide (2000-2013)

For each payload documented in our dataset, we collected its launch date, the identity (and nationality) of the operator(s) and financier(s), the corresponding application, and the geographical site from which it has been launched. When more than one single type of customer financed the launch of the spacecraft (i.e., mixed customers), we decided to consider the principal investor (and operator) as the prime customer of the payload (cf. Figure 4).

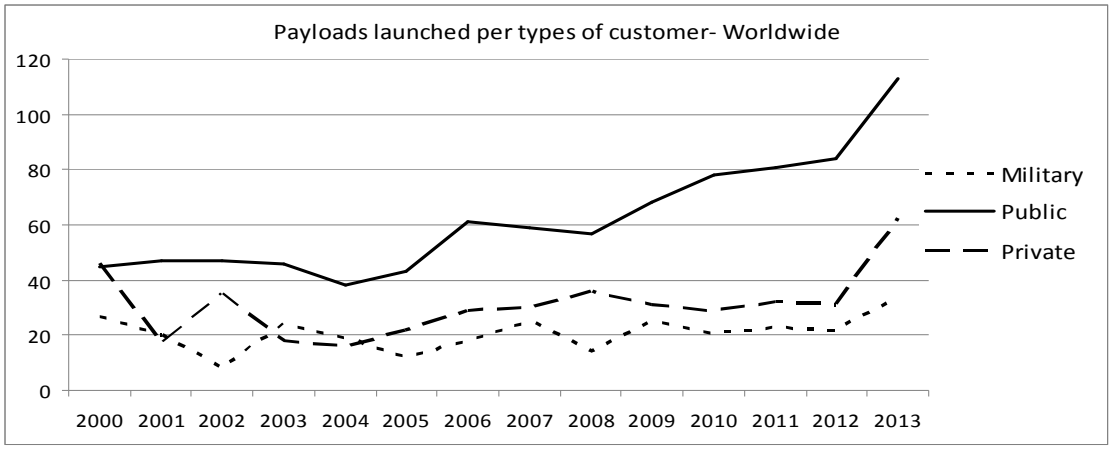


Figure 4. Volumes of spacecraft launched worldwide per type of customers (2000-2013)

In addition, when spaceraft have been launched from a given domestic launch facility (e.g., Baïkonour in Russia, or Cape Canaveral in Florida) but funded by a non-domestic customer (e.g., a Japanese telecommunication company), we considered the launch site as its main attribute, but we also kept record of the customer's nationality in order to estimate the relative weight of domestic *versus* non domestic payloads launched and funded by each space Nation. This, in turn, provides indications regarding the level of internationalisation of national space economies under scrutiny.

3. What does it mean for space industries to become "normal"?

Space products and services basically differ from normal goods. Launching facilities, ground stations and launch vehicles are government infrastructures that belong to the category of quasi-public goods for which public investments are required. In addition, the majority of spacecraft, such as artificial satellites and deep space exploration technology, are produced in small series for very specific client-users. Their unit costs are habitually high and the acquisition life-cycle on which they rely can be very long (life-cycles include all phases from the formalisation of users' need, the realisation of feasibility studies, R&D, tests and experimentations, the validation of concepts, the production and exploitation of systems, and, finally their withdrawal and recycling). Similar to weapons systems, nuclear power plants, passenger aircrafts, banking automation systems, or air-traffic control technology, space technologies can thus be classified as complex products systems (CoPS, Hobday 1998). According to Davies et al. (2005, p. 37), CoPS' market structures are very particular. The latter consist of highly concentrated demand and supply structures (e.g., oligopoly, monopsony), few large transactions, direct government regulation and administration of transactions, negotiated prices between suppliers and customers, and imperfect competitive interactions among economic agents. Space-related economic activities used to display all of these characteristics. Since its inception in 1957 and during the following decades, the space industry has been totally dominated by government customers, mainly national space agencies (e.g., NASA), defence acquisition agencies (e.g., DGA), and military services (e.g., U.S. Air Force). In a recent paper, Barbaroux et al. (2013) provided evidence that military customers had been capable of directing the introduction of all major applications of space technology, including remote sensing, navigation, manned and unmanned

spaceflight, earth observation, science and technology (S&T), and communication. The authors observed that government customers accounted for two-thirds of all satellites launched between 1957 and 2011 (Barbaroux et al. 2013). As Hiriart et al. (2010) explained, "it is fair to say that the space industry was enabled by, and grew because of, the institutional customers, not commercial market forces" (Hiriart et al. 2010, p. 54). For all these reasons, space industries can not be considered as "normal" businesses for which market mechanisms apply and, until recently, profit-oriented rationality and self-interested, commercial motives did play a minor role in shaping the dynamics and structure of space industries.

But the time has come for a change. Scholars and experts suggest that the space industry is slightly evolving towards a more balanced structure between government and non-government customers. Military and institutional orders still represent a significant share of total payloads launched yearly, but major sources of revenue currently come from commercial applications (e.g., communication, navigation, earth observation) ordered by non-government customers (e.g., private companies, universities, amateurs). At the end of 2002 for example, 83% of total revenues generated by space-related businesses came from communication applications, the latter being heavily dependant upon commercial interests expressed by private companies (Shove 2005, p. 192). Although the above statement is quite tautological[5], Hiriart et al. (2010) confirmed that trend by focusing on quantitative (i.e., number of satellites launched), not financial data (i.e., sources of revenue). From 1990 to 2008, the authors observed that 50% of all launched satellites around the world belonged to the (non-military) communication segment (Hiriart et al. 2010, p. 54). That clearly indicates the increasing role played by commercial motives and non-government actors in the development of space industries. As Kreisel et al. (2007, p. 222) argued, "The space economy has changed rapidly in the past few decades, from a government-driven sector to one that now boasts many private initiatives". In addition, a number of traditional space assets (e.g., launchers and space vehicles) have matured enough to induce a significant reduction of operational costs and technical risks, triggering the emergence of entrepreneurial firms investing private resources in commercial applications of space technology (e.g., space tourism, road and maritime transport, fleet management, precision agriculture, mining etc.). "Downward pressure on launch prices and cost-saving advances in satellite technology have combined to open the door for small and midsize companies to enter the market, providing new niche services an solutions to a growing number of customers" (Space Foundation Report 2014, p. 5).

Another indication of this gradual transformation of space industries is related to their increasing level of "openness". Investigating the evolutionary path followed by space technologies (e.g., launchers and satellites) and personal computers, Whitney (2000) developed a model of industry development that is based on three stages: centralised, decentralised and distributed. By moving from one stage to another, the author argued, industries evolve through a progressive process consisting in "opening-up" the organisational structures and regulatory frameworks on which they rely. During the centralised period, industries are under the central control of governments, core industry groups, and large, heavy technology (Whitney 2000, p. 172). Therein, commercial services and applications are only nascent businesses that are both economically and technologically immature and underdeveloped. This period clearly corresponds to the first two decades (1957-1975) characterising the evolution of space industries in major space Nations (Barbaroux et al. 2013). The second stage is marked by technological changes supporting the diffusion and commoditisation of goods and services, first on a regional and national basis, then on a multinational scale. This is exactly what happened in space industries from the mid-seventies to the end of the eighties. Major technological changes affecting the structure and development of space industries included advances in payloads' miniaturisation (Petroni et Santini 2012) and innovation in ground stations' capabilities.

[5] Communication applications are by definition profit-oriented activities; it is therefore very logical that they represent the principal sources of revenue in space industries.

Space systems slightly became smaller, cheaper, and lighter than inherited technology (Whitney 2000, p. 173). A cheaper access to satellite communication services enabled the development of promising business opportunities (e.g., mobile telephony, broadcasting), triggered the creation of multinational organisations in charge of commercialising space assets (e.g., EUTELSAT in Europe, INSAT in India) and induced an alteration of space regulation and policy frameworks (e.g., ITAR revisited). Finally, the last stage, called the distributed stage, is reached when multiple domestic consortia and/or international groups compete for commercial markets. At this stage, the level of openness of industries is high, both geographically (e.g., emergence of new space Nations) and economically (e.g., international competition between private companies and growth of the global industrial "ecosystem"). The diffusion of technology to other industries is further facilitated by technological innovation, deregulation and privatisation of national telecommunication networks (Whitney 2000, p. 175). This is what happened in space industries in the early 1990's and after. As an illustration, INTELSAT and EUTELSAT moved from a centralized cooperative multinational entity to a privately owned and decentralised company in 2001. Industrial manufacturers created private companies through spin-offs (e.g., Boeing and Lockheed Martin space vehicle's capabilities merged to create United Launch Alliance), and introduced large-scale production and marketing techniques to maintain and expand their competitive advantages. National space agencies also created private companies to exploit commercial opportunities (e.g., CNES created Arianespace to develop commercial businesses). As a result, the global space economy's current and future sources of revenue are likely to come from commercial businesses, the latter being dominated by non-government and private organisations that interact in a global, competitive market.

This contribution aims at discussing the accuracy of the above description of the transformational path followed by space industries. It contends that, if space industries are progressively transforming towards getting "normal", then the structures, processes and behaviours on which they rely should exhibit a number of pervasive features. In particular, one should discern a market characterised by a balanced distribution of civil *versus* military orders, government *versus* non-government customers, and commercial *versus* non-commercial applications. Since our case study builds on payloads-related (not revenue or financial) data, three empirical regularities must be observed if one is to validate the conjecture: (i) a more balanced distribution of payloads ordered by government *versus* non-government customers (i.e., civilianisation), (ii) an increasing weight of commercial *versus* non-commercial applications (i.e., commoditisation), and (iii) an increasing level of openness in both market structures and policies (i.e., internationalisation and deregulation). If evidence is provided that these three stylised facts are currently observed, then one could reasonably suppose that space industries are on the path towards getting "normal". It would mean that they are increasingly based on a balanced open market structure involving both commercial and non-commercial applications, government and non-government customers, and civil and military outlets.

4. Characteristics of space industries in major space Nations (2000-2013)

Next sections start by studying the characteristics of space industries within major space Nations (e.g., the U.S., the E.U., Russia, China, India and Japan) during the 2000-2013 period. Attention is first paid to the evolution of the relative share of total payloads ordered by military, institutional and private customers respectively (section 4.1.). Then, research efforts are directed towards exploring the relative share of commercial *versus* non-commercial applications (section 4.2.). Finally, the last section aims at evaluating the level of internationalisation of space industries by focusing on the relative share of domestic *versus* non-domestic payloads launched during the last fourteen years (section 4.3.).

4.1. Is the demand structure for space technology balanced?

Figure 5 depicts the distribution of total payloads launched per types of customers between 2000 and 2013. It is first observed that military customers ordered less than 19% of total payloads, while private customers accounted for 27%. 54% of total payloads have been funded by institutional customers, essentially by national space agencies, central administrations other than defence & space, and universities. Among institutionally ordered payloads (867 payloads), 95% has been funded by central-government agencies, the lasting 5% being funded and operated by non-government public customers, such as European and Japanese universities or German technical universities. Education and research organisations have been classified as public, non-government, institutional customers, with the notable exceptions of U.S. universities which have been classified as private customers (U.S. universities are parts of the 27% of total payloads ordered by private customers). Finally, we estimated that government-only customers accounted for 70% of total payloads launched between 2000 and 2013, and non-government –both private and public- customers accounted for 30% (cf. Figure 6).

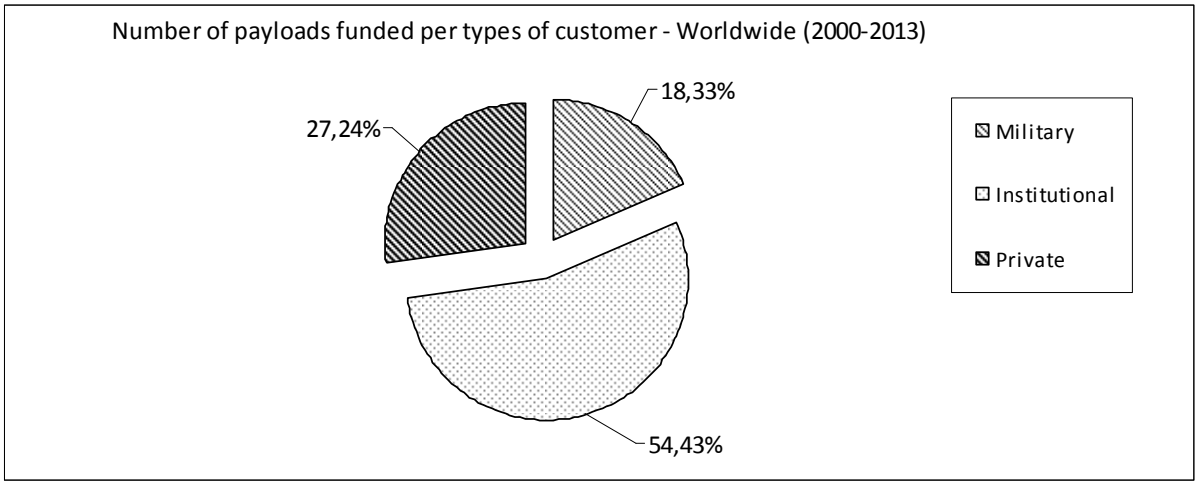


Figure 5. Distribution of payloads launched per types of customer (2000-2013)

Interestingly (cf. Figure 6), privately funded payloads exceeded both military and institutional funded spacecraft, once in fourteen years: in 2000. This "peak" in space commercial activity, representing almost 40% of total payloads launched coincided with the zenith of the "dot.com" bubble that involved high volumes of spacecraft orders from ICT sectors. Finally, with the notable exception of 2002, private customers' orders accounted for one-quarter to one-third of total payloads since 2005.

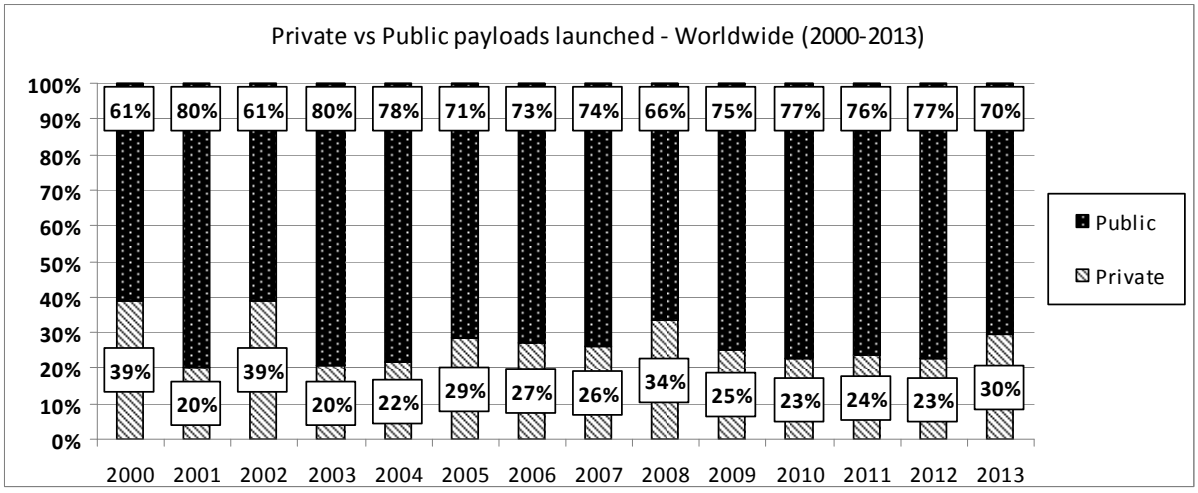


Figure 6. Evolution in percentage of public *versus* private orders in total payloads (2000-2013)

One cannot conclude by examining the evolution of total payloads launched between 2000 and 2013 that space industries are progressively relying on a balanced, 50/50, market structure between public and private customers. However, evidence is provided that space industries are not military-dependent any more, civil customers accounting for 81% of total payloads launched during the 2000-2013 period. In addition, since 2005, space industries' global market structure achieved stability with a distribution of government *versus* non-government payloads that equals 70/30 on average.

4.2. Are space industries commoditised?

To estimate the level of commoditisation of space industries, one should discriminate between commercial and non-commercial payloads launched per applications. Basically, commercial applications include communication and, to some extent, earth observation and navigation, and non-commercial applications are associated with D&I, transportation, science, and technology applications. However, frontiers between commercial and non-commercial applications are getting blurred. Novel entrepreneurial opportunities emerged within traditional non-profit, non-commercial, government-only space activities. For example, space transportation businesses have become increasingly attractive for private investors (e.g., the Space Exploration Technologies Corporation, SpaceX, resupplying the ISS); in the same vein, research institutions are increasingly involved in the valorisation of space-related knowledge, and utilisation of the space milieu for Research and Technology (R&T) experimentations. It has also been acknowledged that Defence & Intelligence (D&I) space products and services rely more heavily on commercial space sectors, particularly in the U.S. It is therefore (very) difficult to identify clearcut delimitations between commercial and non-commercial applications of space technology by focusing on payloads launched per applications. In addition, customers' types provide incomplete information since a number of government, institutionally funded payloads aim at supporting the development of commercial businesses. The U.S. government space agency (NASA) for example, decided to promote the expansion of the transportation segment through direct funding of commercial companies. The program, called Commercial Crew Program (U.S. Government Accountability Office, 2014a) aims at stimulating private-sector interest in providing commercial space transportation capabilities which might be critical for the U.S. economy[6] (U.S. Government Accountability Office, 2014b). There are many other examples of publicly funded commercial activities, in particular in the communication, navigation and earth observation markets. Commercial communication satellites are very oftenly funded and operated by national and/or multinational government agencies, such as Insat in India, NigComSat in Nigeria or Intelsat (before 2001), thus complementing the investments made by private companies.

In order to make things simple, this contribution assumes that D&I applications are fundamentally non-commercial (we do not consider "others" applications since they only represent 0.5% ot total payloads launched during the period). Six categories of applications are thus capable of generating profit-oriented, commercial products and services: communication, navigation, earth observation, science, technology, and transportation. To evaluate the relative share of commercial *versus* non-commercial applications in total payloads, we start by studying customers' types (cf. Figure 7). This provides a first basis for discriminating between commercial and non-commercial spacecraft lauched during the 2000-2013 period.

[6] Both entrepreneurial firms such as SpaceX, and large aerospace and defence companies such as Boeing participate in this program. SpaceX received 460€ millions from NASA to develop the Dragon-Rider project, while Boeing was awarded a 480€ millions R&D contract for developing the CST projects. Each projects aim at experimenting with novel technological solutions (e.g., capsule, reusable launch vehicles) to enable cargo and crew transportation from low-Earth orbit (LEO).

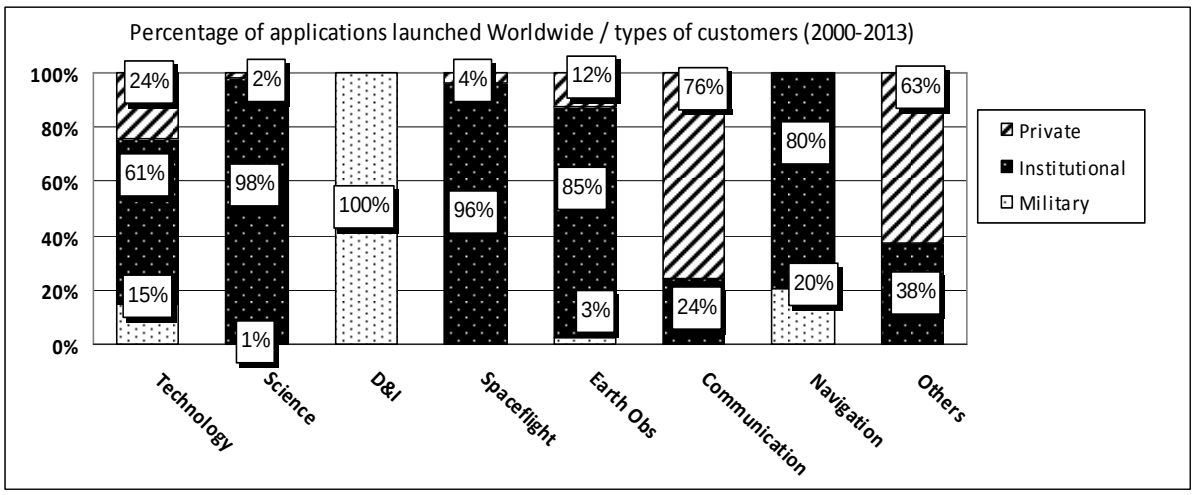


Figure 7. Percentage of applications per types of customers (2000-2013)

Figure 7 provides evidence that science and technology applications are significantly funded by private customers (26%) and military organisations (16%). However, the majority of privately funded payloads launched for the purpose of scientific and technological experimentations is ordered by private universities and research laboratories, not commercial firms. In addition, the economic value generated by science and technology is not realised instantaneously. When first launched, these payloads are basically non-commercial. We shall assume that the percentage of commercial payloads in the technology segment is null during the 2000-2013 period. We are aware that this assumption leads to underestimate the real share of commercial payloads, science and technology applications accounting for one-third of total payloads launched during the 2000-2013 period.

By contrast, communication applications are massively ordered by private companies (76%) that basically express commercial motives. In addition, when communication payloads have been ordered by public institutions (e.g., Insat), they also aim at achieving commercial objectives. We thus consider that 100% of total payloads belonging to the communication segment is commercial (please note that military communication spacecraft are already classified into the D&I application).

We now turn to the remaining applications capable of supporting commercial activities, namely transportation, earth observation, and navigation. Commercial activities in space transportation are heavily dependent upon the advance of suborbital reusable vehicles (SRV). The U.S. Federal Aviation Administration (FAA) identified eight distinct commercial markets SRVs could (potentially) address (FAA 2013): human spaceflights, basic and applied research, aerospace technology test and demonstration, media and public relations, education, satellite deployment, remote sensing, and point-to-point transportation. With the notable exception of human spaceflights, other market niches are already classified into science, technology, communication and earth observation applications. During the 2000-2013 period, only 7 launches corresponded to commercial human spaceflights. The foregoing accounted for 4.72% of total transportation activities, while 95.28% corresponded to ISS assembling and resupplying non-commercial missions.

Earth observation (EO) applications are massively ordered and operated by institutional customers (85%). But a significant percentage of total earth observation applications (12%) have been funded by private customers (e.g., imagery private companies such as Spot Image or ImageSat). We consider this percentage as a first basis for the purpose of estimating the weight of commercial applications within the earth observation market segment. This estimation must be consolidated through the integration of institutionally funded payloads that support commercial activities. However, such an estimation is delicate. Among institutionally funded earth observation satellites, we observe that 30% corresponds to meteorology applications, the latter being mostly non-commercial (if not,

meteorology payloads would be operated by private customers and taken into account in the 12% share quoted above). In addition, for some countries, it has been very difficult to discriminate between institutional and military EO customers. As an illustration, 55% of all Chinese institutionally funded earth observation spacecraft are –or are suspected to be- military spacecraft. They have not been integrated to Chinese D&I payloads (should they?) because of the institutional ambiguity characterising China's space economy. Anyway, many navigation spacecraft have already been classified as D&I (e.g., IMINT) or science applications (e.g., Earth science) in our database. By and large, we estimated that the percentage of commercial EO payloads launched during the 2000-2013 equals 35% of total EO payloads.

Finally, regarding navigation applications, 20% of total payloads has been ordered by military customers, and 80% from institutional customers. Similar to earth observation applications, a significant share of institutionally funded navigation spacecraft support the development of Global Navigation Satellite Systems (GNSS) commercial applications within a variety of industries (e.g., land and maritime transport, traffic management, mining, etc.). Pham (2013) estimated that during the period 2005-2010, the U.S. Global Positioning System (GPS) market –that is the world leading navigation infrastructure- originated 25% of revenues come from commercial equipement sales, 59% from non-commercial, civil applications, and 16% from military clients. Compare with the U.S. navigation system, other space Nations' GNSS commercial applications are less developped. The European GNSS Agency (2013) estimated that only 20% of receivers are compatible with China's "Beidou" GNSS for example. That percentage reached 30% for the European "Galileo" GNSS. Russian "GLONASS" navigation system, the second constellation of choice after GPS, is also heavily dependent upon government-only customers, but commercial applications are highly encouraged by Russian space authorities. As an illustration, the transport segment now represents 50% of total GLONASS commercial revenues with 2 millions of vehicles being equiped with GLONASS navigation compatible devices (Kupriyanov 2014). However, GLONASS interoperable equipments did not exceeded 50% of the market for receivers in 2013 (EGA, hampering the potential development of commercial applications. As a consequence, to evaluate the volume of commercial navigation payloads launched between 2000 and 2013, we have multiplied the number of GPS, GLONASS, Galileo and Beidou payloads by the percentage of receivers that appear compatible with each system respectively. Results are presented in Figure 8.

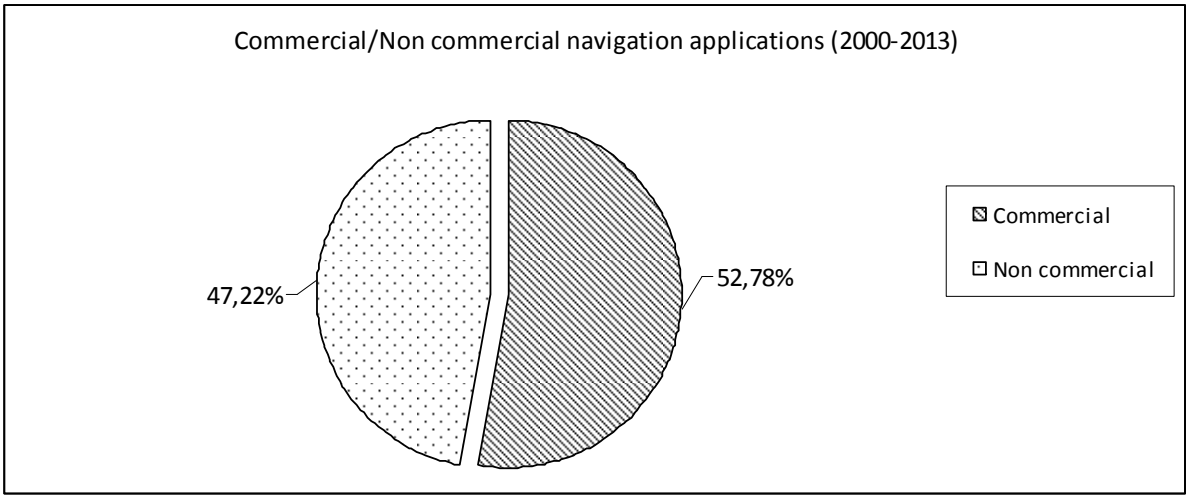


Figure 8. Estimation of commercial *versus* non-commercial navigation payloads (2000-2013).

Are space industries getting commoditised? Table 1 summarises the distribution of commercial *versus* non-commercial payloads for the communication, earth observation, navigation and transportation applications. Commercial payloads accounted for 1/3 of total payloads launched

during the 2000-2013 period[7]. It means that 33.65% of total payloads launched engendered on average 80% ot total revenues of the space economy (in 2013, 76% of the global space economy turnover was dependent upon commercial space products and services, infrastructure and support activities; The Space Foundation Report 2014, p. 4). Not surprisingly, 76% of total commercial payloads launched from 2000 to 2013 belongs to the communication market segment.

	Communication	Earth Observation	Navigation	Transportation
Total Payloads	409	180	108	154
Commercial payloads*	536 (33.65% of total payloads)			
Non-commercial payloads**	1057 (66.35% of total payloads)			

Table 1. Percentage of commercial applications in total payloads (2000-2013) - Worldwide

**Commercial payloads (% of total payloads per application) include communication applications (100%), earth observation (35%), navigation (53%), and transportation (5%).*

***Non-commercial payloads (% of total payloads per application) include D&I (100%), science (100%), technology (100%), others (100%), earth observation (65%), navigation (47%), and transportation (95%).*

4.3. Are space industries opening-up?

Figure 12 presents the evolution in percentage of domestic *versus* non-domestic payloads launched by the four major space Nations during the 2000-2013 period: the U.S., the E.U., Russia, and China. On average, 39% of total payloads have been ordered by non-domestic customers, reflecting a high degree of internationalisation of transactions. Non-domestic orders exceeded domestic ones in 2006, and a 50/50 equilibrium has been approached in 2007, 2011 and 2013. The share of non-domestic payloads in total spacecraft launched did not reached the 30% threshold only twice in 2004 and 2012.

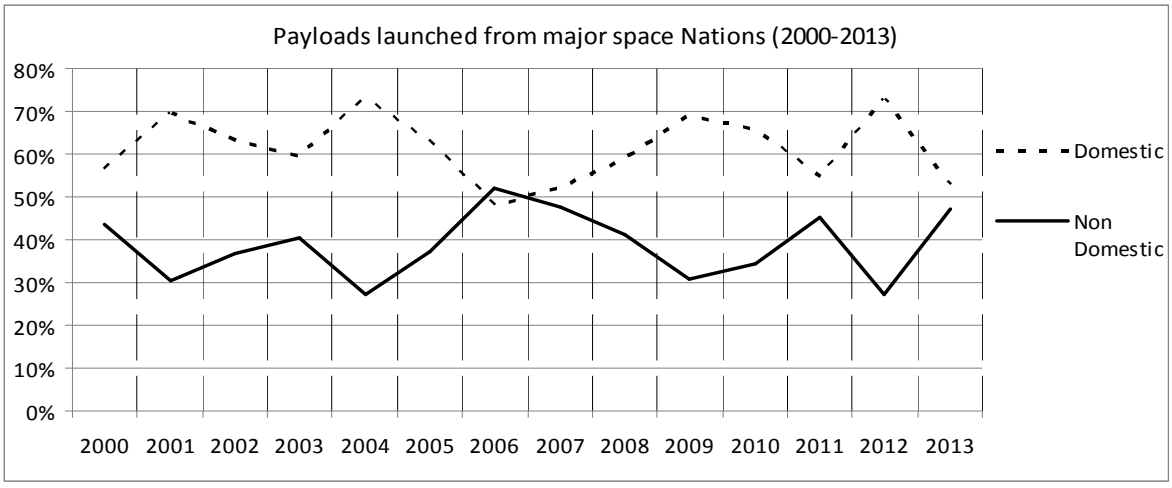


Figure 9. Domestic versus *non*-domestic transactions

Beyond the global 60/40 distribution of domestic *versus* non-domestic orders, national circumstances exhibit sharp contrasts. The Russian space industry is very sensitive to non-domestic customers (cf. Figure 10). 58% of total payloads launched from Russian launch facilities (e.g., Baïkonour, Plesetsk, Dombarovskiy AB, Kasputin Yar, Svobodniy) has been ordered by foreign

[7] Note that this estimation is superior to the percentage of payloads launched by private customers (i.e., 27.24%, see Fig. 5).Furthemùore, since our estimation of the relative share of commercial space payloads launched does not take into account both science and technology applications (i.e., accounting for one third of total payloads), its true value certainly exceeds 33.65%. In our opinion, 38% to 40% is a realistic approximation.

customers. One should therefore consider that the Russian Federation is akin to offer its launch facilities to the world, in particular to foreign private telecommunication companies. Interestingly, 50% of all privately funded payloads launched from Russia has been ordered by U.S. companies. A recent report of the U.S. GAO (2014b) pointed to high insurance costs in the U.S. that hamper privately funded payloads to be launched from domestic facilities. Only 6% of Russian privately funded payloads have been ordered by domestic customers. 17% has been ordered by European companies, and 26% by other Nations' private firms. In addition, 50% of total institutional payloads launched from Russia has been ordered by non-domestic customers, with European agencies and universities accounting for 25% and other Nations for 74% (note that U.S. customers accounted for less than 1% of total institutional payloads launched from Russia).

The E.U. space industry's structure is very similar to the Russian since almost 48% of total payloads launched from European launch facilities (i.e., Kourou) has been ordered by U.S. and other Nations (Russian customers did not ordered any launch from the E.U.). Interestingly, the distribution of privately funded payloads launched from the E.U. per types of customer, is well balanced: 28.57% of all privately funded payloads has been ordered by U.S. private companies, 33.04% by other countries, and 38.39% by European companies. Finally, 61.4% of payloads funded by institutional customers has been ordered by European organisations, and 38.6% by foreign institutions (note that U.S. and Russian institutional customers did not order any launch from the E.U. out of multinational, cooperative partnerships).

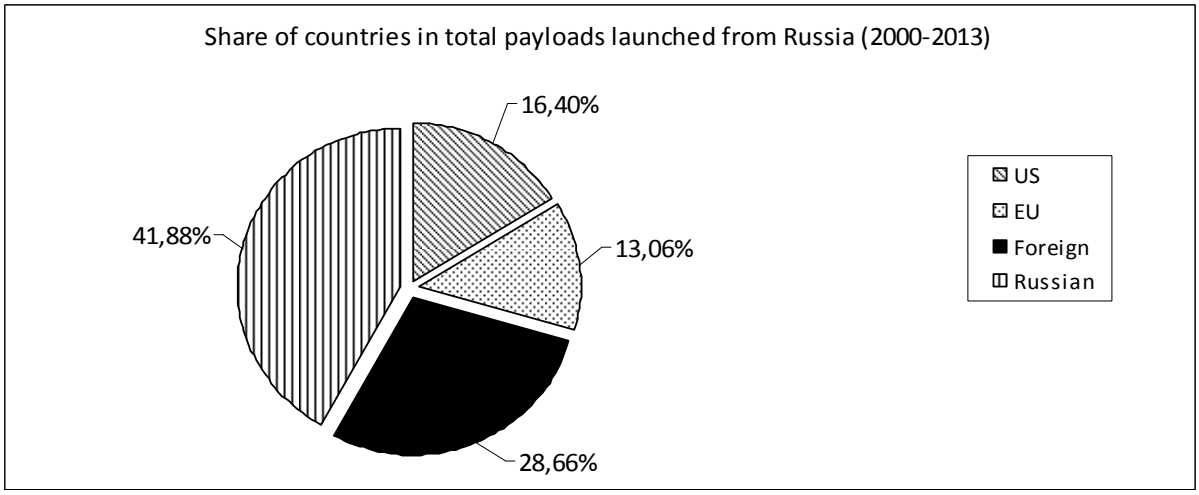


Figure 10. Domestic *versus* Non-domestic payloads launched from Russia (2000-2013)

The European and Russian space economies are in contrast with the U.S. and Chinese. These two major space Nations are indeed very insensitive to non-domestic investors. Surprisingly, the U.S. have the same distribution of domestic *versus* non-domestic payloads as China: 92% of total payloads launched from the U.S. and Chinese launch stations has been ordered by domestic customers, with a majority of orders coming from government customers (i.e., military and institutional). We could have expected that the level of internationalisation of the U.S. domestic space economy would have been greater than the Chinese. But while Chinese customers are quasi-exclusively launching spacecraft from China (i.e., Taiyuan, Jiuquan, Xichang), a significant share of U.S. privately and institutionally funded spacecraft has been launched from Russian and, to some extent, European launch facilities. Indeed, U.S. customers (whatever their types) ordered 538 payloads during the 2000-2013 period (accounting for 33.7% of total payloads launched worldwide). The geographical distribution of U.S. payloads during the 2000-2013 period is as follows: 379 spacecraft from the U.S. territory (70%); 102 spacecraft launched from Russia (19%); 32 spacecraft launched from the E.U. (6%); 4 spacecraft launched from Japan (0.7%); and 15 spacecraft launched by using Sea Launch

facilities (2.7%), a multinational private company that is controlled by Russian public and private investors until 2009. Compare to China, the U.S. space economy is thus more internationalised as soon as we consider payloads that are *funded* by U.S. customers but *launched* from non-U.S. launch facilities. In addition, while 99% of total payloads launched from China have been ordered by government-only customers, the percentage of U.S. privately funded payloads reached 40%, exhibiting a more balanced demand structure (the remaining payloads funded by U.S. customers being distributed as flows: 33% by institutional customers, and 27% by the military).

5. Implications

What is the answer to be brought to the question raised in this contribution? Are space industries getting "normal"? Some would be tempted to answer "yes". Indeed, at a global-level, it has been demonstrated that profit-oriented motives expressed by private and, to some extent, institutional customers are increasingly shaping the dynamics and structure of the world space economy. Evidence has also been provided that the distribution of domestic *versus* non-domestic payloads on the one hand, and of government *versus* non-government orders on the other hand, evolved towards getting more balanced during the 2000-2013 period. However, at a national level, descriptive statistics indicate that the shift toward a (more) balanced, commoditised, and international market structure is not homogeneous among major space Nations. Table 2 summarises the major characteristics of space industries in the U.S., Russia, E.U., and China.

	U.S.A.	Russia	E.U.	China
Total payloads (launched)	412	628	195	160
Military customers (%)	34.7%	12.9%	13.3%	14%
Institutional customers (%)	47.1%	55.4%	29.2%	82%
Private customers (%)	18.2%	31.7%	57.4%	4%
Domestic payloads *(%)*	92%	42%	52%	92%
Commercial (domestic and non-domestic customers) payloads *(%)*	19%	35%	57%	4%
Civil (private and institutional customers) payloads (*%*)	65.3%	87.1%	86.7%	-

Table 2. Main features of the four major space Nations' industries (2000-2013)

The major implication of this contribution is that transformation of space industries is likely to take different forms depending on the particular national context. If one builds on *launched* payloads, then two distinctive groups among major space Nations emerge: the first group, made up with the E.U. and Russia, exhibits the features of an open, internationalised and commoditised, balanced space economy; the second group, consisting of the U.S. and China, is aligned with the historical architecture of space industries, with strong asymmetries between domestic and non-domestic launches, government and non-government customers, and commercial and non-commercial applications.

However, if attention is placed on *funded* payloads, then the world space economy changes its face. The U.S. and the E.U. space industries for example, have more features in common than previously mentioned. At first glance, the U.S. and European space economies exhibit a balanced, civilianised and internationalised demand structure. As an illustration, the distribution of payloads between government and non-government customers is more equilibrated and stable (60/40) than in Russia and, a fortiori, in China. The same balanced structure (60/40) is evidenced if one observes the distribution of commercial *versus* non-commercial payloads funded by the U.S. and European customers. By contrast, the Russian space economy appears less "normal" than previously indicated,

since the relative shares of both commercial, non-government, and privately funded payloads are very limited, and the volumes of spacecraft funded by Russian customers and launched from abroad, quite insignificant.

If we now turn to military customers and their relative weight in both national and global demand structures, data analysis indicates that U.S. military organisations accounted for 49% of total D&I payloads launched worldwide during the 2000-2013 period. At a national level, U.S. military customers ordered 37.7% of total domestic payloads launched from the U.S. This percentage is a even superior to what has been observed in Russia. Indeed, Russian military customers accounted for 29.6% of total domestic payloads launched from Russian launch sites. By contrast, the E.U. space economy is more civilianised since military domestic customers represented "only" 23% of total domestic payloads launched from European launch facilities. However, the above percentage is similar to the U.S. if one accounts for the total payloads *funded* by U.S. military customers, whatever the nationality of the launch site.

To summarise, it first appears that the E.U. is the only major space Nation which space economy is altogether civilianised, internationalised, competitive, and commercially oriented. This is merely due to the particular political and economic context in Europe (e.g. weakness of public spending and lack of political coordination on Defence and Security issues). By contrast, the Chinese space economy is closely aligned with the characteristics of pre-Cold War "centralised" space industries (in the sense of Whitney 2000). Second, if one focuses on domestic spacecraft launched, the U.S. space economy exhibits characteristics similar to the Russian space economy. In particular, the U.S. and Russian domestic market structures are comparable[8]. A majority of spacecraft launched from Russian and U.S. launch sites, and funded by domestic customers, are non-commercial. Indeed, U.S. private companies massively use foreign industrial facilities -notably Russian- for the purpose of launching commercial spacecraft.

6. Final comments

This article investigated the evolution of space industries by focusing on total spacecraft launched by major space Nations during the 2000-2013 period. It suggested that the asymmetry between government and non-government customers, commercial and non-commercial applications, and domestic and non-domestic transactions decreased progressively, suggesting that the world space economy would be on the path towards getting "normal" (e.g., civilianised, commoditised, and internationalised). However, this gradual shift towards a (more) balanced market structure took different forms within major space Nations.

Besides descriptive statistics, understanding the direction of space economies' current evolution requires a holistic analysis of the local and global circumstances characterising each national context. An in-depth study of the political, economical, regulatory and technological factors influencing the dynamics and structure of space industries is thus needed. The characteristics attached to the four major space economies are dependent upon such factors as national security policies, defence and space budgets, macroeconomics, industrial and technological bases, and regulation bodies. Within this framework, a promising path for research would be to investigate the relationship between these contextual factors and the expression of customers' behaviours and motives, government and non-government demands being the leading forces that shape the dynamics and structure of space industries.

[8] . In the U.S., the distribution of total payloads funded by U.S. customers and launched from the U.S. is as follows: 15.8% by private customers, 37.7% by military customers and 46.4% by institutional customers. In Russia, the distribution is as follows: 4.5% by private customers, 29.6% by military customers, and 65.6% by institutional customers. Therefore, domestic government customers account for the largest part of total spacecraft launched from the U.S. and Russian domestic launch facilities.

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