THE EVOLUTION OF JAPANESE ROBOTICS: FROM THE BEGINNING TO THE NEWEST TENDENCIES

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Bachelor’s degree in International Business

TFG 2nd semester

Abstract

This study will go through the robotics sector of Japan. It will show when the robots in concept arrived in Japan and its evolution through history and the rise of it as a robotics superpower, with historical and economic data. It will also discuss the presence of robots in cultural aspects of Japan and the reasons of the good relationship between Japanese citizens and their creations. By the ending, the worrisome future scheme for Japan will be shown and the response of Japan's government as well as its companies to counteract this situation with the usage of robots.

Key words

robotics, Japan, Japanese history, Japanese culture, future, humanoid robots, aging population, robotic market, research & development, exports

Resum

Aquest treball estarà enfocat en el sector de la robòtica al Japó. Es mostrarà quan el concepte de robot va arribar al Japó i la seva evolució durant la historia, amb dades històriques i econòmiques. També es parlarà de la presència dels robots en el àmbit cultural japonès i les raons de la acceptació entre japonesos i les seves creacions. Per finalitzar es tractarà del seu preocupant futur en termes de població i com s'encararà aquest problema per part del govern japonès i de les seves empreses amb la utilització de robots.

Paraules clau

robòtica, Japó, historia japonesa, cultura japonesa, futur, robots humanoides, població envellida, mercat robòtic, recerca i desenvolupament, exportacions

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I. INTRODUCTION

1.1 Justification

I have chosen to do the final paper about Japanese robotics because from my childhood I have grown with Japanese anime which I saw in the public Catalan TV channel K3, being some of them mentioned during the work. This early contact let me to attain more attention for the Japanese culture as well as its situation.

As I reached the adolescence, I have become more curious about the future. I found the Japanese robots which I saw in TV such as the ASIMO fascinating, thinking about that sooner the population will have to convive with them. The science fiction genre also grew in me and some films and comics I have seen and read have in common the robotics in a fictional future,

But what it hits the nail on its head when deciding the topic that I had to choose for the final paper was a notice which I read in a Spanish online newspaper, *"El Mundo"*. The notice explained that in the Japanese city of Nagasaki, there was a hotel which was ruled completely by robots. I find it interesting to talk about the robots and about a country which I admire so finally I decided to do the final paper about the robotics sector in Japan.

1.2. Hypothesis and objectives

The main hypothesis of this work is, as it is reflected in its title, to see how the Japanese robots have evolved in time, from its roots to its future. By doing so, I will be able to explain the importance that has Japan in the worldwide scope for the robotics sector and its paper as the main ambassador of it.

The main objectives which I have put in the are: to see the origin of the Japanese robots; to explain why Japanese citizens show a friendly attitude towards robots have; to see in figures the Japanese robotics markets and calculate estimations to see the probable likelihood; to see why nowadays are more focused in other types of robots.

1.3. Methodology and division

The methodology which I will use in this paper is: the collection of articles found in online magazines; the collection of news found in online newspapers; the collection of data such as ratios, sales and population via trade associations, country's bureau of statistics; the estimation of some data with the data previously collected; the elaboration of tables to interpret and explain them.

To do so, I will divide the main work in four sections:

- The first one will explain the history of Japanese robots, from its origin to the present days.
- The second one will treat about how robots are seen by Japanese citizens, influenced by their culture.
- The third one will show some figures of the Japanese robotics market and then some predictions up to 2020.
- The last one will see the future panorama of Japan and how robots can help.

1.4. Special thanks

I would like to thank in the first place my maternal grandparents, to accompany me to school during my childhood when my parents could not and to always take care of me. In the second place I would like to thank my family, my parents and my sister, to support me in every step of my life and tell me to not give in tricky situations. The last, but not least thanks I would like to give is to Maria Àngels Pelegrin Solé, my former work's tutor, to take the initial stages of the paper work and to show me even more interest in Japan.

II. HISTORY OF JAPANESE ROBOTS

2.1. First indicators

A common idea that Japanese robots were firstly introduced in the 20th century is partially wrong since there were some precedents before, most specifically during the Edo period (1603-1868).

The Edo period was known as the isolation of Japan to the rest of the world. Foreign trade with Western countries was highly restricted, but only the Dutch were permitted to trade with the Japanese, once a year, within the artificial island of Dejima, in the Nagasaki Harbor. Thanks to that annual trading, foreign knowledge and accomplishments began to be introduced.

The first ancestor of the Japanese robots was the karakuri puppet (*karakuri ningyō* - からくり人形). The word *karakuri* means "mechanism or trick" and the word *ningyō* means "doll or puppet". In other words, the karakuri puppet was a puppet, made in most of the cases of wood, which had a clockwork mechanism inside that provided it the capacity to move and do unexpected things, fascinating the people or audience who was addressing.

The clockwork mechanism followed the Western standards thanks, on the one hand, to the introduction of the western clock in the year 1551 by the Francisco de Xavier, a Spanish Jesuit missionary, and, on the other hand, to the Dutch trade, which permitted the transmission of information on how to handmade new clocks like the ones of other European countries.

There were three types of katakuri[1], which are:

- **Stage karakuri** (*butai karakuri* - 舞台からくり): Katakuri puppets that performed plays in theaters. They were firstly introduced by the clockwork master Takeda Ōmi in 1662, when he opened a theater to demostrate how his karakuri puppets could perform. The people who
- **Festival karakuri** *(dashi karakuri* - 山車からくり): Katakuri puppets created in order to be seen in religious festivals (*matsuri*). They were normally 2 or 3 puppets, representing myths and legends of the Japanese mythology in top of a Dashi float, carried by approximately 20 people.
- **Tatami room karakuri** (*zashiki karakuri* - 座敷からくり): Katakuri puppets designed for domestic issues. The most recognizable *zashiki* are:
    - The *chahakoby ningyo* ¸or the tea-serving doll. It worked as the following: the karakuri had a small cup of tea in a tray, moving around the guests. When one

[1] See a website specialized in karakuri: http://karakuri.info/

of them got the cup, it stopped and stand still until the person return it, empty or not, and rebegin the process.

  - The *yumihiki doji*, or the archer doll. It worked as the following: it sat on a stand around 30 cm high. Then, it picked up an arrow and threw it to the bullseye. It usually threw four arrows, three of which went directly to the bullseye and one that failed to achieve the objective, gaining the admiration of the people watching it since it seemed like a normal person who can win or fail.

When we talk about the karakuri puppets, three famous karakuri masters come to mind:

- **Hosokawa Hanzo Yorinao**, born in the domain of Tosa in 1741 and dead in 1796. His most famous work was a three-book compilation, called "Illustrated Compendium of Clever Machines" or "*Karakuri Zui"*. They contained detailed information about the mechanical structure of the karakuri puppets and Japanese clocks. It was a revolutionary work because the karakuri technology was highly private, since the transmission of information flowed from master to apprentice, and this work was the introduction of the karakuri technology to the Japanese people.
- **Hisashige Tanaka**, born in the city of Kurume in 1799 and dead in the capital, Tokyo, in 1880. Tanaka is mostly recognized as the creator of the Myriad year clock (*Mannen Jimeishou* - 万年自鳴鐘）, a clock which could show the time in seven ways, from time of day until Solar term, and the inventor of the first Japanese steam locomotive, the first steamship and the first telegraph.

  During his youth, Tanaka specialized in the making of karakuri puppets. Their most recognized work of that period was the previously mentioned *yumihiki doji* and the *chahakoby ningyo*. Years later, in 1852, he opened a shop called 'Hall of Automata' in Kyoto, where most of his inventions could be seen and bought.

  At the final stages of his life, Tanaka moved to Tokyo, where he opened a small shop of *Hoji-ki*, an instrument like a telegraph that emitted a time signal at noon, created by him. He died at age 81 and his apprentice, Daikichi Tanaka took over the business and became Hisashige II. Two years after Tanaka's death, in 1882, Hisashige II founded Tanaka Engineering Works, the later Shibaura Engineering Works, the predecessor of the Toshiba Corporation.
- **Ohno Benikichi**, born in the village of Ohno-machi in 1801 and dead in the same village in 1870. The clear majority of his karakuri work can be found in the prefecture of Kanagawa, in the village where he lived, including tea-serving dolls and toys. But Benikichi is mostly recognized for the *erekiteru*, a massaging machine supplied with a Volta electricity battery, which functioned with two rods held by a person, which were connected to a machine and, when rotating a disk, an electric shock came to the body part where the rods were held.

With the beginning of the Meiji period in 1868, Japan remove its isolation from the rest of the world and began to receive influences from the Western civilizations. From that moment, western knowledge and assets began to be easily transmitted and traded, so karakuri puppets mechanisms was not a secret kept from their masters. Also, karakuri masters were highly asked to transmit their western knowledge to adapt it to their daily technology.

2.2. 20th century

The word 'robot' was firstly introduced in the play 'Rossum's Universal Robots', mostly known as 'R.U.R', of the Czech author Karel Capek in 1921. 'Robota', robot in Czech, referred to a machine with the purpose of replacing human labor by doing repetitive and expensive labor. The first play of 'R.U.R' in Japan was performed three years after its creation, in 1924, in the *Tsukiji Shogekijo*, one of the Tokyo's most famous theaters. The title of the play was translated as *Jinzo Ningen* (人造人間), 'Man-made man' in English. This word drove to a more common one, *Robotto* (ロボット), in 1928.

Gakutensoku, translated as 'learning from laws of nature', became the first modern robot created in Japan in 1928, being the biologist Makoto Nishimura (1883-1956) its inventor. The first appearance of the *Gakutensoku* was in the same year, at the World Exhibition of Kyoto. With a height of 3 meters and 20 cm, *Gakutensoku* consisted of a half-upper body covered of gold that simulate it was sitting in a desk. The robot itself could change its facials expressions, move its chest and act as it was writing in the table, with a pen on its right hand thanks to an air compressing system consisting of hidden rubber tubes.

During World War II, Japan signed the Tripartite Pact in 1940 along with Germany and Italy, later knowing them as the Axis Powers. One year later, the attack on Pearl Harbor, Hawaii, where the United States had a naval base. This action permitted the entrance of the US to the World War II and the Pacific War with Japan. Four years later, in 1945, after the WW2 ended, the atomic bombs were thrown to the cities of Fukushima and Nagasaki, causing the surrender of Japan and the posterior US occupation. It permitted Japan to transition from an old-fashioned empire to a parliamentary democracy.

In 1961, Joseph Engelberger and George Devol introduced the first industrial robot of the world, the Unimate 1900, in a trade show opened to the public held at the Chicago's Cow Palace. It would be developed and sold by their company, Unimation Inc. The robot itself consisted of a robotic arm that worked for factory activities, such as transporting die-cast objects from assembly line and welding them into their respective finals assets.

Eight years later, in 1969, Kawasaki Heavy Industries signed a technical agreement with Unimation Inc., to be pioneer in Japan by introducing the Unimate robot for industrial tasks.

Later in that year, the Kawasaki-Unimate 2000 seen the light and became the first industrial robot of Japan.

One year later, in 1970, Masahiro Mori, a professor from the University of Tokyo, described a phenomenon that nowadays explain the relationship between robots and humans. He published it in a science magazine named "Energy" and called it "The Uncanney Valley". The human-robot relationship is compared within a x-y function, being the x the familiarity of humans to robots and being the y the human likeness of robots.

At the beginning, the least similar robots are the industrial robots, which only can perform industrial tasks with only one arm and are based on functionality, not resembling humans and so having no affinity with them. When creating a humanoid robot, the familiarity increases as well as the likeness to people but in some point, it will fall due to this likeness will scare people to a point that they will see robots as zombies, a fall similar to a valley. To inverse this situation, robots have to be redone in parts, for instance a prosthetic hand, to gain people's attention from the beginning and not at the total.

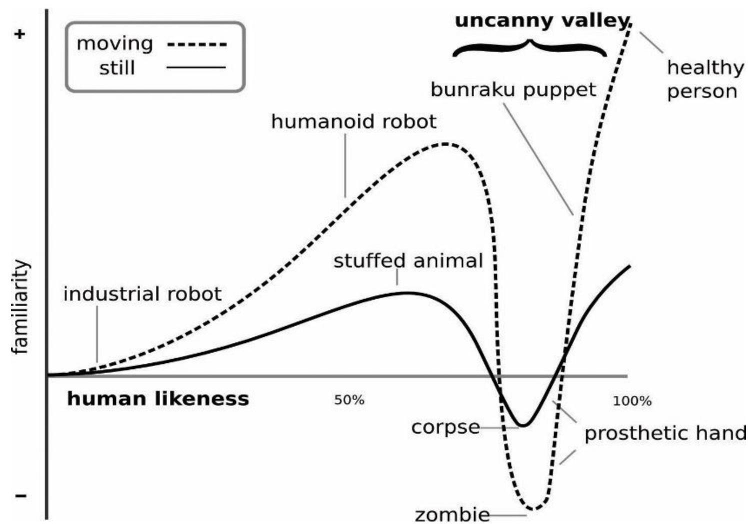

Figure 1. Graphic that summarizes the process of acceptation of robots from humans. **Source**: Energy Magazine (1973)

In the 1970s, a project carried out by the Waseda University called 'WABOT' began. The main objective of the project was to develop an anthropomorphic intelligent robot that in a future will convert into a 'personal robot' which will be the closest robot regarding a person. Two robots seen the light thanks to the WABOT project:

- The WABOT-1, created between 1970 and 1973. Recognized as the first anthropomorphic robot of the world. It was able to move thanks to a limb-control system and take objects with artificial hands with tactile sensors. It was able to interact in Japanese with persons. Also, was capable to measure distances and directions to object using a vision system consisting of a pair of artificial ears and eyes and external receptors.

- The WABOT-2, created between 1980 and 1984. It drove from the versatility of its predecessor to the specialization in one task, in that case playing a keyboard instrument. It was able to do the same stuff of a musician such as read a musical score of a normal difficulty, play tunes of average complication and accompanying a singer.

In 1978, a research group led by professor Hiroshi Makino and followed by five Japanese companies was established in order to develop Makino's robot prototype SCARA (Selective Compliance Assembly Robot Arm). The SCARA robot permitted to solve the "peg-and-hole problem"[2], very typical of the assembly process. It used a new structure, the *byobu*[3]-like, having a similar functioning to the folding parts of it.

By the middle of the 80s, in 1986, Honda began the development of the Honda E Series robots, a group of humanoid robots that simulate the lower body of humans. The E series development phase ended in 1993, after developing seven humanoid robots:

- E0, the predecessor. It was capable to walk, in a slowly and steady path of five seconds, by putting one leg before the other was completely done.
- E1 to E3, the successors of the EO. They were given joints functions to simulate the hip, the knee and the food joints of a human body.
    - The first one, the E1, was developed in 1987 and was able to walk faster than the E0, at 0.25 km/h, but with a better movement distinction between the legs.
    - The second one, the E2, came to live in 1989. It achieved a dynamic movement while increasing the speed of movement respect the E1, at 1.2 km/h.
    - The third one, the E3, arrived in 1991. It was faster than the E2, reaching a 3 km/h speed of movement, while giving it pieces that simulate the thighs.
- E4 to E6, the successors of the E3. They were higher in comparison to the E3 and were more focused on the posture of movement rather than the walking path.
    - The first one, the E4, was developed along with the E3 in the same year, 1991. The knees measured 40 cm length, simulating the quickness of the human's walking. It reached a movement speed of 4.7 km/h.
    - The second one, the E5, saw the light the following year, in 1992. It achieved an autonomous walking while having a large head that differentiate it from the previous E series robots.

[2] It consists of a problem of misalignment arising when a peg is inserted nto a hole.

[3] Byoubu is a foldable screen from Japan which permits to divide the diverse house parts.

- The third and last one, the E6, arrived in 1993. It achieved an autonomous control balancing, being able to take the stairs in both ways, going up and down and passing obstacles.

After the E series development ended in 1993, Honda decided to follow the development of a humanoid robot but then putting an upper body to simulate a complete human body. The functions given were basically heritated from the E series robots, but then the P series robots were able to carry objects up to 2 kg, pushing carts, and open and close doorways. So, in the same year, the Honda P series robot development phase began. It ended in 1997, after developing 4 robots.

- The first one, the P1, saw the light in 1993. It had a height like a high height human body, 191.5 cm, and was the first to have an upper body.
- The second one, the P2, arrived in 1996. It was the first Honda humanoid robot to be exposed publicly. It was nearly 10 cm shorter than its predecessor.
- The third one, the P3, was developed in 1997. It had a more common height for the humans, 160 cm, and the body evolutioned to a one more similar to a person.
- The fourth and last one, the P4, was developed in 2000 but never saw the light because another Honda's humanoid eclipsed it.

By the end of the century, in 1999, Sony launched the first pet robot and also the first robot to be launched for consumer purposes, the AIBO (Artificial Intelligence roBOt). AIBO was able to develop from the puppet stage to the adult one, shaping its personality with the consumer's interaction and surroundings' development. In May of that year, 5,000 AIBO units were launched in Japan and the United States of America, selling 3,000 in less than 20 minutes in Japan while the remaining 2,000 were sold in four days in the US.

2.3. 21st century

At the beginning of the 21st century, in 20th November 2000, Honda launched probably the most famous humanoid robot in the world[4], the ASIMO[5] (Advanced Step in Innovative Mobility). ASIMO used the best features of the previous P series robots while improving the cohabitation with humans, including brand new characteristics such as prediction movement control thanks

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[4] ASIMO has visited some countries such as the United States, the United Kingdom and the Czech Republic for instance, and has been used in diplomatic visits to Japan, such as Barack Obama's in 2014.

[5] See Honda's webpage of ASIMO and its predecesors: http://world.honda.com/ASIMO/history/

to i-WALK[6], and a more convenient height (120 cm) and weight. This robot had some improvements in the following years:

- In 2002, Honda added a recognition technology, via visual and sound features, which permitted ASIMO to react to some typical human gestures such as shaking hands and greeting, letting a more naturally interaction with people, and being able to do Internet research while performing other tasks.
- In 2005, ASIMO increased in height by 10 cm. The walking speed was 2.7 km/h and the running speed was 6 km/h while absorbing the impact of both legs to the ground. The recognition system improved, being able to avoid obstacles without stopping with an environment sensor (visual, ultrasonic and ground). Apart from that, to identify people, the IC Communication Card permits it within the visual sensor and personalizes the situation. Finally, ASIMO was able to carry objects on a tray to a previously specified destination and putting them on the table.
- In 2007, Honda created a new charging station for ASIMO which permits it to charge itself. Also, it was able to collaborate with two or more ASIMOs to perform and distribute efficiently the tasks.
- The last version of ASIMO arrived in 2011. It has the same height of its predecessors but was 6 kg lighter, weighting 48 kg. The running speed increased to 9 km/h. Also, the sensors are actualized to simulate the visual, auditory and tactile senses, now being able to recognize a situation and so determine the robot's behavior, reacting to persons' unpredictable movement and surrounding situations. The legs are strengthened along with an expanded range of leg movement, permitting ASIMO to do staff such as run backward, do hops and adapt to typical walking situations such as an uneven surface. Finally, the hands are more developed and so being able to cap a bottle and pour the content into a glass or a cup and do sign language expressions

Regarding the AIBO robots, Sony decided to cancel its production in 2006, as well as the QRIO (Quest for CuRIOsity) robot. It was a bipedal humanoid robot which was focused to entertainment. The first prototype was developed in 2003 and is considered the first running humanoid robot. Despite it was expected to be launched to the Japanese market, it never seen the light.

Despite Toyota is most know for its automotive section, it also has a robot project, beginning with the launching of its industrial robots in the 1970s. Some examples which were presented in the 21st century[7], were:

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[6]It permits a more smoothly and naturally walking without pauses, not so mechanic.

[7] See Toyota's webpage: http://www.toyota-global.com/innovation/partner_robot/concept/history/

- In 2007, Toyota presented its first humanoid robot Robina. It was able to play two instruments, the trumpet and the violin, thanks to fully functioning fingers and lips. It was expected to be a companion for the elderly and help nurses and doctors.
- In 2011, three robots were presented and included in the Partner Robot family:
    - The Walk Assist Robot, to help people with leg paralysis to move.
    - The Care Assist Robot, to reduce the exigence of moving patients from bed.
    - The Human Support Robot, to help house members in home activities.
- In 2013, a robot astronaut, Kirobo, was revealed as a part of the Kibo Robot Project. It spent the milestone of 18 months in the International Space Station, being the first robot to be able to travel and speak in the space. A smaller version of Kirobo arrived two year later, the Kirobo Mini, with a height of 10 cm. It was created to help and accompany people in their daily routine.

SoftBank Robotics presented in 2014 the first humanoid robot to be able to read the emotions of humans and adapt the conversation to them, called Pepper[8]. Pepper was developed by the French Aldebaran Robotics. Nowadays Pepper can be found in more than 140 SoftBank stores working as an attendant to customer, welcoming them and informing about SoftBank issues. It also can be seen in some Japanese family houses since it is available to buy.

[8] See Softbank's webpage: https://www.softbankrobotics.com/emea/en/robots/pepper

III. CULTURAL IMPACT OF ROBOTS IN THE JAPANESE SOCIETY

The most notable fact when somebody travels to Japan is the coexistence between citizens and robots and the presence the robots have almost every corner, from TV advertisings to its own anime series and film. In this chapter I will discuss how robots have impact in the Japanese citizens in some manners.

3.1. Manga/Anime

When talking about manga[9], "*Tetsuwu Atom"* (known outside Japan as *Mighty Atom* or *Astro Boy*) was the pioneer in the robotics theme. Launched in 1951 by the medicine student Osamu Tezuka, the manga series[10] told the story of Atom, a humanoid robot created the 7th April 2003 by doctor Tenma, who firstly was created to assemble doctor Tenma's lost son, later sold to a circus and finally developed to a fighter against crime.

Atom, despite it seems a little boy, has powers given by the advanced technology of the future scheme such as massive strength, the capacity of flight and the ability to speak diverse languages. It also lives with harmony with humans, being able to go to school with other human kids and having a robotic family like a typical human one while protecting them from dangerous enemies.

In other words, what Osamu Tezuka did when he created *Astro Boy* was to develop a model which readers can see that robots can be between humans and be able to help them, creating a new friendly-attitude to robots. Thanks to his work, later broadcasted in TV between 1963 and 1968[11], a generation of Japanese citizens grew with this concept and normalized the situation with robots.

Another pioneer in the robotics theme for Japanese manga was "*Tetsujin-28go*" (known outside Japan as *Ironnman 28*). Its creator, Mitsuteru Yokoyama, alongside his work are known as the ancestors of the manga subgenre "mecha". The mecha refers to gigantic humanoid robots that can be controlled by humans or have its own will. "Tetsujin-28go" was written and published in 1956, five years later than Astro Boy.

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[9]Manga are the Japanese comics, either being some small vignettes or complete anthologies.

[10] In Japan, the manga can be read in magazines which are launched in a weekly basis, depending the targeted audience. For instance, the most common manga magazine is mostly known as *shonen,* which is addressed for male teenagers, being its counterpart the *shojo,* for female teenagers. Despite the themes included within both magazines, anyone can read it.

[11] This was the original series, which consisted of 193 aired episodes. Later it had two reboots, in 1980 and 2003 (aired during Atom's birthday, the 3rd April 2003).

Ironnman 28 narrates the story of a gigantic robot of the same name, whose functioning was via remote control. Firstly, it was a secret weapon of the Japanese Army during World War II and later a gift from its creator, Doctor Kaneda, to his son Shotaro, who is a known detective in Tokyo. Together, they will fight against crime in the city. Eight year later after its paper publication, an anime[12] series was broadcasted in the Japanese TV[13].

But probably the most famous mecha manga outside Japan was "*Majingā Zetto*" (*Mazinger Z*[14] outside Japan) created by Go Nagai. *Mazinger Z* was pioneer within the mecha genre in having robots controlled within a cockpit inside the robot. As some previous mecha works, its episodes were launched in a shonen magazine from 1972 to 1974, at the same time launching the anime series in the Japanese TV.

Mazinger Z tells the story of Koji Kabuto, the grandson of Doctor Kabuto, a well-known scientific who died in an assassination planned by Doctor Hell, the antagonist of the manga. Before dying, Doctor Kabuto gives Koji a gigantic robot in which he had worked to stop the evil plans of Doctor Hell, Mazinger Z. Although Koji is a teenager without robot controlling experience, he can control the robot and so fight against the Doctor Hell robots and his allies, being the most known the Baron Ashura, a half-man and half-women.

Another mecha, in this case an anime series, was "*Kidō Senshi Gandamu*" (known as *Mobile Suit Gundam* in foreign countries). The TV series was created by Yoshiyuki Tomino along with the animation studio Sunrise in 1979. It lasted only one year due to low audience, with 43 episodes aired. Despite this fact, it later developed in a franchise called "*Gundam*", whose revenues in 2014 accounted for 80.2 billion Japanese yen[15], including toy sales as the main revenue source, anime reboots, manga and videogames.

The action of *Mobile Suit Gundam* takes place in a fictional universe, in the year 2179 or UC 0079 according to the Gundam Calendar. The Earth is divided in several territories, having colonies in the outer space. A war is settled and the principality of Zeon, which declared it, had the advantage as it introduced humanoid weapons called mobile suits. To respond this menace, a prototype humanoid robot, the RX-78-2 Gundam, is found by Amuro Ray, a teenager from the colony Side 7. During the war, controlling the robot and with some robot allies, he will fight against Zeon rivals such as Commander Char Aznable.

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[12]Anime, diminutive of animation, can be either TV series and films which can be found in both cinemas and television, with a manga background behind them or not.

[13] In the United States, the anime series was adapted and changed its name to *Gigantor*.

[14] It was launched in Europe (Spain was the first), the United States, Mexico and South America (Chile was the first).

[15] See the Bandai Namco's Financial Results of 2014: https://www.bandainamco.co.jp/files/E8A39CE8B6B3E8B387E69699EFBC88E88BB1EFBC89.pdf

Moving apart from the mecha genre, robots can be seen in other target audiences. One case is "*Doraemon*", a manga created in 1969 by Fujiko F. Fujio addressed to Japanese school students[16]. The publication lasted for 27 years, ending in 1996. Due to success, "*Doraemon*" turned into a franchise which included an anime series that saw the light firstly in 1973 (other versions arose in 1979 and in 2005), films, toys and films.

One of its protagonists, Doraemon, is known outside Japan as the first anime ambassador of Japan[17], as well as to be promoted in the 2020 Tokyo Summer Olympics as one of its representatives, being able to participate in the 2016 Rio Summer Olympics Closing Ceremony[18].

"*Doraemon*" narrates how Doraemon, a robotic cat from the 22nd century, goes back on time to the present to help the ancestor of its owner, Nobita Nobi, to turn back the future situation of debt of the Nobi family. It will help him thanks to future gadgets, stored in a 4-dimensional pocket in its stomach, such as the anywhere door, which permits to visit a place where you want to go in a matter of seconds. The episodes follow the structure of the introduction of a problem which can be commune from the audience and its resolution via future gadgets.

Now turning into a more comedy scheme, a robot manga which explains it perfectly is "*Dokutā Suranpu*" (*Dr. Slump* in foreign countries). It was the second manga work of Akira Toriyama, mostly known as the creator of *Dragon Ball*[19]. It was launched in a *shōnen* magazine called "*Weekly Shōnen Jump*" in 1980, ending four years later. The anime series began simultaneously in the Japanese TV in 1981, ending two years after the manga ended, in 1986, with a total of 243 episodes. Eleven years later, a remake was launched with less episodes.

The story of *Dr. Slump* was set in the fictional village of Penguin Village, the home of the inventor Senbei Norimaki. He creates a robot girl, Arale, which at the beginning seems to be perfect but later finds out that she is naïve and needs glasses. To sum up, the episodes tell how Arale tries to understand humans while his creator do some inventions while having romantic interests.

One of the foreign genres seen in books and films that would be exported to Japan was the cyberpunk[20], being the film Blade Runner one of its examples. This new genre could be seen

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[16] For the case of young children, they have a type of magazines and publications addressed to them, the *kodomo*, like the cases of *shonen* and *shojo*.

[17] See the notice attached: http://web.archive.org/web/20080318231731/http://www.japantoday.com:80/jp/news/431177

[18] See the video attached: https://www.youtube.com/watch?v=s23qwzu4Mb8

[19] The characters of "Dr Slump" came back for a cameo in the beginning of "Dragon Ball", helping Son Goku, the protagonist, to fight the Red Ribbon Army, the antagonist of the first sagas.

[20] Cyberpunk is a science fiction genre which describes typically a future where computers and technology predominate in modern urban cities.

in Shirow Masamune's manga "*Kōkaku Kidōtai*" (translated as *The Ghost in the Shell* in other countries). It was written in 1989 and distributed in a *seinen* magazine until 1990. Five years later, in 1995, a film was made adapting the manga, being one of the most known anime films outside Japan, even influencing the Wachowskis[21] when creating the *Matrix* films.

The plot of *The Ghost in the Shell* is pretty similar between the manga and the film. It is located mainly in the fictional city of New Port City after two World War occurred and tell the story of Major Motoko Kusanagi and its organization, Public Security Section 9, which fights against cyberterrorism.

The character of the Major is quite different between the manga, in which she is a cyborg which immature and humoristic character, while in the anime is a non-emotional cyborg[22] which questions its existence. But one common thing is that they both fight against a cyberterrorist called The Puppet Master, who hacked humans with cyberbrains. Within the story, the Puppet Master will have an influence in Major, beginning to ask if she has some remains as a human such as the consciousness and the soul or began to turn into a fully robot.

To conclude with the examples of robots' anime or manga, the final example and one of the latest exponents of the mecha genre is "*Shin Seiki Evangerion*" (*Neon Genesis Evangelion* outside Japan). It is an anime series created and directed by Hideaki Anno in 1995[23], along with producers Gainax and Tatsunoko Production. It later turned in a franchise which include films, music soundtracks, videogames and even a section in an amusement park[24], Fuji-Q Highland, in Fujiyoshida. It is also considered as the anime that led the expansion of Japanese animation worldwide[25].

The main protagonist of *Neon Genesis Evangelion* is Shinji Ikari, a teenager boy who is conceded the pilotage of a mecha robot called Evangelion Unit 01, or EVA U1. The Evangelion units are created in 2015 to fight against monsters called Angels, who were the main culprits of the Second Impact, a cataclysm event which took place in 2000, when the sea levels increased causing several tsunamis and floods. During the anime, we will see the love-hate relationship of Shinji towards the technology of the EVA units.

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[21] Can be found in an interview with Joel Silvers, the producer of the *Matrix* saga, inside the DVD edition.

[22] In the work a cyborg is a human who has either a full-body cyberization or almost of it.

[23] Before the airing of the Neon Genesis Evangelion anime, a manga series was launched the previous year in order to promote the TV debut. It ended later than the anime, in 2013, with only 14 volumes published in shonen and seinen magazines. Seinen magazines have a young adult audience.

[24]See the news link in Japanese: http://gigazine.net/news/20110405_mari_evangelion_world_2nd/

[25]See the news link: https://www.animenewsnetwork.com/news/2009-01-29/tv-tokyo-iwata-discusses-anime-road-to-survival

What differentiate the EVA units from the previously robot works mentioned is that they are similar to the monster who are fighting, being a mixture of organic beings like Angels but with a robotic protection technology. They can connect with its pilots, who are motherless teenagers whose soul is integrated in the EVA to permit a solid psychic link, via mental thoughts which simultaneously convert into the EVA actions.

3.2. Religion

In Japan, its citizens have some religious roots in either Shinto or Buddhism, even practicing both. According to the CIA World Factbook[26], Shinto is the most followed religion in Japan with 79.2%, being the Buddhism the second with 66.8%. The percentages exceed the total of 100% because of practicing both, being difficult to measure[27].

Shinto is not a religion itself but a collection of ancient mythology and natural beliefs. The word Shinto consist of the words *shin* (god in Japanese) and *to* (way in Japanese, with the union meaning "the way to God". For Shinto, the gods or better called spirits can be found in almost every passage, animals and objects they find. There is no exact moment when Shinto arrived to Japan, but there is a theory which says that its origin came from shamanic and animist beliefs who were brought from immigrants during the Yayoi Period[28]

So, basically, robots are seen for Shinto believers as living entities which have a kami inside, being treated with the same status as humans.

We can find some examples of robots used in Shinto practices. During Matsuris, Shinto festivals which took place in significant dates, the previously mentioned karakuri puppets were used to entertain the masses and sometimes even nowadays. A more recent example is a robot priest which can take part of funerals, even delivering prayers and taking care of the tombs when death date arrives.

The other followed religion of Japan, Buddhism, arrived in the 6th century, during the Kofun Period[29] via Korean Buddhist monks. Several year later, it was widely spread during Heian Period[30], being practised by the upper classes.

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[26] CIA's World Factbook is an annual reference resourced which provides information of countries around the world.
[27]See the CIA World Factbook for Japan: https://www.cia.gov/library/publications/the-world-factbook/geos/ja.html

[28] Yayoi Period is one of the oldest periods of Japan, beginning in 300 BC and ending in 300 AD.

[29] Kofun Period is the one that followed Yayoi, beginning in 300 AD and ending in 538 AD.

[30] Heian Period is considered the last classical period, running from 794 AD to 1185 AD.

Masahiro Mori, the author of *The Uncanney Valley* previously mentioned, wrote in 1974 the book *The Buddha in the Robot: A Robot Engineer's Thoughts on Science and Religion*. In it, Mori discussed how Buddhism is approaching robots. He believed that Buddha could be found in the robots, so attaining the Buddhahood, and so as all the things found in the universe which are related one to another. The connection between the being and the body is totally flawed, being ruled by "*ku*" or basic life-force. Since all things have matter or soul, a robot can have the nature of Buddha.

Another argument that Mori gives is that an interdependency and reciprocity exist between people and machines. Since robots are human creations, there is a reflection of their will in them, as well as both share the Buddha nature, feeling a closer relationship.

The Dalai Lama in 2001 expressed that there is a idea of a possible reincarnation, a Buddhist belief, that a human can revive in its creation, comparing the situation of a scientist who has worked during his life in computer research and a computer.

IV. JAPANESE MARKET ANALYSIS

In order to analyze the robotics market of Japan, I will use the data of the Japan Robot Association (JARA). JARA is a trade organization, whose main objective is to promote the usage of robots and incite the research and development in the robotics area. It is formed by the manufacturers that take part of the Japanese robotics market, being the most famous:

- **Hitachi Group**: A business group created in 1910. Some of its business segments are I&T systems, social infrastructure, industrial systems, electronic systems, equipment and construction machinery. The revenue of the group in Japan in 2017 was 4,757.6 billion Japanese yen[31].
- **Kawasaki Heavy Industries**: A corporation established in 1896. Some of its business parts are: precision machinery, robot company, motorcycle & engine company, energy system and rolling stock company. The total net sales for fiscal year ended in March 2018 were 1,574,242 million Japanese yen[32]
- **Panasonic Corporation**: A multinational created in 1918. Some of its divisions include: automotive, consumer electronics, eco solutions, industrial systems and

[31] Hitachi's Outline: http://www.hitachi.com/corporate/about/en_Outline_2017-2018.pdf

[32] Kawasaki Heavy Industries' Outline: http://global.kawasaki.com/en/corp/profile/outline.html

automotive. The total net sales for fiscal year ended in March 2018 were 7,982.2 billion Japanese yen[33].

- **Sony Corporation**: A multinational created in 1946. Some of its major divisions are: mobile communication, gaming, network services, components and home entertainment and sound. The consolidated sales for fiscal year ended in March 2018 were 8,543,982 million Japanese yen[34].
- **Toshiba Group**: A business group created in 1875. Some of its business segments are: energy business, electronic devices, digital solutions and social infrastructure. The total net sales for fiscal year ended in March 2018 were 4,870.8 billion Japanese yen[35].
- Yamaha Corporation: A corporation created in 1887. Some of its business divisions are: musical instruments, audio equipment, automobile, factory automation and electronic devices. The total net sales for fiscal year ended in March 2018 were 432,967 million Japanese yen[36].

In its webpage, https://www.jara.jp/e/, we can find some data, from its current member list, news, etc., to a statistics section. In this section we can see the data about domestic and foreign sales of the robotic sector of Japan. We can choose the results between a yearly or a quarterly manner.

The period that I will cover in that section is between the years 2012 and 2020. The main reason to take this eight year-period is because 2012 was the first year that JARA showed both units sold and revenues in the Japanese robotics market. Before 2012, only the revenues could be seen. I will end in the year 2020 because it will be the year of the 2020 Summer Olympics in Tokyo, and I think it will be important to know how the robotics sector will evolve into such important event.

From 2012 to 2017, all data can be found in the yearly or quarterly results file of the year analyzed. I will use the quarterly data because it will be more precise to see if there are some fluctuations than using the yearly one. To summarize it, I will sum up the four quarters for each year to see the total amount.

After that, I will predict the results from 2018 to 2020. To carry out my predictions, I will use a program called "GRETL". It is a software which is mainly used in macroeconomic issues, and among its functions there is one, which is forecast, that can be run out after calculating the Ordinary Least Squares Model. The predictions made cannot take into account the possible

[33] Panasonic Corporation's Outline: https://www.panasonic.com/global/corporate/profile/overview.html

[34] Sony Corporation's Outline: https://www.sony.net/SonyInfo/CorporateInfo/data/

[35] Toshiba's Outline: http://www.toshiba.co.jp/worldwide/about/corp_data.html

[36] Yamaha Corporation's Outline: https://www.yamaha.com/en/about/profile/

events that can vary the production and selling of robots in Japan upwards or backwards, so this will be a limitation.

3.1. Size

Firstly, I will introduce which is the size, in units, of the Japanese robotics market. I would sum up both domestic and foreign sales to the see the total amount. For the following table, I will show the results of the OLS model calculation which I have calculated using the program "GRETL".

```
Model 1: MQO, emprant les observacions 2012:1-2017:4 (T = 24)
Variable dependent: Units
Desviacions típiques HAC, amb amplada de banda 2 (Kernel de Bartlett)
Omeses atesa la col·linealitat exacta: dq4

             Coeficient   Desv. Típica     z      Valor p
  ---------------------------------------------------------
  const       16770,1       2470,41      6,788   1,13e-011 ***
  time         1271,08       206,034     6,169   6,86e-010 ***
  dq1          2156,39      1392,76      1,548   0,1216
  dq2          3403,32      1940,40      1,754   0,0794    *
  dq3          2696,07      1550,80      1,739   0,0821    *

Mitj. de la vble. dep.   34722,50   D.T. de la vble. dep.   9766,194
Suma de quad. residus    3,52e+08   D.T. de la regressió    4302,320
R-quadrat                0,839683   R-quadrat ajustat       0,805932
F(4, 19)                 14,30439   Valor p (de F)          0,000015
Log-versemblança        -232,0570   Criteri d'Akaike        474,1140
Criteri de Schwarz       480,0042   Crit. de Hannan-Quinn   475,6767
rho                      0,794714   Durbin-Watson           0,327619

Sense considerar la constant, el valor p més alt ha estat el de la variable 3 (dq1)
```

Figure 2. OLS model calculation for the Japanese robotics market. **Graphic:** Own elaboration using GRETL. **Source:** JARA

When calculating an OLS model for a time series data, in this case a quarterly one, we have to subtract one of the dummy variable generated, in our case dq4 is automatically excluded (for quarter 4). The r-square value is equal to 0.84, which means that an 84% of the model can explain the dependent variable, being total units. This value is good because is closer to 1, which would be the best value.

Per a intervals de confiança 95%, t(19, .0,025) = 2,093

	Units	predicció	Desv. Típica	Interval de confiança 95%
2012:1	27014,00	20197,58		
2012:2	27110,00	22715,58		
2012:3	26012,00	23279,42		
2012:4	22048,00	21854,42		
2013:1	22545,00	25281,88		
2013:2	24280,00	27799,88		
2013:3	27241,00	28363,72		
2013:4	26624,00	26938,72		
2014:1	29943,00	30366,18		
2014:2	33616,00	32884,18		
2014:3	33499,00	33448,02		
2014:4	30433,00	32023,02		
2015:1	33948,00	35450,48		
2015:2	35927,00	37968,48		
2015:3	35251,00	38532,32		
2015:4	34237,00	37107,32		
2016:1	37048,00	40534,78		
2016:2	36485,00	43052,78		
2016:3	37680,00	43616,62		
2016:4	41357,00	42191,62		
2017:1	46952,00	45619,08		
2017:2	55140,00	48137,08		
2017:3	56258,00	48700,92		
2017:4	52692,00	47275,92		
2018:1		50703,38	5183,330	39854,55 - 61552,22
2018:2		53221,38	5868,651	40938,15 - 65504,61
2018:3		53785,22	6003,509	41219,73 - 66350,71
2018:4		52360,22	5596,572	40646,46 - 64073,98
2019:1		55787,68	5634,971	43993,55 - 67581,81
2019:2		58305,68	6405,369	44899,09 - 71712,27
2019:3		58869,52	6574,194	45109,57 - 72629,46
2019:4		57444,52	6141,143	44590,96 - 70298,08
2020:1		60871,98	6164,194	47970,18 - 73773,79
2020:2		63389,98	6998,203	48742,58 - 78037,39
2020:3		63953,82	7194,188	48896,21 - 79011,42
2020:4		62528,82	6742,704	48416,17 - 76641,46

Figure 3. Total robots units sold and to be sell in the Japanese robotics market. **Table:** Own elaboration using GRETL**. Source**: JARA

According to JARA, in 2012 the Japanese robotics market was capable to sell 102,184 units. The next year, 2013, it dropped a 2.93%, being 99,185 the robots sold. In 2014 it recovered from that fall quickly, being able to increase a 28.54% and reaching an amount of 127,491 robots sold. The two following years, 2015 and 2016, experienced a stable progression (a rise of 9.31% in 2015 and 9,48% in 2016), being 139,363 and 152,570 the robots sold for both years. In 2017, the market reached a peak of 211,042 units sold, an increase of 38,32 % respect the previous year.

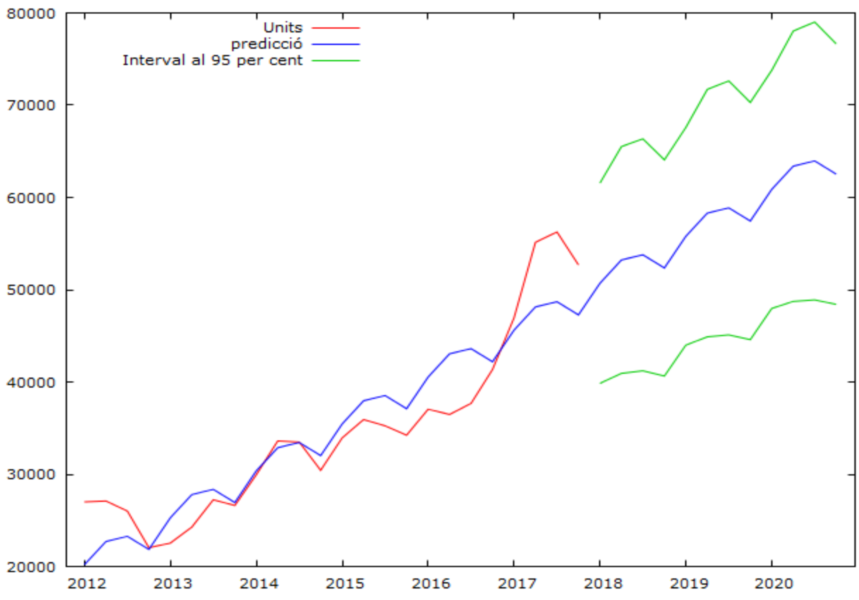

Figure 4. Total robots units sold and to be sell in the Japanese robotics market. **Graphic**: Own elaboration using GRETL. **Source**: JARA

According to the predictions I have made, in 2018 the number of robots sold will decrease a few, a 0.46%, being the sales 210,070 units. The upcoming year, 2019, will recover from the decreasing trend by scoring a 9.68% increase, with total sales of 230,407 units. Lastly, in 2020, the global sales of robots will rise an 8.83%, being 250,745 the robots sold. To summarize, the robotics market for Japan is expected to increase in worldwide units sold by 2020, despite a seasonality fall by the last quarter of the year.

3.2. Revenue

Secondly, I will introduce which is the revenue, in million yen, of the Japanese robotics market. I would sum up both domestic and foreign sales to the see the total amount. The result will be showed in Japanese yen, which is the Japanese currency, but also will appear the US dollar, the most famous worldwide currency, in brackets. As done in the previous section, I will show the results of the OLS model calculation which I have calculated using the program "GRETL" in the table below.

```
Model 2: MQO, emprant les observacions 2012:1-2017:4 (T = 24)
Variable dependent: Revenue
Desviacions típiques HAC, amb amplada de banda 2 (Kernel de Bartlett)
Omeses atesa la col·linealitat exacta: dq4

             Coeficient   Desv. Típica     z      Valor p
  ---------------------------------------------------------
  const       77151,4      7985,35       9,662   4,39e-022 ***
  time         3432,04      648,978      5,288   1,23e-07  ***
  dq1         11817,6      4496,34       2,628   0,0086    ***
  dq2         11699,3      5573,63       2,099   0,0358    **
  dq3         14746,7      5094,96       2,894   0,0038    ***

Mitj. de la vble. dep.  129617,8   D.T. de la vble. dep.   27281,44
Suma de quad. residus   3,47e+09   D.T. de la regressió    13518,21
R-quadrat               0,797171   R-quadrat ajustat       0,754470
F(4, 19)                16,17541   Valor p (de F)          6,36e-06
Log-versemblança       -259,5342   Criteri d'Akaike        529,0684
Criteri de Schwarz      534,9586   Crit. de Hannan-Quinn   530,6310
rho                     0,759535   Durbin-Watson           0,364193
```

Figure 5. OLS model calculation for the Japanese robotics market revenue. **Graphic:** Own elaboration using GRETL. **Source:** JARA

The r-square value is equal to 0.79, which means that we can explain the dependent variable, being total revenue, by a 79% of the model. This value is good because it is closer to 1, but not such as the previous OLS model for the units.

Per a intervals de confiança 95%, t(19, .0,025) = 2,093

	Revenue	predicció	Desv. Típica	Interval de confiança 95%
2012:1	117197,00	92401,07		
2012:2	116511,00	95714,74		
2012:3	109266,00	102194,24		
2012:4	86054,00	90879,57		
2013:1	97875,00	106129,24		
2013:2	100460,00	109442,91		
2013:3	105873,00	115922,41		
2013:4	96834,00	104607,74		
2014:1	116443,00	119857,41		
2014:2	119229,00	123171,08		
2014:3	133453,00	129650,58		
2014:4	115988,00	118335,91		
2015:1	130179,00	133585,59		
2015:2	134903,00	136899,25		
2015:3	134497,00	143378,75		
2015:4	128861,00	132064,09		
2016:1	138111,00	147313,76		
2016:2	132563,00	150627,42		
2016:3	140045,00	157106,92		
2016:4	143852,00	145792,26		
2017:1	160524,00	161041,93		
2017:2	176545,00	164355,60		
2017:3	195954,00	170835,10		
2017:4	179611,00	159520,43		
2018:1		174770,10	15704,911	141899,34 - 207640,86
2018:2		178083,77	16920,968	142667,77 - 213499,76
2018:3		184563,27	18684,911	145455,30 - 223671,23
2018:4		173248,60	17670,197	136264,45 - 210232,75
2019:1		188498,27	16998,444	152920,12 - 224076,42
2019:2		191811,94	18391,305	153318,49 - 230305,38
2019:3		198291,44	20438,475	155513,22 - 241069,66
2019:4		186976,77	19378,741	146416,60 - 227536,94
2020:1		202226,44	18566,837	163365,61 - 241087,28
2020:2		205540,11	20090,759	163489,67 - 247590,55
2020:3		212019,61	22356,524	165226,87 - 258812,35
2020:4		200704,94	21267,647	156191,25 - 245218,64

Figure 6. Total and future revenue in the Japanese robotics market. **Table**: Own elaboration using GRETL. **Source**: JARA

As reported by the JARA results, in 2012 the total revenue was 429,028,000,000 Japanese yen (4,955,160,694.34 US $ for 31/12/2012 exchange rate [37]). The following year, 2013, it experienced a decrease of 6.52% respect 2012, being 401,042,000,000 Japanese yen the total revenue (3,809,443,697.02 US $ for 31/12/2013 exchange rate). It recovered rapidly for the next year, 2014, being able to have a revenue of 485,113,000,000 Japanese yen (4,050,558,640.07 US $ for 31/12/2014 exchange rate), increasing significantly by a 20.96%.

For 2015, it rose an 8.93% respect the previous year, being 528,440,000,000 Japanese yen the total revenue (4,392,498,122.50 US $ for 31/12/2015). For the next year, it will still increase but in a lower mood compared with the previous years, a 4.94%, having a total revenue of 554,571,000,000 Japanese yen (4,741,159,023.24 US $ for 31/12/2016). The last year accounted, 2017, experienced a relevant increase of 28.50% respect 2016, reaching a pick of 712,634,000,000 Japanese yen (6,325,322,779.63 US $ for 31/12/2017).

[37] For the exchange ratio for Japanese yen/US dollar I have used the one from the webpage www.xe.com , searching which was the last for the year mentioned, in that case and the following the 31st of December.

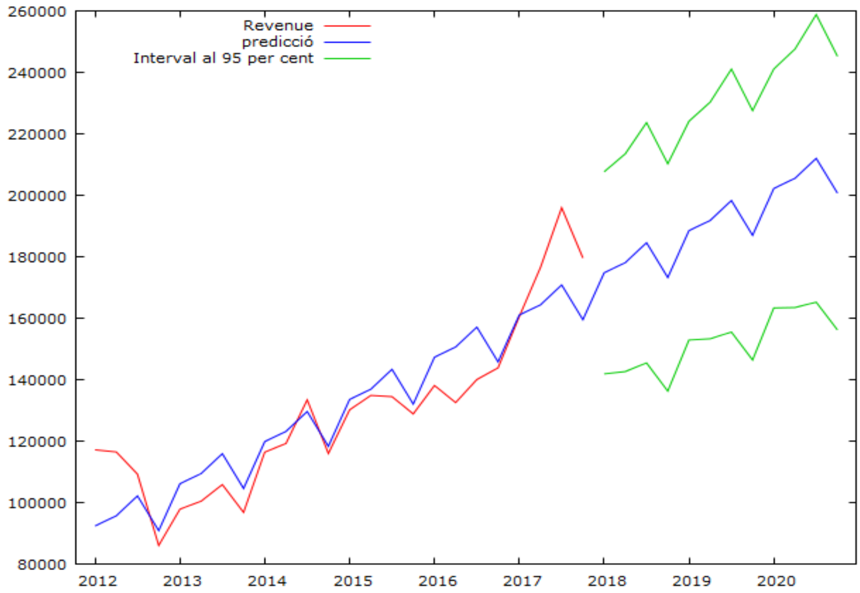

Figure 7. Total and future revenue in the Japanese robotics market. **Graphic**: Own elaboration using GRETL. **Source**: JARA

Having run out the predictions, we can see that for the present year, 2018, it will decrease a bit from 2017, a 0.46%, having a total revenue of 710,665,000,000 Japanese yen. For 2019, it will rise to 765,578,000,000 Japanese yen, a 9.68% from the previous year, establishing a new pick. Arriving to 2020, it will score a new record of 820,491,000,000 Japanese year, having an 8.83% increase rate. Summing up, the robotics market of Japan will experience an increasing trend to 2020, despite the seasonality decrease of the last quarter for the year.

3.3. Domestic Shipments and Exports

From now on, I will compare the size and revenue for both domestic and foreign sales, so I can see which one of the cases is the most important for the Japanese robotics market, being able to say that Japan is domestic-focused or exporting-focused.

3.3.1. Size

Before starting this section and the next one, I would like to say that I will follow the structure of the previous sections, but now comparing the domestic and foreign shipments inside, beginning with domestic first, secondly the foreign and finally making the comparison in the last paragraph of the section. So, in the next figure, we will see the OLS calculation for the domestic units sold:

```
Model 1: MQO, emprant les observacions 2012:1-2017:4 (T = 24)
Variable dependent: Domestic_Units
Desviacions típiques HAC, amb amplada de banda 2 (Kernel de Bartlett)
Omeses atesa la col·linealitat exacta: dq4

             Coeficient   Desv. Típica     z       Valor p
  --------------------------------------------------------
  const       5069,34       474,200      10,69    1,13e-026 ***
  time         184,666       31,6336      5,838   5,29e-09  ***
  dq1         1438,83       308,922       4,658   3,20e-06  ***
  dq2         -459,001      284,020      -1,616   0,1061
  dq3          751,666      233,821       3,215   0,0013    ***

Mitj. de la vble. dep.  7810,542   D.T. de la vble. dep.   1588,064
Suma de quad. residus    9650837   D.T. de la regressió    712,6982
R-quadrat               0,833620   R-quadrat ajustat       0,798593
F(4, 19)                36,97125   Valor p (de F)          1,02e-08
Log-versemblança       -188,9085   Criteri d'Akaike        387,8171
Criteri de Schwarz      393,7074   Crit. de Hannan-Quinn   389,3798
rho                     0,657232   Durbin-Watson           0,595131

Sense considerar la constant, el valor p més alt ha estat el de la variable 5 (dq2)
```

Figure 8. OLS model calculation for the Japanese domestic robotics market. **Graphic**: Own elaboration using GRETL. **Source**: JARA

Looking at the model, we can say that the r-square value is equal to 0.83, which means that we can explain the dependent variable, being domestic units, by an 83% of the model. This value is good because it is closer to 1, being similar to the one for the total units.

Per a intervals de confiança 95%, t(19, .0,025) = 2,093

	Domestic_Units	predicció	Desv. Típica	Interval de confiança 95%
2012:1	7762,00	6692,84		
2012:2	6258,00	4979,67		
2012:3	7450,00	6375,01		
2012:4	5992,00	5808,01		
2013:1	6314,00	7431,50		
2013:2	4700,00	5718,34		
2013:3	6360,00	7113,67		
2013:4	5878,00	6546,67		
2014:1	7744,00	8170,17		
2014:2	6401,00	6457,00		
2014:3	7612,00	7852,33		
2014:4	6852,00	7285,33		
2015:1	8800,00	8908,83		
2015:2	7354,00	7195,67		
2015:3	8117,00	8591,00		
2015:4	8212,00	8024,00		
2016:1	10328,00	9647,50		
2016:2	7632,00	7934,33		
2016:3	9290,00	9329,66		
2016:4	8565,00	8762,66		
2017:1	10289,00	10386,16		
2017:2	8613,00	8672,99		
2017:3	10501,00	10068,33		
2017:4	10429,00	9501,33		
2018:1		11124,83	806,948	9435,86 - 12813,79
2018:2		9411,66	755,722	7829,91 - 10993,40
2018:3		10806,99	799,301	9134,04 - 12479,95
2018:4		10239,99	874,321	8410,02 - 12069,97
2019:1		11863,49	860,155	10063,16 - 13663,81
2019:2		10150,32	799,398	8477,16 - 11823,48
2019:3		11545,66	854,941	9756,24 - 13335,07
2019:4		10978,66	947,124	8996,30 - 12961,01
2020:1		12602,15	927,680	10660,50 - 14543,81
2020:2		10888,99	859,640	9089,74 - 12688,23
2020:3		12284,32	924,656	10348,99 - 14219,65
2020:4		11717,32	1030,375	9560,72 - 13873,92

Figure 9. Total and future domestic units sold in the Japanese robotics market. **Table**: Own elaboration using GRETL. **Source**: JARA

Having a look at the JARA reports, in 2012 the Japanese robotics market was capable to sell 27,462 units domestically. The next year, 2013, it decreased significantly, a 15.33%, selling 23,252 robots in Japan. In 2014 it was able to recover rapidly, increasing a 23,04% respect the previous year and reaching an amount of 28,609 robots domestically sold.

For the following year, 2015, experienced a rise not so good as the previous year, a 13.54%, selling 32,483 robot units in Japan. The next two years, 2016 and 2017, the market reached its peak, 35,815 robots for 2016 and 39,832 robots for 2017, having similar rates(10.26% in 2016 respect 2015 and 11.22% in 2017 respect 2016.

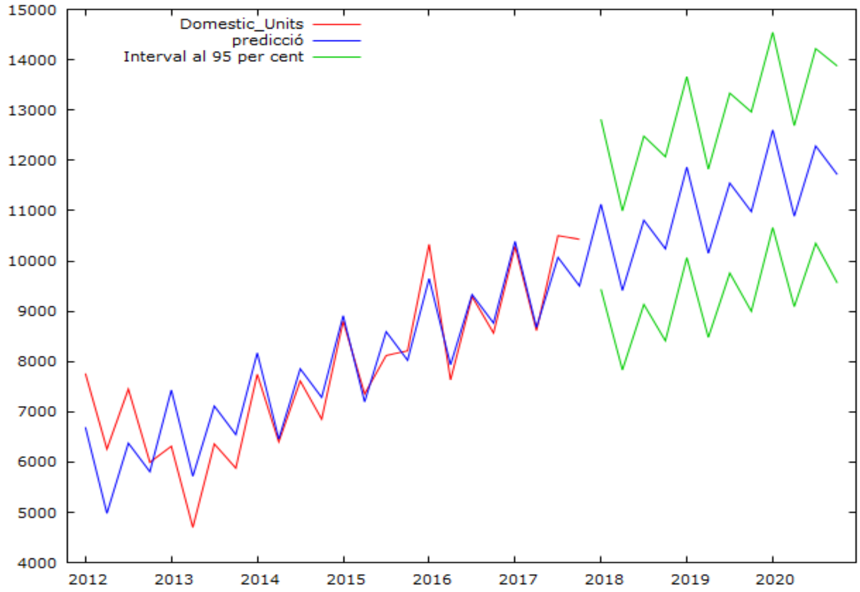

Figure 10. Total and future domestic units sold in the Japanese robotics market. **Graphic**: Own elaboration using GRETL. **Source**: JARA

After the predictions are made, we can see that for the present year, 2018, it will increase a less compared with previous year, a 4.40%, selling 41,583 robots in Japan. For 2019, it will rise a 7.11% from the previous year, establishing a new pick of 44,538 robots sold in the domestic market. Finally, reaching 2020, it will surpass again the previous record, having a 6.63% increase rate, being 47,493 the robots sold in Japan.

Summing up, as the previous calculations, the robotics market for Japan will experience an increasing trend to 2020, despite the seasonality decrease of the last quarter for the year. Subsequently, we will see the OLS calculation for the exports of the Japanese robotics market:

```
Model 1: MQO, emprant les observacions 2012:1-2017:4 (T = 24)
Variable dependent: Export_Units
Desviacions típiques HAC, amb amplada de banda 2 (Kernel de Bartlett)
Omeses atesa la col·linealitat exacta: dq4

             Coeficient   Desv. Típica     z      Valor p
  --------------------------------------------------------
  const      11476,6       2243,68      5,115    3,14e-07 ***
  time        1094,47       187,323     5,843    5,14e-09 ***
  dq1          853,081     1266,82      0,6734   0,5007
  dq2         3919,11      1833,53      2,137    0,0326   **
  dq3         1994,97      1475,89      1,352    0,1765

Mitj. de la vble. dep.  26849,25   D.T. de la vble. dep.   8591,415
Suma de quad. residus   2,98e+08   D.T. de la regressió    3959,457
R-quadrat               0,824544   R-quadrat ajustat       0,787606
F(4, 19)                10,80697   Valor p (de F)          0,000097
Log-versemblança       -230,0638   Criteri d'Akaike        470,1277
Criteri de Schwarz      476,0179   Crit. de Hannan-Quinn   471,6904
rho                     0,792212   Durbin-Watson           0,341622

Sense considerar la constant, el valor p més alt ha estat el de la variable 4 (dq1)
```

Figure 11. OLS model calculation for the Japanese foreign robotics market. **Graphic**: Own elaboration using GRETL. **Source**: JARA

Looking at the model, we can say that he r-square value is equal to 0.82, which means that we can explain the dependent variable, being foreign units, by an 82% of the model. This value is good because it is closer to 1, being closer to the one for the domestic units.

Per a intervals de confiança 95%, t(19, .0,025) = 2,093

	Export_Units	predicció	Desv. Típica	Interval de confiança 95%
2012:1	19252,00	13424,12		
2012:2	20852,00	17584,62		
2012:3	18562,00	16754,95		
2012:4	16056,00	15854,45		
2013:1	16231,00	17802,00		
2013:2	19156,00	21962,50		
2013:3	20468,00	21132,84		
2013:4	20078,00	20232,34		
2014:1	22199,00	22179,89		
2014:2	27215,00	26340,39		
2014:3	25887,00	25510,72		
2014:4	23581,00	24610,22		
2015:1	25148,00	26557,78		
2015:2	28573,00	30718,28		
2015:3	27134,00	29888,61		
2015:4	26025,00	28988,11		
2016:1	26720,00	30935,66		
2016:2	28853,00	35096,16		
2016:3	28390,00	34266,50		
2016:4	32792,00	33366,00		
2017:1	36663,00	35313,55		
2017:2	46527,00	39474,05		
2017:3	45757,00	38644,38		
2017:4	42263,00	37743,88		
2018:1		39691,43	4858,352	29522,78 - 49860,08
2018:2		43851,93	5529,899	32277,72 - 55426,15
2018:3		43022,27	5581,514	31340,02 - 54704,51
2018:4		42121,77	5108,972	31428,57 - 52814,97
2019:1		44069,32	5285,292	33007,08 - 55131,56
2019:2		48229,82	6039,053	35589,94 - 60869,70
2019:3		47400,15	6110,249	34611,25 - 60189,05
2019:4		46499,65	5600,282	34778,13 - 58221,18
2020:1		48447,20	5778,227	36353,24 - 60541,17
2020:2		52607,70	6594,195	38805,90 - 66409,51
2020:3		51778,04	6681,309	37793,90 - 65762,18
2020:4		50877,54	6143,907	38018,19 - 63736,88

Figure 12. Total and future foreign units sold in the Japanese robotics market. **Table**: Own elaboration using GRETL. **Source**: JARA

According to the JARA reports, in 2012 the Japanese robotics market sold 74,722 units outside Japan. The next year, 2013, it increased by a small number, a 1.62%, exporting 75,933 robots. In 2014 it was able to rise significantly, a 30.22% respect 2014, shipping 98,882 robots overseas.

Entering 2015, it experienced an increase, lower compared to the previous year, an 8.09%, selling 106,880 robots as foreign sales. The next year, 2016, the market still increased, with a 9.24%, being 116,755 the robots sold overseas. The last year accounted, which is 2017, the foreign market for Japanese robotics

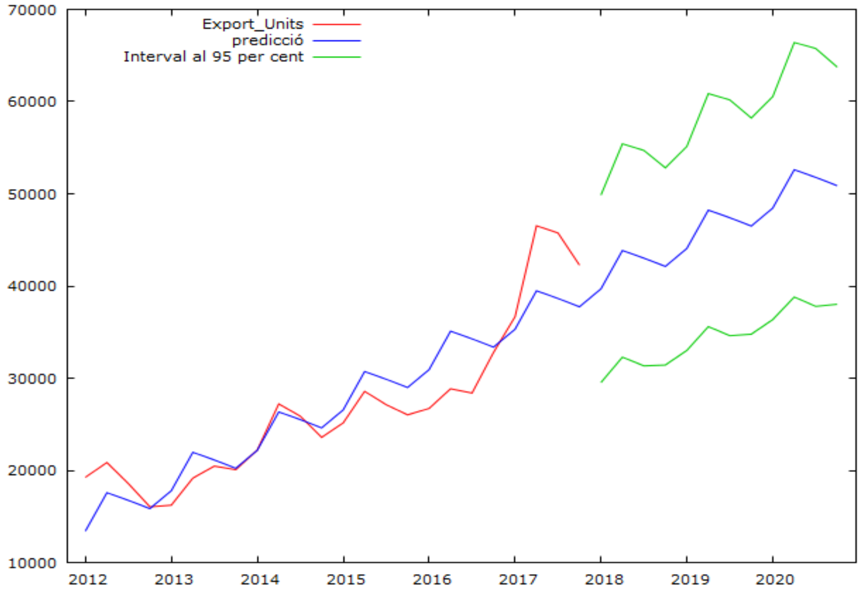

Figure 13. Total and future foreign units sold in the Japanese robotics market. **Graphic**: Own elaboration using GRETL. **Source**: JARA

After the predictions have been carried out, we can see that for 2018, the present year, the exports will account for 168,687 units, decreasing a 1.47% respect 2017. For the following year, 2019, it will recover from the last year's fall rapidly, being 186,199 the robots sold outside Japan, with a rise of 10.38%. The last year predicted, 2020, the foreign market for Japanese robots will set a record of 203,710 robots sold outside Japan, increasing a 9,40%.

To summarize, we can see that the export market for Japanese robotics will increase until 2020, despite the fall of 2018, which can be explained by the seasonality of the last quarter of the year.

Now we will compare the domestic market and the foreign market for Japanese robotics, so I will be able to explain which of the two is the most important. To do so, I will compute the percentages for the domestic and foreign market for the Japanese robotics market for each year, including the predictions, and show the results in a table.

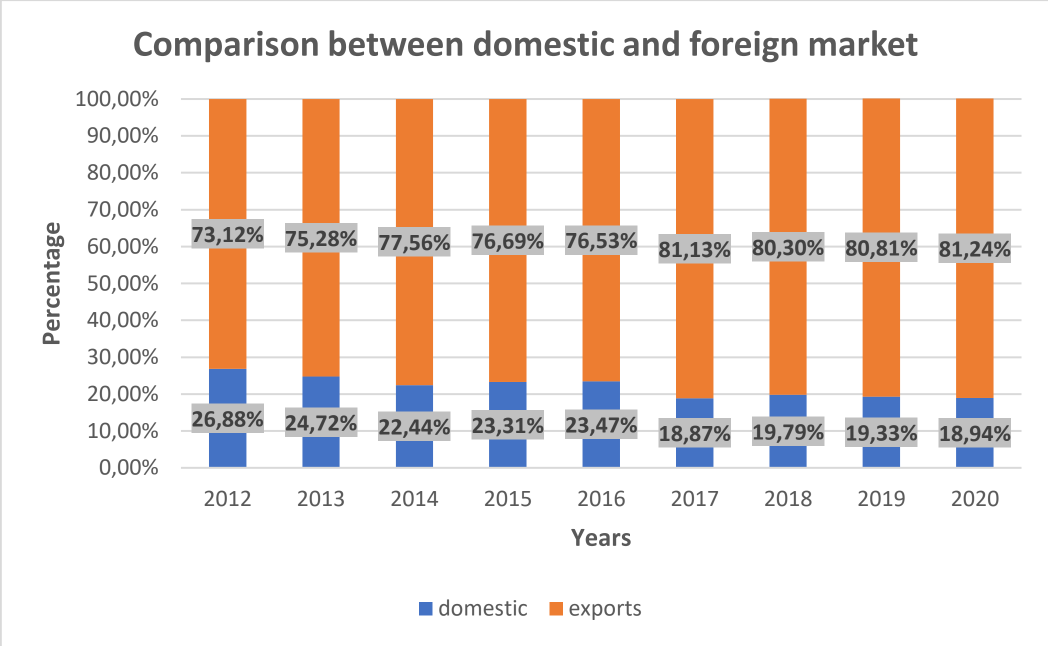

Figure 14. Percentages between the domestic and the foreign market size for Japanese robots.
Graphic: Own elaboration using Microsoft Excel. **Source**: JARA

After calculating the percentages, we can see that the foreign market is the most important part for Japanese robotics. From 2012 to 2020, it will have nearly 3 out of 4 quarters on average of the total market, while the domestic market will only have the rest. To conclude, we can say that the robotics market for Japan is more export oriented.

3.3.2. Revenue

After comparing the robot units sold between Japan and its foreign buyers, now we will compare both parts again but now in terms of revenue. So, as the previous sections, I will compute the OLS calculation for domestic revenue:

```
Model 2: MQO, emprant les observacions 2012:1-2017:4 (T = 24)
Variable dependent: Domestic_Revenue
Desviacions típiques HAC, amb amplada de banda 2 (Kernel de Bartlett)
Omeses atesa la col·linealitat exacta: dq4

             Coeficient    Desv. Típica      z        Valor p
  -----------------------------------------------------------
  const       22814,1       2153,81        10,59    3,23e-026 ***
  time          839,813      139,118        6,037   1,57e-09  ***
  dq1          8633,27      1182,37         7,302   2,84e-013 ***
  dq2         -1067,88      1221,88        -0,8740  0,3821
  dq3          4156,98      1203,99         3,453   0,0006    ***

Mitj. de la vble. dep.   36242,38   D.T. de la vble. dep.    7397,894
Suma de quad. residus    2,00e+08   D.T. de la regressió     3246,535
R-quadrat                0,840907   R-quadrat ajustat        0,807414
F(4, 19)                 47,11627   Valor p (de F)           1,32e-09
Log-versemblança        -225,2994   Criteri d'Akaike         460,5988
Criteri de Schwarz       466,4891   Crit. de Hannan-Quinn    462,1615
rho                      0,668674   Durbin-Watson            0,535127

Sense considerar la constant, el valor p més alt ha estat el de la variable 5 (dq2)
```

Figure 15. OLS model calculation for the Japanese domestic robotics market revenue. **Graphic**: Own elaboration using GRETL. **Source**: JARA

Looking at the OLS model, we can see that the r-square value is equal to 0.84. It means that the model can explain the dependent variable, in this case domestic revenue, by an 84%. This value is good because it is closer to 1, being 5 points higher than the one for the total revenue.

Per a intervals de confiança 95%, t(19, .0,025) = 2,093

	Domestic_Revenue	predicció	Desv. Típica	Interval de confiança 95%
2012:1	37763,00	32287,21		
2012:2	28731,00	23425,88		
2012:3	34795,00	29490,54		
2012:4	26398,00	26173,38		
2013:1	32681,00	35646,46		
2013:2	24823,00	26785,13		
2013:3	29510,00	32849,79		
2013:4	26369,00	29532,63		
2014:1	36073,00	39005,71		
2014:2	25462,00	30144,38		
2014:3	33939,00	36209,04		
2014:4	30072,00	32891,88		
2015:1	41087,00	42364,96		
2015:2	35124,00	33503,63		
2015:3	37480,00	39568,29		
2015:4	38112,00	36251,13		
2016:1	48042,00	45724,21		
2016:2	35981,00	36862,88		
2016:3	43283,00	42927,54		
2016:4	39878,00	39610,38		
2017:1	48466,00	49083,46		
2017:2	40823,00	40222,13		
2017:3	48325,00	46286,79		
2017:4	46600,00	42969,63		
2018:1		52442,71	3593,379	44921,68 - 59963,74
2018:2		43581,37	3519,691	36214,58 - 50948,17
2018:3		49646,04	3617,745	42074,02 - 57218,07
2018:4		46328,88	3926,438	38110,75 - 54547,00
2019:1		55801,96	3814,318	47818,50 - 63785,42
2019:2		46940,62	3721,822	39150,76 - 54730,49
2019:3		53005,29	3845,549	44956,46 - 61054,12
2019:4		49688,13	4234,170	40825,91 - 58550,34
2020:1		59161,21	4099,388	50581,09 - 67741,33
2020:2		50299,87	3991,868	41944,80 - 58654,95
2020:3		56364,54	4136,151	47707,48 - 65021,60
2020:4		53047,38	4588,986	43442,52 - 62652,23

Figure 16. Total and future domestic revenue in the Japanese robotics market. **Table**: Own elaboration using GRETL. **Source**: JARA

According to the JARA reports, for 2012 the domestic revenue was 127,687,000,000 Japanese yen (1,474,751,306,63 US $ for 31/12/2012 exchange rate). The upcoming year, 2013, it experienced a significant decrease, a 11.20% respect 2012, being 113,383,000,000 Japanese yen, the revenue coming from Japan (1,077,009,776.28 US $ for 31/12/2013 exchange rate). It recovered fast for the next year, 2014, being able to have a domestic revenue of 125,546,000,000 Japanese yen (1,048,274,185.66 US $ for 31/12/2014 exchange rate), increasing a 10.73%.

For 2015, the domestic revenue rose significantly, a 20.91% respect the previous year, having earnings of 151,803,000,000 Japanese yen (1,261,816,653.72 US $ for 31/12/2015 exchange rate). For the upcoming years, 2016 and 2017, it increased in a constant mood, 10.14% for 2016 respect 2015 and 10.18% for 2017 respect 2016. The 2016 domestic revenue was 167,190,000,000 Japanese yen (1,429,346,967.47 US $ for 31/12/2016). Finally, the domestic revenue for 2017 accounted an amount of 184,214,000,000 Japanese yen (1,635,079,171.81 US $ for 31/12/2017).

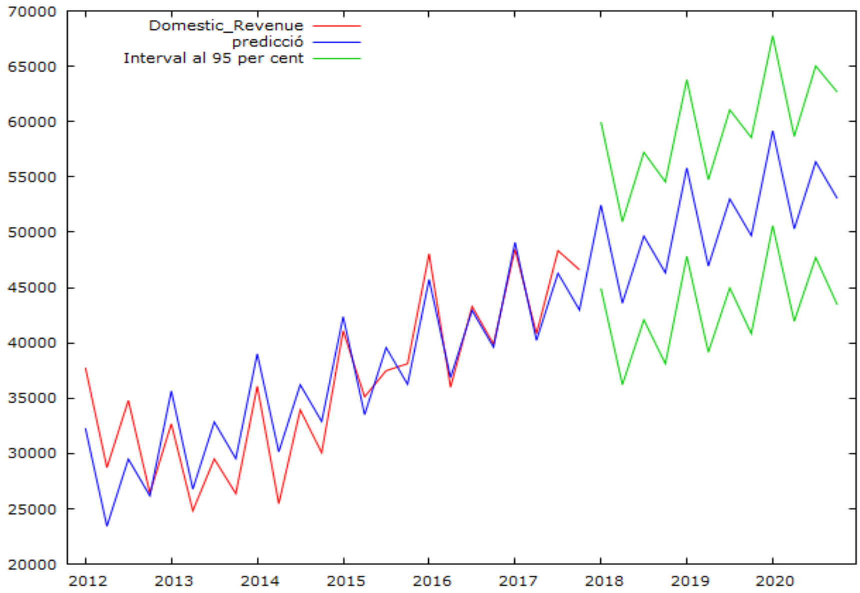

Figure 17. Total and future domestic revenue in the Japanese robotics market. **Graphic**: Own elaboration using GRETL. **Source**: JARA

After running out the predictions with GRETL, we can see that domestic revenue for 2018 will increase a few compared with the previous years, being capable to earn 191,999,000,000 Japanese yen. For the following year, 2019, it will still rise a 7% respect 2018, having earnings for domestic market of 205,436,000,000 Japanese yen. The last year predicted, 2020, it will follow the increasing trend for the previous domestic revenues, a 6.54% respect 2019, being 218,873,000,000 Japanese yen the revenue for that year.

To finalize, we can say that domestic revenue for the Japanese robotics market will have an increasing trend until 2020, despite the seasonality fall for the second quarter of each year accounted and predicted. After seeing domestic revenue, next we will run out the OLS model calculation for the foreign revenue.

```
Model 3: MQO, emprant les observacions 2012:1-2017:4 (T = 24)
Variable dependent: Exports_Revenue
Desviacions típiques HAC, amb amplada de banda 2 (Kernel de Bartlett)
Omeses atesa la col·linealitat exacta: dq4

             Coeficient   Desv. Típica     z       Valor p
  ---------------------------------------------------------
  const       54293,3       6479,79      8,379    5,34e-017 ***
  time         2595,34       542,964     4,780    1,75e-06  ***
  dq1          3192,03      3857,45      0,8275   0,4080
  dq2         12873,0       4798,80      2,683    0,0073    ***
  dq3         10593,2       4585,98      2,310    0,0209    **

Mitj. de la vble. dep.  93399,71   D.T. de la vble. dep.   21660,62
Suma de quad. residus   2,57e+09   D.T. de la regressió    11623,27
R-quadrat               0,762129   R-quadrat ajustat       0,712051
F(4, 19)                9,032246   Valor p (de F)          0,000291
Log-versemblança       -255,9095   Criteri d'Akaike        521,8190
Criteri de Schwarz      527,7093   Crit. de Hannan-Quinn   523,3817
rho                     0,766080   Durbin-Watson           0,377894

Sense considerar la constant, el valor p més alt ha estat el de la variable 4 (dq1)
```

Figure 18. OLS model calculation for the Japanese foreign robotics market revenue. **Graphic**: Own elaboration using GRETL. **Source**: JARA

Seeing the model, the r-square value equals 0.76. It means that we can explain the dependent variable, in our case foreign revenue, by a 76% of the model. This value is positive because is closer to 1 rather than 0, but it has a lower value compared with the total revenue, decreasing 3 points.

Per a intervals de confiança 95%, t(19, .0,025) = 2,093

	Exports_Revenue	predicció	Desv. Típica	Interval de confiança 95%
2012:1	79433,00	60080,72		
2012:2	87781,00	72357,05		
2012:3	74471,00	72672,55		
2012:4	59656,00	64674,72		
2013:1	65194,00	70462,10		
2013:2	75638,00	82738,43		
2013:3	76363,00	83053,93		
2013:4	70465,00	75056,10		
2014:1	80369,00	80843,48		
2014:2	93767,00	93119,81		
2014:3	99514,00	93435,31		
2014:4	85916,00	85437,48		
2015:1	89092,00	91224,86		
2015:2	99779,00	103501,19		
2015:3	97017,00	103816,69		
2015:4	90748,00	95818,86		
2016:1	90059,00	101606,23		
2016:2	97176,00	113882,57		
2016:3	96762,00	114198,07		
2016:4	103974,00	106200,23		
2017:1	112058,00	111987,61		
2017:2	135722,00	124263,95		
2017:3	147629,00	124579,45		
2017:4	133010,00	116581,61		
2018:1		122368,99	13791,735	93502,56 - 151235,43
2018:2		134645,33	14917,395	103422,86 - 165867,79
2018:3		134960,83	16485,167	100456,97 - 169464,68
2018:4		126962,99	15098,317	95361,85 - 158564,13
2019:1		132750,37	14929,691	101502,17 - 163998,57
2019:2		145026,70	16219,613	111078,66 - 178974,74
2019:3		145342,20	18010,061	107646,71 - 183037,69
2019:4		137344,37	16521,565	102764,34 - 171924,40
2020:1		143131,75	16279,228	109058,93 - 177204,57
2020:2		155408,08	17693,415	118375,34 - 192440,83
2020:3		155723,58	19657,003	114581,00 - 196866,16
2020:4		147725,75	18094,170	109854,22 - 185597,28

Figure 19. Total and future foreign revenue in the Japanese robotics market. **Table**: Own elaboration using GRETL. **Source**: JARA

After having a look to the JARA reports, in 2012 the foreign revenue for the Japanese robotics market was 301,341,000,000 Japanese yen (3,480,409,387.72 US $ for 31/12/2012 exchange rate). The following year, 2013, it experienced a decrease of 4.54% respect 2012, being 287,660,000,000 Japanese yen, the revenue coming from outside the Japanese country (2,732,443,419.60 US $ for 31/12/2013 exchange rate). For the next year, 2014, was able to recover quickly, rising a 25% respect 2013, having a foreign revenue of 359,566,000,0000 Japanese yen (3,002,276,104.70 US $ for 31/12/2014 exchange rate).

For 2015, the exports revenue rose less than 2014, a 4.75%, having foreign earnings of 376,636,000,000 Japanese yen (3,130,673,156.58 US $ for 31/12/2015 exchange rate). For the upcoming year, 2016, it increased similarly to 2015, a 3.01%, earning abroad an amount of 387,971,000,000 Japanese yen (3,316,856,105.72 US $ for 31/12/2016). Ending in 2017, the foreing revenue rose significantly respect the previous year, a 36.20%, having earnings of 528,419,000,000 Japanese yen (4,690,234,731.84 US $ for 31/12/2017).

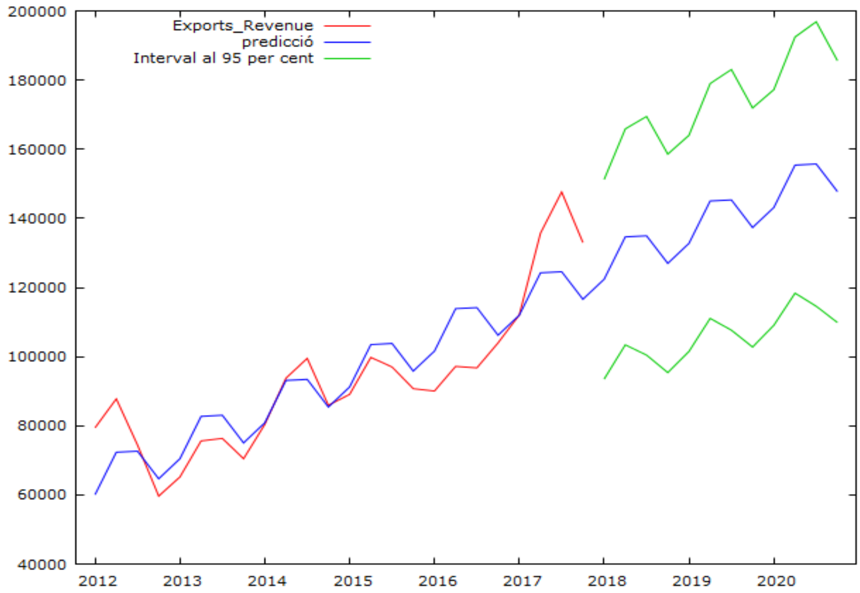

Figure 20. Total and future foreign revenue in the Japanese robotics market. **Graphic**: Own elaboration using GRETL. **Source**: JARA

After the predictions have been calculated, we can say that for the current year, 2018, it will decrease respect 2017, a 1.79%, having an exports revenue of 518,938,140,000 Japanese yen. The following year, 2019, it will recover quickly from that fall, rising an 8%, being the foreign revenue 560,463,640,000 Japanese yen. The last year predicted, 2020, it will an increase similar to 2019, a 7.41%, having earnings of 601,989,160,000 Japanese yen.

To summarize, the foreign revenue for the Japanese robotics market will have an increasing trend, despite the seasonality fall for the second quarter of each year accounted and predicted.

To end up with the section, I will compare both domestic and foreign revenue in order to see which of them is the most important for Japan and its robot market.

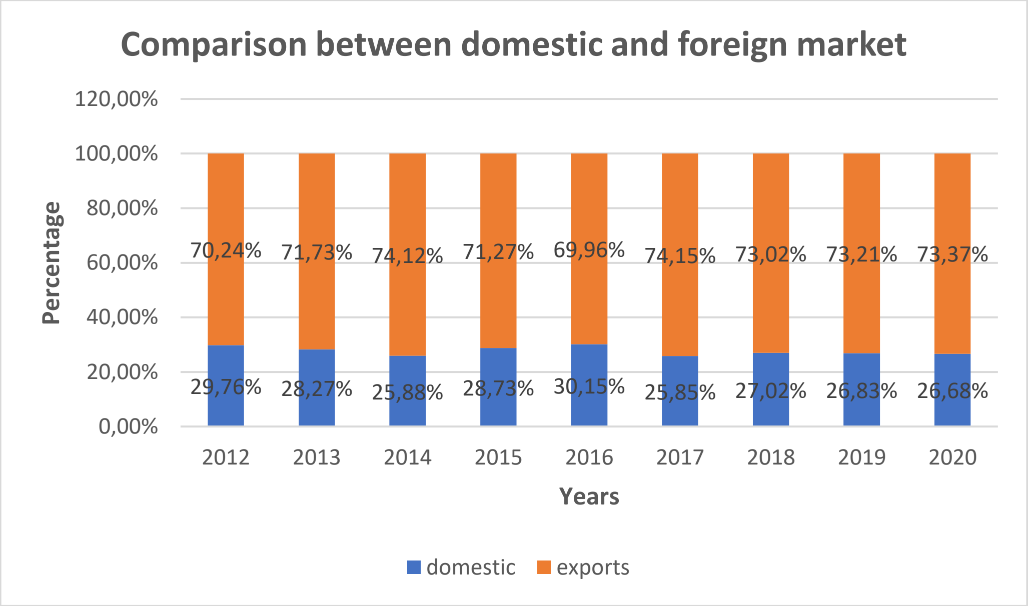

Figure 21. Percentages between the domestic and the foreign market revenue for Japanese robots. **Graphic**: Own elaboration using Microsoft Excel. **Source**: JARA

After computing and compering the percentages, we can see that the foreign revenue is the highest part for Japanese robotics. From 2012 to 2020, it will move between 70% and 74% of the total revenue, while the domestic revenue will be the lowest source of the total revenue, with values moving between 26% and 30% for the period covered. To finish, we can say that the revenues from Japanese robotics market mostly come from foreign countries.

IV. THE FUTURE OUTLOOK OF JAPANESE ROBOTICS

As other countries such as China and the United States, which are investing in a faster pace in the development of robots, Japan is ready to follow them and with some reasons. The first one is that because of its status of "Robotics superpower" it must be an example and face the new challenges for robots which are coming. The second one is that, due to low birth rate and an aging population, robots will have to be used in work fields as well as the daily life routines of the Japanese people. In the following graph we will see of the population of Japan has changed between 1900 and 2016, with further estimates from years 2020, 2030, 2040 and 2050.

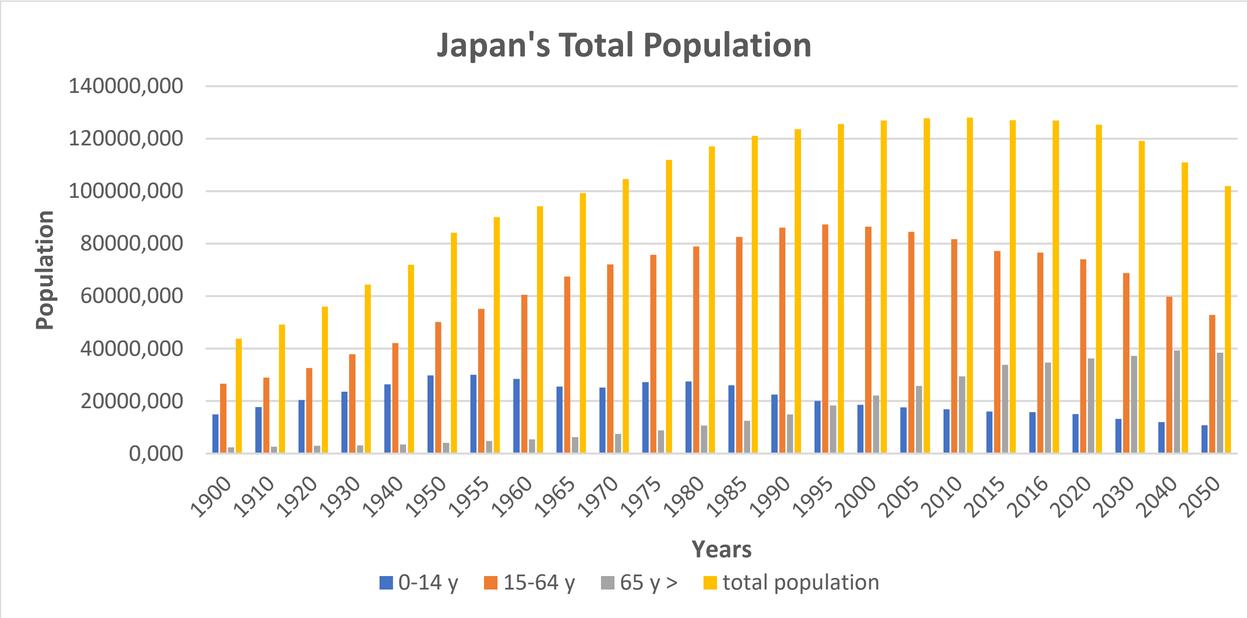

Figure 22. Evolution of the Japanese population between 1900 and 2016, with poster predictions. **Graphic**: Own elaboration using Microsoft Excel. **Source**: Japan Bureau of Statistics

As we can see, the distribution of population by means of age throughout the 116 years analyzed. In 1900, the population between 14 and 64 years old, the active population, was the 60.7% of the total, while the elderly, who had 65 years and more, were only the 5.4%. The younger population, between 0 and 14 years old, was the 33.9%.

As we arrive to the 21st century, in 2000 the things turned back. The active population still was the highest in proportion, with a 68.1%, but then the retired Japanese citizens surpassed the younger population, being the elders a 17.4% and the youth 14.6%. Comparing the year 2000 to 1900, the population of Japan increased nearly by 83 million but the elders in comparison were more compared to 100 year ago.

The last data collected, in 2016, shows us that the elderly population increased its gap with the younger population, being the 27.3% of the total population while youth are the 12.4%. However, the active population is still the highest in proportion with the 60.3% of the total population of Japan. Comparing it with the year 2000, Japan's population only increased by 7 thousand, but nowadays the elderly gained even more presence respect 2000.

The predictions carried out by the Japan Bureau of Statistics show that elderly population will gain more presence in the following years while Japan's total population will decrease, starting from a predicted value of 125,325,000 in 2020, being the elders a 28.9%, to an estimation of 101,923,000 in 2050, representing the elders a 37.7%. The estimated dependency ratio[38] for 2020 will be a 69.20%, being 2050 worst with a 93.24%. To sum up, Japan will find it difficult to pay pensions in the future if it does not do something about it. Now we will see why Japan's population will decrease.

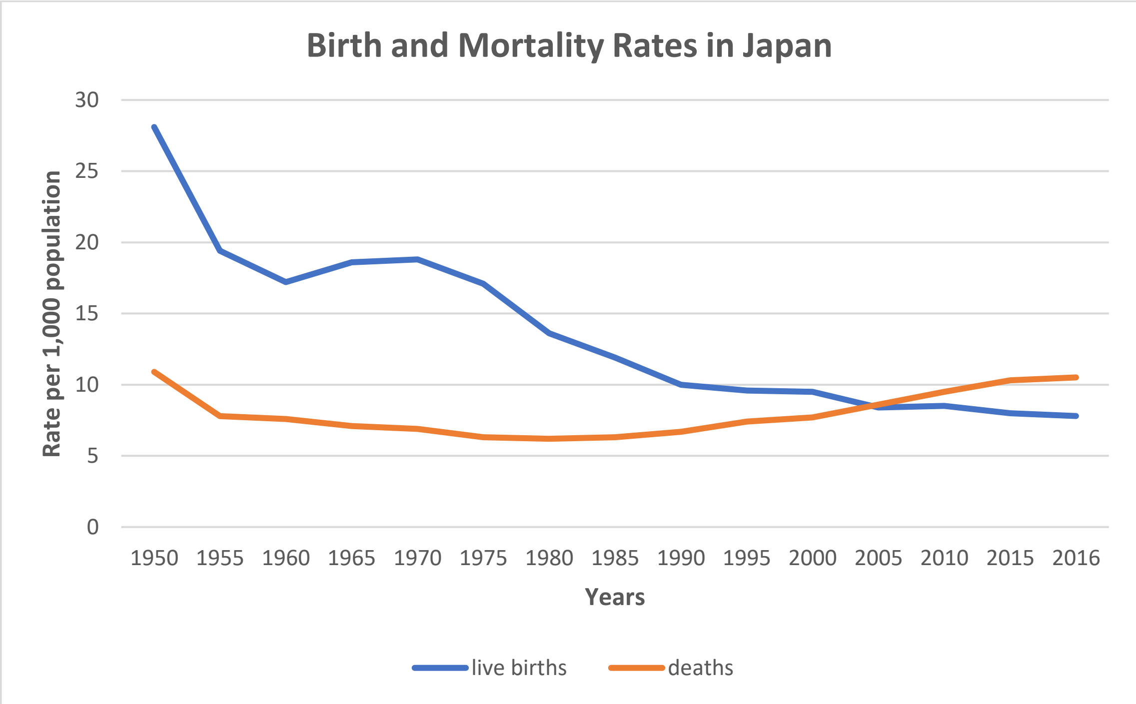

Figure 23. Birth and mortality rates in Japan between 1950 and 2016. **Graphic**: Own elaboration using Microsoft Excel. **Source**: Japan Bureau of Statistics

Looking at the graph we can see that between 1950 and 2000, the births in Japan surpassed the deaths, permitting a steady increase in population. But things changed in 2005, when the deaths surpassed the births, so letting a reduction in population. It seems that this decrease will not stop due to the even higher deaths than births, having a natural change[39] of -2.7 in 2016.

[38] The dependency ratio is a ratio between the non-labour workforce (0-14 and >65 years) and the labour workforce (15-64 years). The lowest value, the better, which means that population can have better pensions and healthcare. The highest value, the worst, which means that there will be difficulties to maintain social security.
[39] The natural change is the difference between the births and deaths within a country in a given year.

One important fact that can explain that there will be more deaths than births soon, alongside the increase in elderly population, is the life expectancy[40]. According to the World Health Organization[41], Japan is the country with the highest life expectancy, with a value of 83.7 years. Next, we will see the evolution of Japan's life expectancy between 1950 and 2015, dividing it between male and female population.

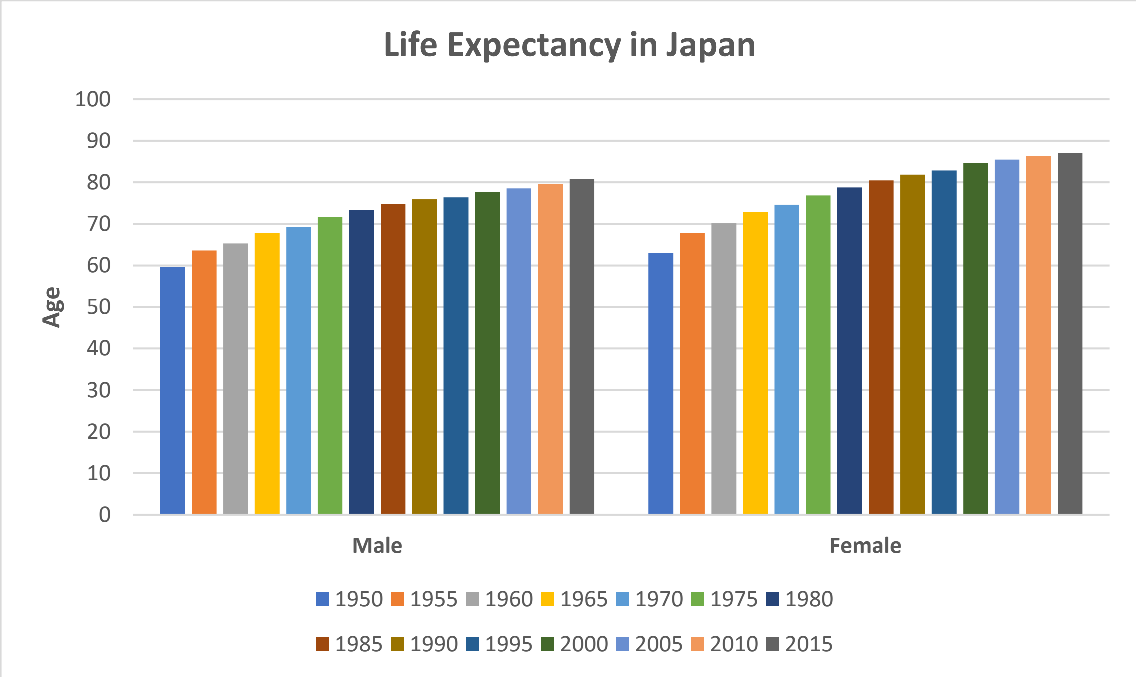

Figure 24. Life expectancy for Japanese male and female between 1950 and 2016. **Graphic**: Own elaboration using Microsoft Excel. **Source**: Japan Bureau of Statistics

Seeing the graph, we can say that female have a higher life expectancy than male in the period covered. In 1950, the men were expected to live 59.67 years while the women had it around 62.97 years. In the last year covered, 2015, Japanese men increased its life expectancy by more than 20 years, being 80.79 the years lived, while Japanese women also increased it by approximately 24 years, being 87.05 the years lived. This increase can be explained with having a good public health system and eating a good diet[42].

[40] The life expectancy is a measure that calculates the expected life of an individual, taking into account the gender and other factors.

[41] See WHO notice: http://www.who.int/en/news-room/detail/19-05-2016-life-expectancy-increased-by-5-years-since-2000-but-health-inequalities-persist

[42] See the Guardian news: https://www.theguardian.com/world/2011/aug/30/japan-life-expectancy-factors

4.1. Japan Robot Strategy

Taking into account these problems in the future, Japan needed to do something to counteract this dangerous situation. The Shinzo Abe administration launched the New Robot Strategy in 2015, in order to reverse the situation.

This strategy follows the idea that there must be changes in production of robots. It has to pass from an industrial point of view to an approach that robots have to be present in almost every device we can find, either being cars, consumer electronics and even houses, and also helps in both work areas and daily life matters. Along with the strengthening of international competitiveness, in which the robot has a new value for the society, we will reach the so-called Robot Revolution.

The Robot Revolution will follow three pillars:

1) Global base for robot innovation – Drastic reinforcement of robot creativity: Japan must support innovation via promotion of public-private partnerships, the creation of a link between users and developers/manufacturers, the normalization and standardization of it within the HR and recent technology perspectives of development along with global expansion.
2) World's leading society maximizing robot capacity – Showcasing (realization of daily life with robots): It is necessary for Japan to promote strategic development and employment of robots in almost every sector, from services to agriculture, while reaching a better environment readiness for robots to work.
3) World's leading strategy for a new robot era: Since the actual times are influenced with the usage of big data, which is a source of added value, Japan must set up rules to promote business which are built with bot autonomous data accumulation and its utilization via interconnection with robots, also reaching global standards.

To activate the Robot Revolution, a five-year plan will be put in action. The plan is discussed in two issues:

1) The Cross-Cutting Issues: They include
   a. The foundation of "Robot Revolution Initiative": A foundation called "Robot Revolution Initiative" will be born to promote the usage of robots in actual fields, involving industry, academics and government.
   b. Technology development towards next generation: There is a need to promote R&D (collaboration and information sharing among researchers via workshops, contests…) for core element technologies (AI, sensor and cognition systems…) to win a data drive society.
   c. Policy on Global Standardization of Robotics: It has to be indispensable in order to let expand the robot technology worldwide. It has to fulfil: securement of

compatibility, assurance of quality and safety and establishment of necessary test methods.

d. Field-Testing of Robots: It will lead to a faster development and introduction of robots.
e. HR Development: By fostering software human resource, Japan will have a key in robot utilization. Some examples are: use retired workers to helps in production technical fields, utilization of public job training and integrative curriculum at college levels.
f. Implementation of Robot Related Regulation Reform: Promotion of well-balanced reforms in both deregulation and rule establishment aimed at robot usage, letting to coordinate with government and other regulatory reform bodies and built a robot barrier-free society.
g. Expansion of Robot Award: It will make an impact by permitting excellent cases to be seen in public.
h. Consideration of an Olympic Robot: It will be a good chance for introducing robots to society.

2) The Sectorial Issues: They include
   a. Manufacturing: Promote the usage of robots in labour-intensive work such as processing of parts and assembly, as well as in areas which have been difficult in the past.
   b. Service: Introduce robots in areas such as logistics, wholesale, etc., letting to solve labour shortages
   c. Nursing and medical fields: Help nurses to do their job via nursing robots and spread the utilization of surgical robots and other medical devices.
   d. Infrastructure, disaster response and construction fields: Due to the probably labour shortage in the future, robots will permit to automate tasks and so save labour and have a faster comprehension of the disaster situation.
   e. Agriculture, Forestry, Fishery and Food Industry: Due to the same reason of the previous part, the introduction of GPS automatic navigation in agriculture machines will save labour, and assistant robots which permit to do not so hard work in the field.

4.2. Newest trends in Japanese robotics

The new direction which Japan must take to accomplish the Robot Revolution is clearly enough: develop robots which have to be able to reduce the tasks from the Japanese workforce, take care of the housing issues as well as the elderly and be present in almost every area that we can imagine, from construction to health.

For the principal sector of robotics, the industrial manufacturing, the robot industrial population is increasing to solve the nearer labour shortage, gaining more presence in the assembly lines and clean rooms as well as increasing the quality of the products they are making. One example of this fact is the robots who can take the task of plastic moulding, named take-out robots. They move the plastic from the cooled area to the next process of the chain or into containers to keep it.

Due to the higher increase of the retired population of Japan, many of them have no family to take care of them. So, some robots are being created to solve that problem. The therapeutic robots[43], for instance, helps elders to reduce stress when they are hospitalized while stimulating the social interaction between patients and caregivers. Talking about hospitals, robots which introduce drugs to patients and store medical data are being used. Another example is that transportation robots[44] whose function is to pick up and drop off passengers autonomously.

Some humanoid robots are being introduce to the daily routines of the Japanese people. One example is the robot Pepper, mentioned in Chapter 2. Its main goal is to get along with persons thanks to its interpretation of human emotions, in their respective houses and other typical situations (go shopping, going to the bank…).

But not all robots have to accompany people. They also must be able to save them in situations of risk such as earthquakes, tsunamis and other disasters either natural or artificial. For instance, robots were used during the 11th March 2011, some rescue robots were used to check nuclear installations, removing humans to go there because of risk of radiation. Other robots are under development, with tasks such as supplies' delivery (medical treatments, food…), evacuations of persons…

Finally, some companies will be focused more on RoboTech[45]. Visual sensors will be improved up to the point that will allow robots to perform more advanced operations such as determining where to put a weld, inspecting objects that have been assembled… Servomotors will increase its speed, precision and efficiency ratio, letting to have better robot arms and legs. Cables will have more resistance in fields such oil resistance, heat resistance and so one, and more flexibility to let perform better industrial robots.

[43] Robot PARO is the most common exemple, simulating a sea seal.

[44] Ropits (RObot for Personal Intelligent Transport System) from Hitachi is the most know example.

[45] It is the field which is mainly focused on the components of robots (servomotors, cables, sensors…).

V. CONCLUSIONS

As we have seen through the pages of this paperwork, Japan has had some appreciation to robots from the 17th century, despite their predecessors were not exactly robots. Also, the quality standards which define Japanese works can be seen in the karakuri puppets, putting the finishing touches to every minimal detail. The tasks performed despite being initial put to entertain people, they show some indicators that Japanese citizens began to realize that they have to be in home helping the household, being an example the tea room karakuri.

The first attempts of modernization of Japan gave the necessary information to move a step forward in the developing of robots. Its first robot, *Gakutensoku*, had these technology improvements which come from Western countries, but kept the essence of performing typical tasks in this case the simulation of writing something on a table.

From the last 25 years of the 20th century to the present year, Japanese companies have tried to create a humanoid robot who resembles humans even in its aspect and functioning. The introduction of them in modern day issues, from talking to a person to even be in a visit of the President of the United States of America, is seen as a modernization process.

But the acceptance of robots is also a main indicator that robots in Japan can have coexistence. Japanese citizens who grew seeing the first robot anime to the adults who see the latest ones, they have had a positive point of view on robots, who are seen as equals as them and are able to help them even in the worst situations. The religions also helped to the acceptance since both Shinto and Buddhism see everything having a soul inside, even robots, so gaining the same status for humans.

The Japanese importance on the robotics market is relevant since almost three quarters of the market are focused on exports, meaning that Japanese robots have more presence outside Japan than rather Japan. Foreign companies buy Japanese robots because they see the Japanese tradition on them as well as the perfection to put the best product possible. I would have like to compare the Japanese robotic market with some foreign ones such as China and the United States of America but I have found it difficult to obtain a detailed information similar to the one of the Japanese market, despite it comes from a trade organization rather than an official body.

To maintain this importance in the times to come, Japan is focusing even more in the presence of robots in almost every village, town and Japanese city. The decrease of population as well as the increase of older population, is the point were robots will have to become a relevant part in the workforce of Japan and also to take care of the larger number of elders. To make things easier, some robots are beginning to be introduced in Japan to see how they can work outside its previous specifications.

To end this work, I would like to mention the hypothesis of it: “*to see how the Japanese robots have evolved in time, from its roots to its future”*. I can affirm that I have been able to explain this evolution throughout the pages of the work. I would say that Japan’s greater introduction in workforce to fight against the ageing and decreasing population can be an example for Spain, since is the second country with the largest live expectancy but first it has to resolve the unemployment problem of its youth population.

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