The lack of innovation in the Dutch construction sector through an economic policy point of view

Intermediate report for bachelor final project SI 0BEPS0

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Upper picture on cover: (*Dutch social housing*, 2018)
Lower picture on cover: (Vastgoed Business School, 2019)

Summary

This report researches the lack of innovation in the Dutch construction sector. The Netherlands is facing a housing crises, in a situation with many restricting factors for the construction sector. To be able to build sufficient housing to solve this crisis, innovation in the sector is urgently needed. Simultaneously, however, the Dutch construction sector is very non-innovative and recognized as a conservative sector.

To analyse why this is the case, an economic policy perspective will be used, in which the construction market is analysed from a bird's-eye view. Both intrinsic market failures, as well as regulations that influence the sector will be analysed as potential sources of the lack of innovation.

A theoretical discussion analyses the market qualitatively, using economic policy theory. The result of this discussion is that both the positive externality characteristics of innovation and a number of regulations are together responsible for this lack of innovation.

To compensate for this lack, innovation stimuli are needed. However, the question is if they are effective in the Dutch construction sector to promote innovation. Public procurement is quantitatively analysed as a policy tool to promote innovation, and is found to be effective in the Netherlands.

To further promote innovation in the construction sector, the Dutch government should consider to use public procurement contract awards as leverage, so that the Dutch construction sector becomes more innovative.

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1. Introduction

Innovation is widely considered as one of the most important factors for promoting economic growth and improving societal well-being (Galindo & Méndez-Picazo, 2013). In every sector, innovation takes place that improves the quality of products or the processes to produce them. In different sectors, there are different levels of innovation.

The construction sector has largely and internationally been recognized as a conservative and non-innovative sector, which has been documented in several indicators/proxies for innovative output, such as R&D spending (Xue et al., 2014). Next to these more objective metrics, a lack of innovation can be observed in large parts of the Dutch built environment, with most residential neighbourhoods looking very similar and most residential developments following one of only a handful of designs. This lack of innovation in the Dutch construction sector will be the focal problem in this bachelor end project. The point in time of which the lack of innovation is studied is now, 2021, when the housing crisis is a major topic of public debate and the call for new development in the coming years is high.

The innovation that is present in the construction sector is mostly incremental: better insulation, a small increase in the height of ceilings, or a more material-efficient construction process. More radical innovations in buildings that could be possible, like modular buildings, buildings in other shapes, significantly higher buildings, etc. are all relatively sparse. (Tangkar & Arditi, 2000)

The goal of this BEP is to analyze why this lack of innovation exists, from the point of view of economic policy. The construction sector will be treated as being a free market in the basis, steered by demand for buildings and supply of buildings. This market is then influenced by laws, regulations, and taxes that make it a less free market. From an economic policy view, which will be explained in more detail further in this report, it will be analyzed to what extent there are intrinsic market failures involved in the construction sector that might lead to a lack of innovation. Simultaneously, the economic policy view will be used to critically assess the economic justification for the existing policies, to identify if they act as institutional barriers to innovation.

It will not be possible to analyze all the policies that apply to the construction sector in the Netherlands. There are many different kinds of policies - for example urban planning regulations, financial incentives, sustainability requirements, and safety requirements – that could in principle all be studied in separate papers. Therefore, this research will start with a helicopter view of the types of policies that influence the Dutch construction sector. The effects of these regulations on a free market and their economic justification will be briefly speculated upon, informed by economic policy theory (more specifically, the neoclassical economic approach) and additional resources. After that, one specific policy will be analyzed more elaborately from this perspective, followed by empirical testing of the effects of the policy on innovative output.

The above leads to the following main research question: “Which factors are responsible for the current lack of innovation in the Dutch construction sector, and which regulatory changes would help this situation?”. In this question, the word “factors” represents both existing regulations, which might work as institutional barriers to innovation, and the lack of regulations that are necessary following the neoclassical approach (market failures).

This encompassing question can be divided into the following subquestions:

- Which market failures exist in the Dutch construction sector, and how do they impact innovation in the sector?
- How does the Dutch government address these market failures, and how does this impact innovation in the sector?
- Are there further policies that impact innovation in the sector?
- Are efforts by the Dutch government to promote innovation in the sector effective?

The first three questions will be dealt with in the theory section. In the context of the helicopter view mentioned above, both market failures and policies are seen as possible causes for the lack of innovation in the sector. The theory section will first answer the first question by searching for the existence of all three types of market failures in the sector. For the found market failures, it will be hypothesized what their impact on innovation in the sector could be. Secondly, governments traditionally have the task of correcting market failures. Therefore, for each of the identified market failures, it will be researched how the Dutch government currently addresses them, which will then be compared with the economically most efficient approach, therefore analysing the impact on innovation of these market failure-correcting policies. In this second question, several types of regulations in the construction sector will have been considered. However, many others might still exist that also impact innovation in the sector. Therefore, the theory section will lastly answer the third subquestion by listing other regulations that could have considerable impacts, and explaining how they could have this impact.

The fourth subquestion will be answered in the empirical part of this report. After having analysed the relevant market from a theoretical perspective by answering the first three subquestions in chapter 3, the question remains if current Dutch policy to promote innovation in the sector is actually effective in practice rather than in theory. The variables that will be used in the analysis, the used methods, and the results of the analysis will be dealt with in chapter 4.

The rest of this report will look as follows. In the problem exploration in chapter 2, the problem will be placed into more context: the societal and academic relevance and the relation to sustainability of the research, the ethical issues surrounding the problem, and the stakeholders that are involved in the situation will all be identified and explained. Chapter 3 is the theory section, which will analyse the complete construction market from the neoclassical economic point of view. The first three subquestions explained above will be answered in this chapter. This chapter will be a critical analysis, in which all policy must be justified within the framework of neoclassical economic theory. Even long-established policies will not be taken for granted, in order to have the purest possible theoretical overview of how regulation impacts innovation in the sector.

In chapter 4, the empirical analysis will be introduced, after which every step of the analysis, from determining which variables to analyse towards interpreting the regression results, is explained. Chapter 5 contains the conclusion and discussion, reaching conclusions from the results, critically discussing the approaches and procedures followed in this report, and formulating policy recommendations based on all insights from the report. The report concludes with a bibliography of the references.

2. Problem exploration

In this section, the problem of the lack of innovation in the construction sector will be placed into the broader societal context.

Analysing this lack of innovation has a high social relevance. With the current housing crisis, it is imperative that more houses need to be built. Simultaneously, however, the construction sector faces many challenges: for example, land is scarce in the Netherlands and there are many regulations to comply with (e.g. nitrogen emissions and urban planning restrictions). With these limitations in place, it is crucial that the construction sector innovates, so that the nitrogen emissions of construction projects are lower, more people can fit per m2 of land, and/or buildings help to meet sustainable energy targets. In these and other ways, innovation will help the construction sector to house more people within the current limitations, and to contribute to sustainability.

The analysis in this report also has a high academic relevance. A sizable number of papers have already been published that look at reasons for the lack of innovation in construction (Dewulf et al., 2014; Pries & Dorée, 2005), but it seems that none of them specifically investigates that Dutch construction sector from a purely economic policy-based perspective, but rather from a much broader perspective that includes inner-firm factors and non-economic factors.

The Dutch situation is in itself relatively relevant, because the Netherlands is faced with the limitations described in the paragraph above to a larger extent than many other countries with a lower population density. In addition, studying the construction sector from an (economic) policy-based perspective is important, as it enables to analyse the entire construction market. All in all, this report adds to the literature in the sense that it analyses the lack of innovation in the Dutch construction market from a pure economic policy standpoint.

In relation to technology, the idea of this report is that the level of (technological) innovation in the Dutch construction sector will be the focal variable, but the context in which it is studied is economic. In this way, the report itself is not technical, but it will deal with technical issues in construction, like the promotion of new energy technologies in real estate. The topic of this report is related to sustainability in the sense that much of the innovation that will need to happen in the coming years will be related to sustainability, because of regulations that demand it, as well as intrinsic ambitions by construction companies. Increasing numbers of developers are aiming for sustainability certificates for their buildings, as these increase the value of these properties. Next to decreasing the negative environmental impact of the construction process or the usage of building services afterwards, construction innovation can even help in the broader energy transition, e.g. by incorporating solar panels into designs. As sustainable innovation will be a large part of the innovation that will happen in the construction sector, the recommendations given in this report to stimulate innovation will also contribute to sustainability.

When it comes to normative and ethical issues, this report chooses to take a purely economic perspective on purpose. This report is namely purely aimed at how to stimulate innovation from an economic perspective. As mentioned in the introduction, some of the regulatory changes that will be suggested will inevitably disadvantage certain groups of stakeholders. Loosening a restriction will always give an advantage for the developer, but might be disadvantageous for a part of the neighborhood. These trade-offs are always present. Their societal consequences could be covered in many separate papers, and it is arguably less valuable to say something about them without an elaborate analysis or argumentation. This is the justification for not considering the normative or ethical aspects/consequences of economic policies in this report.

However, even though recommendations in this report will only be justified economically rather than societally or ethically, these recommendations still do have impacts on several groups of stakeholders. The last part of this problem exploration will thus be devoted to shortly recognising the involved stakeholders, which would need to be taken into account in the real-world exercise of implementing the regulatory changes suggested in this report.

Firstly, the construction market itself consists of construction companies. In the Netherlands, some of the largest ones are BAM, Heijmans, VolkerWessels, etc. The demanders of buildings are often real estate investors, firms that will use and own the building themselves, or housing corporations. Investors and housing corporations are in turn steered by the demand from people that will use the buildings: the people that will buy or rent the buildings. Also, a sizable proportion of housing developments are directly sold by the developers to the new owner-occupier.

Lastly, the government has a large role in the construction market: new developments always need to fall within strictly defined urban plans, and often need to be approved by the city council on top of that. The principle here is that the government represents the will of the people living in the same city as the new development, who are affected in some way by the new development. To an increasing extent, people in the neighborhood of new developments are more directly involved themselves, rather than being represented by elected politicians. In an increasing number of municipalities in the Netherlands, developers now need to have a dialogue with the neighborhood in a way approved by the municipality, and the retrieved feedback from these dialogues needs to be seriously taken into account (Cobouw, 2015).

Summarizing this chapter, construction companies are situated in a context of many stakeholders. They are influenced economically by the demand of amongst others investors and housing corporations, and influenced politically by municipal urban plans and the neighbourhood.

3. Theory section

In this theory section, the construction market will be analysed through the lens of the neoclassical approach towards economic policy, so that the first three research subquestion can be answered. In order for a wide audience to be able to follow this theoretical discussion, the neoclassical approach to economic will first be explained underneath. This explanation runs up until heading 3.1., and can be skipped by people with knowledge of market mechanisms and market failures. Section 3.2. will identify market failures in the sector and the Dutch policy response to them. Section 3.3. will evaluate the Dutch government's responses to these market failures. Section 3.4. will list other policies that might affect innovation in the construction sector. Section 3.5. will conclude the theoretical discussion by summarizing the insights retrieved from it, answering the first three research subquestions, and outlining what question the empirical part of the report will need to answer, so that the theoretical and the empirical sections can together answer the main research question in the conclusion of the report.

3.1. The neoclassical approach

The basis of the neoclassical approach is the assumption that a market is held in equilibrium by demand and supply. Demand and supply in a market can be represented in curves, as can be seen in figure 1 below.

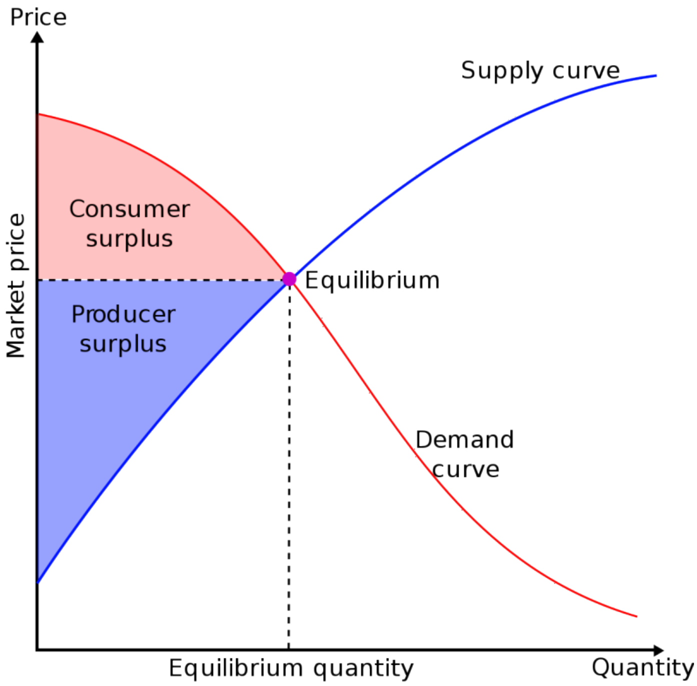


Figure 1: Consumer and producer surplus (Wikipedia contributors, 2006)

Firstly, the two curves will be explained. Curves describe the relationship between the price of a good and the extent to which it is demanded or supplied. Most demanders would like to pay a low price, while most suppliers like to receive a high price for their products, as can be seen in the graph. This conflict in interest unfolds into an agreed-upon price somewhere in the middle, where the highest number of transactions can take place; there is no price at which as many demanders and suppliers still agree with each other to participate in a certain transaction at a certain price. In this situation, the combined surplus of demanders and producers is as high as possible, given the demand and supply curves.

An important principle in this model is that the market regulates itself: when prices get too high, supply becomes higher than demand. In this situation, however, suppliers cannot deliver all their products to demanders, because the number of interested demanders is too low. Therefore, suppliers will decrease their price towards the equilibrium price. In this way, the market automatically steers towards the equilibrium where the largest total surplus is realized and the largest benefits to society are created.

In this view, the free market thus functions perfectly by definition. However, there are three scenarios, also called market failures, in which the above mechanism does not create the highest benefits to society. The first one occurs when the demanders and suppliers depicted above are not the only actors directly influenced by the transaction; there are third parties that are affected, either by damage being done to them, in which case the transaction creates negative externalities, or by being advantaged by the transaction, in which case positive externalities are created. Third parties are in this scenario not compensated for the inflicted damages, but they also do not pay for benefits they might have retrieved from the transaction. This so-called “third party” can also be a party that is involved in the transaction, but then it is affected by another party in the transaction in a way for which no compensation is paid. In this case, it still comes down to damages/benefits to other parties for which no compensation is paid/received.

The second case is when either market party (but most often the suppliers) has too much market power. This is the case in a monopoly, e.g., when the only supplier does not need to be concerned about the prices charged by other suppliers. This sole supplier can charge prices above the equilibrium price while increasing its own profits (the producer surplus). The problem here is that the consumer surplus decreases by a larger amount than the amount by which the producer surplus increases; the total value created for society by this market thus decreases. Below, this is depicted by another graph of a market. MC is the same as the supply curve. The red area is gained as producer surplus because of the above-equilibrium price p*, but the green area is lost because of the lower number of transactions. The demanders only lose in this situation; the consumer surplus decreases by the red and the blue area. In total, the blue and green areas are the lost surplus (called the deadweight loss). This surplus completely disappears in a monopoly situation; the societal value of the transactions that do not happen anymore at the mark-up price is completely lost. Therefore, a monopoly (or other market forms in which there is such a high market concentration that producers can have a significant impact on the market price, such as a duopoly or many oligopolies) is also considered a market failure.

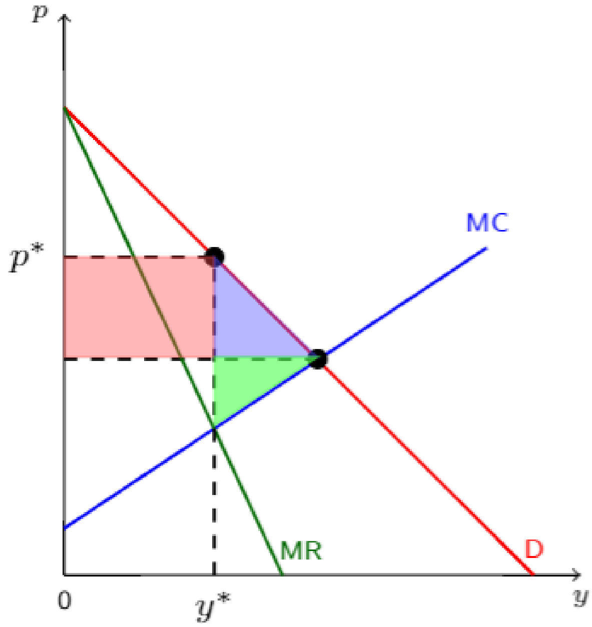


Figure 2: Mark-up pricing (Raiteri, 2020)

The last case in which the free market does not work perfectly, is in the case of public goods. Public goods are all goods for which an effective transaction mechanism can practically not take place. These are goods that are non-rival and non-excludable. Non-rival goods mean that the extent to which one person uses a good does not decrease the extent to which another person uses that good, e.g. national defence. Non-excludable goods means that it is not possible to exclude people from using a certain good, of which national defence is also an example. If both these conditions are met, the neoclassical approach predicts that the market will not be able to supply this good, as there is no(t enough) incentive for it. If society wants these goods to exist, the government would be the actor that can supply it.

An economic theory is only an approximation of reality, and not reality itself. Every theory/model depends on certain assumptions of reality. For the neoclassical approach, these assumptions are threefold (Corporate Finance Institute, 2021):

1. People make choices in a purely rational way.
2. Individuals try to maximize their utility, while companies try to maximize their profits. In terms of the economic equilibrium graph, this can also be simply described as “everyone tries to maximize their own surplus”.
3. People have perfect information.

In reality, these assumptions are not always fulfilled. People can act irrationally, people can have other goals than to maximize their own surplus, and suppliers and demanders often do not have the same information. However, even though not all assumptions might be true all the time, the neoclassical approach is the standard approach in economic science, and will therefore be used in this report as well.

3.2. Market failures

As explained in the introduction, the theory section will start by focussing on the market failures in the Dutch construction market. The existence of the three types of market failures will be considered, after which it is explained if and how they impact innovation in the construction sector. Lastly, the current Dutch government response to each found market failure will be mentioned. In section 3.3., it will then be analysed if this response is economically the most efficient and what the impact on innovation could be. Section 3.2. is thus aimed at answering the first subquestion of this research: “Which market failures exist in the Dutch construction sector, and how do they impact innovation in the sector?”.

3.2.1. Externalities

This section will be divided in firstly negative externalities and then positive externalities. Several negative externalities exist in construction. Mainly, the construction process causes noise pollution and several kinds of emissions. The Dutch way to deal with these externalities is via permits: a certain level of sound is allowed during the construction phase, and limits are set on the emissions that are allowed in a construction process. Via a top-down approach, it is thus determined which level of importunity is allowed.

When finished, a building can be seen from the public space as well. That is, it has an impact on what can be seen from other land than the land owned by the parties that were involved in the transaction that caused the construction of the building. This is thus an externality, but it cannot be objectively defined whether it is negative or positive; a new development might also improve the look of a city. If a building blocks the view of another apartment block, however, the new building presents a negative externality to people in the apartment block. Also, a new development can economically revitalize or further strengthen an urban area. On the contrary, a large residential flat in an area with poor road capacity might cause significant traffic. The influence that buildings have on the rest of the city is dealt with by governments (municipalities) through urban planning, or by government-mandated dialogues between real estate developers and the neighbourhood.

The main positive externality in the Dutch construction sector is not sector-specific: it is when innovation takes place. When new knowledge is created to make innovations possible, it inevitably spreads to other actors than the ones involved in the transaction in question. This advantages these actors, as they can now also introduce the innovation which benefits them in some way. In this way, innovation can also be seen as a public good; others cannot easily be excluded from the knowledge, and the extent to which one person uses knowledge does not directly affect the extent to which other people can use that same knowledge. The knowledge itself is not scarce as multiplying has zero marginal costs. This “public good” nature of innovation/knowledge creation is well-known in policy circles, and there are many ways in which this market failure can be corrected. (Martin & Scott, 2000)

The Dutch government uses many different policy tools to stimulate innovation, also in the construction sector (RVO, 2021). Below is a list of the types of policies that the Netherlands uses to stimulate innovation:

- Intellectual property rights like patents
- Subsidies for innovative projects

- Tax credits for innovative projects
- Public procurement for innovation
- Regulations

3.2.2. Market power concentration

When it comes to market power, the Dutch construction sector is certainly not a monopoly. The two largest Dutch construction companies, the Royal BAM and VolkerWessels, are in fact by far the largest, but these companies do not seem to have a market share significantly over 10% (Bouwend Nederland, 2021; Cobouw, 2020; VolkerWessels, 2019). Consequently, it can be concluded that the level of concentration in the Dutch construction sector is probably not a significant market failure.

3.2.3. Underprovision of public goods

Except for the public good of innovation that has been identified above, other things could be thought of as public goods as well. For example, clean air can be seen as a public good, and a construction process temporarily leads to less clean air. However, this situation might be better described as just a negative externality, when pollution to the air happens.

Likewise, a nicely planned urban environment might be regarded as a public good. People cannot be excluded from enjoying it, as the public space is available to everyone, and the extent to which one person enjoys it does not take away from others. However, the influence that individual buildings have on the quality of the scenery can better be described as an externality is well.

For public goods in construction, it is thus only useful to look at the products delivered: the buildings. In principle, buildings are not public goods. They are rival goods, as the capacity in them is scarce, and they are excludable, e.g. when the building can only be entered by people with a card. Furthermore, the land on which buildings are built is also a private good. Excludability can be achieved with a fence and land is a rival good as well; if one developer uses land for a new building, another developer cannot simultaneously use the same land for a building.

Both buildings and land are thus private goods. However, there is also infrastructure connecting all the buildings: road/rail/other infrastructure on the land, and water/sewage, heating, and power infrastructure under it. A lot of this infrastructure is constructed by construction companies as well. Although the focus of this report is on innovation that is relevant to the construction of buildings, market failures relating to the built environment could all directly or indirectly influence innovation in buildings, as the surrounding infrastructure could be a constraint to buildings in multiple ways.

Infrastructure is in principle excludable, but not rival: one additional person using water infrastructure does in practice not significantly reduce the extent to which other people can use the water infrastructure. However, the water going through this infrastructure is rival, and the same applies to gas, electricity, the heat of district heating systems, and the capacity on roads. Moreover, all of these goods are excludable: if it was not for public policy, the owners of water, power, or other networks could deny access to their systems. From this strict neoclassical perspective, infrastructure does thus also not adhere to a sufficient extent to the conditions for being a public good.

In conclusion, there are no relevant public good related market failures in the construction sector.

3.2.4. Conclusion

Now that it has been established that all market failures relating to the construction sector can be seen as externalities, the following section will only entail government responses to externalities.

3.3. Analysis of policy responses

For the market failures identified above, which are all externalities, the Dutch policy response was mentioned. Underneath, these policy responses will be assessed on how well they fit in the neoclassical approach, and how well they correct the externality according to literature. After this, it is analysed how the Dutch policy impacts innovation, and if the policy could be improved. This section thus aims to answer the second half of the second subquestion: “How does the Dutch government address these market failures, and how does this impact innovation in the sector?”.

The externalities identified in section 3.1.1. were:

- Emissions from the construction process
- Influence of building on scenery
- Influence of building on traffic
- Innovation and knowledge

Ideally, externalities are internalised (Georgakellos, 2010). Sometimes, this is possible in a literal sense. If a steel factory pollutes into a lake that is property of someone else, a contract between them about allowed levels of pollution and possible compensation would internalise the externality: no external parties are affected, because all affected parties participate. This ideal situation is, unfortunately, not always possible. In the case of a large construction project, the developer would need to reach an agreement with each and every household in the area to agree on the importunity that the household accepts and for which compensation. This is impossible. Therefore, in the absence of a better solution, many economists often agree on taxes (e.g. on pollution) that reflect the societal cost of negative externalities as a good solution (Hagmann, 2019). The carbon tax is the example that is receiving the most attention recently. Knowing this, the actual actions of the Dutch government will now be compared to the solution of internalisation.

3.3.1. Emissions and importunity

When it comes to (noise and environmental) pollution inflicted by construction, the government works with permits. This is certainly a way to deal with the problem that guarantees that emissions do not rise too high. However, another option would be to internalize the externalities via taxes. The exact rules are up for debate, but in principle a tax on the amount of nitrogen emissions could be considered, and maybe even on noise. This way, the negative effects of the construction process on the neighbourhood will probably be taken into account more correctly than now. In some cases, this will result in lower emissions: at first, the permit allowed for a certain level of emissions that posed no problem to the developer, while in the new system with the emission taxes the developer allocates more resources towards lowering emissions. If this is a system-wide change, this would lead to more innovation in the construction process: cleaner production methods.

On the other hand, in some cases the new system would lead to more emissions. In that case, the permit in the former system only allowed emission levels at such low levels that they made a certain development completely impossible. In the new system, all levels of emissions are allowed; the developer just needs to pay for it. This might open the door for more types of developments. Again, if this change is system-wide, this would lead to more innovation, as an important limiting factor in creation of innovative, new developments would disappear. The increased level of emissions might be seen as a problem, but economically seen, when the developer is able and willing to pay for it, this means that the additional value of the new development is higher than the additional damage inflicted by emissions, resulting in sum into a higher economic surplus.

Until a carbon tax receives enough political support to be effectively implemented, however, the current system of permits is the best available system to limit the negative externalities of emissions. However, because of the strictly defined limits, innovative developments with too high emissions but also a very high economic value are not possible in this system, limiting innovation.

3.3.2. Influence on scenery

As said above, buildings have an impact on the scenery. Firstly, this externality can impossibly be internalized via contracts with all households that are impacted in this way by the new development. Furthermore, contrary to emissions, it is also very difficult to make an estimation about the tax that a developer would need to pay or the compensation that the developer would need to get from the government in order to correct for the externality. This is probably part of the reason why urban planning is more a political process than an economic process. When there is very high economic demand for new houses in a city, politicians will take this into account in their urban planning vision, but in the end, the urban configuration is dictated by politics rather than economics.

However, the system of urban planning does have very real economic implications. Parameters of what is allowed where are often defined very strictly (color, shape, height, etc.), allowing very little freedom and creativity for the developers. This way, the Dutch urban areas are built full of buildings that fit in very “harmoniously” with the other buildings around it, but it also means that buildings differ from each other to a far lower extent than what would have been possible otherwise.

If urban planning restrictions were less strict and more developments would be allowed, this would increase the variety between new developments and the creativity that developers can put into these buildings. All in all, innovation in building types would increase significantly, to reap the benefits of the new possibilities. Lastly, considering that buildings can also have a positive influence on the scenery, it is also questionable if the current system of relatively narrow possibilities and long procedures is the best way to address externalities, because it might also prevent many buildings with positive externalities from being built.

However, even when alterations to the system of urban planning could possibly be made so that positive and negative externalities in this context are better balanced, some level of urban planning will economically remain necessary. For example, the hypothetical construction of a high factory in the middle of a suburban residential neighbourhood would always lead to enormous societal costs. Some level of urban planning restrictions will thus always need to keep existing, even when it has a potential negative impact on innovation in the construction sector.

3.3.3. Influence on traffic

It is also necessary for the government to deal with the traffic pressures that new buildings put on the road network. Seeing new traffic as an externality that a construction company externalises onto the public space (so onto the government), it is logical that the developer makes a deal with the government about the traffic that may result from the new development. This includes restrictions on the maximum number of people/households that may live/work/shop in the new building, and/or the number of parking spaces that may be included. An alternative could be that the developer needs to pay a tax for the number of persons/households/parking spaces associated with the building, rather than having absolute restrictions imposed by the government.

In theory, this might result in a better equilibrium, as buildings for more people/households can then be built. This might result in more or less traffic (same reasoning as above for the emission taxes), but in principle the final total surplus will always be higher. In practice, however, it would be very difficult to determine how high this tax should be. For many large developments that would cause chaos in traffic, the societal cost would probably be significant yet unpredictable, as traffic is very complex. In some less extreme cases, it might be interesting to do research into this idea. In general, however, restrictions on the size of buildings / number of parking spaces seem justified to deal with the externality of buildings on traffic. However, as explained for earlier restriction, this restriction might also limit innovation.

3.3.4. Innovation and knowledge

The last externality (and the last market failure) is the positive externality or public good nature of innovation and knowledge creation. Because innovation can be regarded as either of these two market failures, there are several ways that the neoclassical approach would approve to stimulate innovation. Firstly, attempts can be made to reduce the market failure by making innovation more of a private good. Knowledge cannot be made more rival (because it is inherently non-rival), but it can be made more excludable. The main system that has been set up for this goal is the system of intellectual property rights. Inventors can e.g. patent their invention, which excludes other people not from the knowledge, but at least from the commercial exploitation of that knowledge. Patents are from a theoretical perspective thus completely justified. Going even further - making the knowledge itself excludable - is not a task of the government; inventors can decide for themselves if they want to tell no-one about their invention, and e.g. only do business with other parties after signing a non-disclosure agreement (NDA). (Stiglitz, 1999)

When looking at innovation from the positive externality angle, the goal would be to internalize the societal gains for the innovator. Doing this via contractual arrangements with anyone who benefits from the knowledge would be impossible, since it cannot be known who used the knowledge once it spreads freely, and also impossible concerning the number of involved people. If innovators keep everything secret and work only with NDA's, this would be possible, but once the innovator wants to sell their products to a larger audience, signing an NDA with every benefactor would be impossible. The free market can thus not in all cases internalize the societal benefits of innovations.

As a result of this, innovators need to be compensated in another way for the benefits that they bring society. In this view, all instances in which the government financially rewards innovators are thus economically justified. These programs include public procurement for innovation, R&D subsidies, and R&D tax credits. While all of these are economically justified, empirical data show that some of these programs are more effective at producing successful innovations than others. Garcia-Quevedo (2004) showed that the evidence for the effectiveness of R&D subsidies is not very strong. Hall (2020) showed that the lost tax revenue in R&D tax credit schemes is about equal to the increase in R&D expenditure, making R&D tax credits schemes quite efficient at stimulating innovation. Lastly, increasing numbers of studies find that public procurement for innovation can also be effective at increasing the innovative behaviour of firms (Guerzoni & Raiteri, 2015).

As for alternatives to these specific policies to reward innovators, it would not really be possible to connect a certain financial reward to each invention for which the creator applies for intellectual property rights because it would be impossible for anyone to assess how much value an innovation has added to third parties in total. Therefore, it seems that the current schemes are the most logical / practical ways to reward innovators.

The last policy that was mentioned that the Dutch government uses to stimulate innovation in construction, is to introduce new/stricter standards and regulations, e.g. on the energy consumption of buildings. From an economic perspective, this policy does not really fit well into either making innovation more excludable, nor in compensating innovators for positive externalities, which were the two market failures identified above that would lead to an underprovision of innovation in a free market. Of course, these stricter regulations will force developers to build more sustainable buildings and as a result, negative environmental externalities will decrease. This effect is, however, outside the scope at this moment, amongst others because environmental externalities can also be corrected by internalization, with e.g. a carbon tax. In other words, correcting negative externalities does not need to happen with regulations that just outright ban (part of) the economic activity that causes these externalities. From the neoclassical perspective, there is thus no justification for commanding innovation specifically via regulations.

In this case, however, although an economic justification is not present, standards and regulations can certainly work to promote innovation. For example, research by De Vries (2016) shows that stricter energy norms for the construction of houses leads to more innovation. The resulting innovation is namely “forced”, while this does not mean that this is economically the most efficient way to promote innovation.

3.3.5. Conclusion

In short, the insights of section 3.3. can be summarized as follows. Several restrictions that are aimed at limiting the negative externalities of the construction sector might not have the ideal effect on innovation in the sector, but the existence of these policies is necessary. When it comes to the promotion of the positive externality of innovation in the construction sector, the policy tools of the Dutch government generally seem to be efficient, although the literature on R&D subsidies provides mixed conclusion, and standards and regulations to promote innovation do fit completely in the neoclassical approach, but they do work.

3.4. Other policies

There are still many more policies active in the construction market (or in the housing market with a significant impact on the construction market) that are not yet talked about. This raises the questions: If these policies are not specifically targeted at any market failures, what is the effect of these policies? This section will list the policies that apply to the construction sector or the housing market that have not been considered yet, but that could have an impact on innovation. Thereby, this section answers the third subquestion: “Are there further policies that impact innovation in the sector?”.

To the construction sector, the following laws and regulations apply (Ministerie van Infrastructuur en Waterstaat, 2020):

- Woningwet
- Bouwbesluit
- Reguling Bouwbesluit
- Besluit bodemkwaliteit
- Wet algemene bepalingen omgevingsrecht
- Besluit omgevingsrecht
- Ministriële regeling omgevingsrecht
- Standards for construction products (EU)
- Guidelines on energy performance of buildings (EU)

All of these are large documents consisting of hundreds or thousands of rules and regulations, all of which an own paragraph could be written about. Because this is not doable, the regulations/fees/programs/procedures/etc. will be handled more categorically. Every category of regulations will first be introduced, after which they are analysed from the neoclassical perspective and the likely influence on construction innovation is discussed.

<u>Mandatory services per building</u>
Starting at the building itself, each building needs to include a number of services, like a bedroom, a bathroom, water, electricity, etc. Also, in order to count as e.g. a bathroom, the room should be at minimum a certain number of square meters. These regulations exist to guarantee that every person has at least a minimum level of services that are considered to be basic necessities. Without these regulations, people might live in buildings that could

cause many kinds of physical or mental health problems. Economically, these regulations therefore prevent the externality of healthcare costs onto society.

However, the policy might have a negative impact on innovation, as developers are less free to experiment with new kinds of buildings that might not adhere to one of the many regulations of this kind.

<u>Regulations on quality and safety of buildings</u>
Relating to the above type of regulations, regulations on the quality and safety of buildings guarantee that everyone lives, works, etc., in buildings in which the probability of serious building malfunction is very low. The economic justification is therefore also identical to the justification above. However, also the impact on innovation might be similar as above. Certain quality/safety regulations might namely not add very significantly to the safety, but do restrict the types of buildings that are allowed to be built by the authorities. Therefore, a side effect of these regulations might again be that innovation is limited.

<u>Regulations on the style of buildings</u>
Furthermore, there are the regulations on the style of buildings. More and more municipalities are repealing these, but they are still present in many municipalities as well, where so-called “welstandscommissies” (aesthetics committees) of the municipality judge if developments fit the style of the street/district/city they are in. This policy connects to externalities. If a building does not fit within the style of the street, this might be regarded as a negative externality, as it breaks down the character presented by the other buildings, making those buildings worth less than if the building in question would fit their style.

However, this policy might also obstruct more innovative developments, as these regulations per definition disallow buildings that are different from the local status quo, while innovation is by definition based on breaking the status quo. In several ways, it is thus not allowed to innovate in certain areas in municipalities with these committees.

<u>Regulations on the dimensions of buildings</u>
Regulations on buildings dimensions also relate to the firstly mentioned type of policies in this section, namely those connect to mandatory services per building. Just like the first regulation, minimum dimensions that need to be met before a unit is allowed to be a dwelling are justified with the argument of physical and mental health. Also similar to the first policy, experimentation with innovative concepts, like tiny houses, might be limited by these regulations.

On the other hand, maximum dimension are often regulated as well, in the context of urban planning. This is justified as these regulations limit negative externalities such as shadow formation, loss of viewing angles in the city, and too high traffic generation in certain areas if too large buildings are developed. However, this of course limits the possibilities for the development of e.g. innovative, modern skyscrapers, thereby again possibly limiting innovation in the construction sector.

<u>Regulations on the use of buildings</u>
In urban planning, the use of buildings is limited per location. Some areas of the city are destined for living, some for offices, some for industrial activity, etc. Urban planning is

justified as it relates to many externalities. Urban planning might ensure that people live close to their work, or might achieve that it becomes more favourable for people to use public transport rather than a private car. In this way, negative environmental externalities are limited. Furthermore, urban planning can be used to lower the crime rates in urban areas (: https://doi.org/10.1080/02697459.2011.582357). Many more justification than these exist. However, sometimes the possible uses of some buildings are very specifically regulated. For example, innovative concepts like mixed-use buildings, where e.g. residences, offices and other functions are combined, are not allowed in many areas, even though they could increase (sustainable) innovation in the built environment: when people live very close to their work, to do not need to commute to work, saving cars on the road and thereby emissions and noise.

Conclusion of this section

Just like section 3.3., the conclusion of this section is that many regulations exist that are economically justified, but that also have a negative impact on innovation.

3.5. Conclusion of theory section

After explaining the neoclassical approach, the theoretical discussion of this chapter started by searching for market failures in the construction sector that could be the cause of the lack of innovation. Problematic levels of market power concentration and possible underprovision of public goods did not seem to exist is the sector. However, several externalities were found, both negative and positive. The negative externalities included emissions or other sources of importunity in the construction process, and influences of buildings on the scenery and on traffic generation. The most important positive externality was innovation itself, which is therefore underprovided without government intervention.

In theory, the best way to address externalities is by internalizing them. As it turned out that this is not always possible, however, other regulations were concluded to be at least partially necessary to limit the negative externalities. The side effects of these regulations were unfortunately that they also limit innovation. The same reasoning holds for the policies considered in section 3.4.: the existence of these policies is economically justified, but they do have a negative impact on innovation.

To address the positive externality of innovation, the Dutch government implements several tools to promote it, amongst which R&D subsidies and tax credits and public procurement. The literature suggest that most of these policies are effective, but for some of them, the findings are mixed. The identified policies that limit innovation form an even stronger basis for why the government should promote it.

As the Dutch government is using a variety of tools to promote innovation economy-wide, but still the levels of innovative output in the construction sector are low, this might imply that the used tools are less effective for promoting innovation specifically in the construction sector. Therefore, an empirical analysis is needed to research the effectiveness of the government's innovation stimuli in promoting innovation in the Dutch construction sector. This empirical analysis will be conducted in the next chapter.

4. Empirical analysis

In this chapter, the effectiveness of an innovation stimulus policy will be empirically analyses. In section 4.1., it will be discussed which variables can best be used for a data analysis in this report. Section 4.2. summarizes the specific research question that this empirical analysis aims to answer. Section 4.3. summarizes the methods used, including data gathering, data checking, finding the right model for analysis, and assumption checking. Section 4.4. shows and discusses the results or the regression. The discussion and interpretation of these results are is done directly, but strictly after the results were shown without any interpretation. Section 4.5. summarizes the outcomes and insights of this chapter.

4.1. Variables

As described above, the aim of the empirical section is to statistically test the relationship between government policy that is relevant to innovation in the construction sector on the one hand, and the actual innovative output of the sector on the other hand. The former is seen as the most important independent variable, while the latter is the dependent variable under study.

Within the boundaries of the Bachelor End Project, it made most sense to focus on one statistical analysis. In other words, the effect of one policy on innovative output is studied. It is thus needed to find a specific policy that relates to innovation, as well as a specific way to represent innovative output in the construction sector.

4.1.1. Main independent variable

As for the policy, the theory section already gave an overview of all the most important policies that influence innovation in the construction sector. These policies can roughly be divided in the following categories:

- Policies that are intended to counter market failures in the construction sector
- Other policies that also impact innovation in the construction sector

Resulting from the theory section, innovation is:

- Negatively influenced by market failures (innovation as a positive externality and a market failure)
- Negatively influenced by policies that counter other market failures (like urban planning restriction, etc.)
- Negatively influenced by other policies that do not relate to market failures (restrictions on building design, several taxes, etc.)
- Positively influenced by innovation stimuli

Innovation stimuli are classically mostly implemented to counter the first point above. However, since innovation is also negatively impacted by the government policy directly (points 2 and 3), the government may also be expected to provide extra stimuli for innovation in the construction sector to compensate.

In other words, there are globally two kinds of policies for which it may be analysed what the impact on innovation in construction is: “innovation-promoting policies” and “innovation-obstructing policies”. For most of the “innovation-obstructing policies”, it is questionable whether it is realistic to expect that these policies will change significantly in the future, like urban planning regulations, property taxes, etc., because there is a large societal support for it, or because the government simply needs certain revenue streams for public finances. More so, for many of these policies, the theory section hypothesized the effects on innovation, but nothing can be said about how these influences will play out in practice in more detail. For example, nothing is known about how long the delay would be between a change in policy X and a consequential change in innovative output Y. Furthermore, the size of the effects are unknown, as the theory section was purely qualitative. Lastly, data availability is in general a problem for these policies.

For the “innovation-promoting policies”, on the other hand, there is much more documentation on the effects of innovation. From this, it could be reasonably expected that there might also be a relationship between this type of policies and innovation in the Dutch construction sector. Especially when the time lag between X and Y variables are unknown, as well as the fact that many of the innovation-obstructing policies might impact innovation in a rather indirect way, it would be difficult to know whether any relationship between “innovation-obstructing policies” and innovation at all is actually significant, or e.g. caused by confounding variables.

Combining the above arguments, it makes most sense to opt for “innovation-promoting policies” as the main X variable. The policies in the Netherlands that fall in this category were listed earlier in this report:

- Intellectual property rights like patents
- Subsidies for innovative projects
- Tax credits for innovative projects
- Public procurement for innovation
- Regulations

Intellectual property rights provide sizable benefits to innovators, and can therefore be expected to have a very significant positive impact on innovation. However, IPRs have existed in the Netherlands for a relatively long time, and have not changed very significantly recently enough, so that statistical analysis around this policy is probably impossible.

Similar arguments can be made about both subsidies and tax credits. The main Dutch system of R&D tax credits in the WBSO, for which the yearly budget remains virtually the same over time. R&D subsidies also exist in the Netherlands, which is already a reason to expect a lower chance of finding a significant relation with innovation if it exists. Next to this, data availability was also a problem in this category.

As a fourth option, regulations could definitely be expected to have a direct and sizable impact on innovation in the Dutch construction sector. When construction companies are forced to use/not use certain materials e.g., they will need to come up with innovations in their processes that allow them to do so. However, the problem with this category is the specificity of policies. Policies can target very precise phenomena, and even if a certain policy were more global (energy requirements of buildings e.g.), then still the rules will be different for different kinds of buildings, etc., making it impossible to link such a regulation to innovation in the construction industry in general. For this option, there would thus not be enough data on the outcome side (innovative output) to detect a significant relation between the regulation and innovation.

Fortunately, the last option that remains is advantageous. Public procurement for innovation is increasingly applied in the Netherlands, and public procurement is a significant income stream for the construction sector. This holds not only for the construction of infrastructure, but also for the construction of buildings, as tens of percentages of all new construction in the Netherlands is social housing, and social housing associations also order new houses to be built via public tender procedures. Furthermore, the public sector makes up a significant share of the Dutch economy, and the construction of buildings for these activities (schools, hospitals, government buildings) also often happens via procurement.

Therefore, the link between procurement and the construction sector is very strong, and also relatively specific to the construction sectors; for many other industries, the share of revenues coming from procurement is far lower. Like in many sectors, procurement in the construction sector is used to a significant degree to promote innovation. This happens in two ways:

- A tender asks for an innovative solution to a problem for which no solutions currently exists, forcing the tender-receiving party to innovate. This is called public procurement for innovation (PPI). The Dutch government actively implements PPI in many building-construction related tenders to promote innovation in the sector (Cobouw, 2019). An example is the Innova58 project, which requires the A58 highway between Eindhoven and Tilburg to be broadened, but also modernized via several smart technologies. In order for the contract winner to be successful in this project, innovation will be crucial. (Innova58, 2019)
- A tender is not necessarily aimed at innovation, but the procurement process still has innovative spillovers; the tender-receiving party needs to innovate to complete the task, even though the tender was not primarily issued in the context of PPI.

If one of the most significant revenue streams of the construction sector is used by governments as a way to promote innovation, it could be expected that this policy has a significant impact on innovative output in the sector. Furthermore, data on public procurement is easily available to the public, as all tenders, award notices, etc. are collected in publicly available databases. In the European Union, these are collected in the Ted; tenders electronic daily (ted.europa.eu). Combining all these reasons, public procurement is used as the main independent variable in the empirical analysis.

4.1.2. Dependent variable

For the dependent variable, a measure for innovation in the construction sector needs to be found. In general terms, there would be a choice between two categories:

- Innovation input (R&D spending)
- Innovation output (Number of patents or other intellectual property rights)

Since the aim of the empirical section of this report is to find if public procurement actually increases innovation in the construction sector, innovative input is inadequate as a dependent variable. The aim is to find a relation with the end results: more innovation in the sector. A measure of innovative output is thus better.

There are several types of intellectual property rights that measure the innovative output of a sector. The most important ones are patents, trademarks, and copyrights. In creative industries, copyrights are an important tool for protecting new knowledge/ideas. Trademarks are used in many industries, and are mostly associated with brand names. If a company has a new name for a new product (line), the name of it can be protected in order to protect the authenticity of the new product against imitators. Patents mostly apply to (physical) technical artefacts, but they are also used to protect a variety of other inventions, like business models. In this way, copyright, trademarks and patents are issued when new ideas/knowledge/innovations is/are created, and therefore the number of them over time and space can be used to describe trends in innovative output.

Because of the characteristics of the construction sector (very physical and not very marketing-oriented), patents are the most relevant IPR tool to protect innovation in the construction sector. On top of that, the construction sector is one of the sectors in the Netherlands that relatively makes a lot of use of patents (Koenen, 2011). Therefore, the number of patents of the Dutch construction sector will be used as the dependent variable in this analysis.

4.2. Research question

All in all, the specific research question that this empirical part of the report will answer is “Is the volume of public procurement in the Dutch construction sector related to the number of patents that the sector applies for?”. This question serves as the best possible approximation for a BEP to the broader question “Do policies aimed at promoting innovation actually promote innovation in the construction sector?”.

4.3. Method

Note: When the rest of this report mentions patent applications or procurement volume, it means patent applications and procurement that are related to the construction of buildings.

4.3.1. Balanced panel

The main aim of the statistical analysis is thus to test the relationship between public procurement volume and patent applications in the Netherlands over time. It is thus needed to construct a dataset that reports both of these values per year. However, there is a delay between these two variables. If a procurement contract is awarded to a certain company, this company will start a process to meet the demands of the contract. In many cases, this process will require the company to innovate, and many companies will patent their inventions when they do. However, this innovative process might take one to several years. Therefore, for this analysis datasets are required that do not link the volume of procurement of one year to the number of patents of the same year, but rather that link this volume to the number of patent applications one, two, or three years later. Therefore, the statistical analysis will be run for all of these time lags.

Furthermore, patent applications and procurement volumes are not homogeneously distributed over the Netherlands. Some provinces might have higher patent numbers than others, e.g. because of a higher population, a larger economy, a larger construction sector, or other factors that cannot be explained with available data. Therefore, it is also interesting to control for these influences of provinces, by reporting the patent numbers and procurement volume separately per province.

In this way, a balanced data panel is created in which the number of patents and procurement volume are reported for each panel member (in this case, provinces) every year. The number of observations *n* is therefore equal to $n = N * T$, where *N* is the number of panel members and *T* is the number of periods (years). (Wikipedia contributors, 2020)

This balanced panel data will be analysed with a regression analysis. When doing an analysis on panel data, a choice needs to be made between a fixed effects and a random effects model. Fixed effects means that the variables per group are fixed, while in random effects models, the model parameters are random variables. Because in the dataset to be constructed, the value per group is a "group-specific fixed quantity" (wiki), a fixed effects regression model will be run. (Wikipedia contributors, 2020b; Wikipedia contributors, 2021)

4.3.2. Data gathering

The goal is thus to construct a dataset with the following basic structure:

Year	Province	Nr of patents	Public procurement	Several columns for other control variables
1	1			
1	2			
1	3			
…	…			
2	1			
2	2			
2	3			
…	…			
3	1			
3	2			
3	3			
…	…			
…	…			

Both the number of patents and the volume of procurement need to be reported per year and province, along with several control variables that will be handled later. In the base dataset, the number of patents and public procurement are reported in the same year. It will later be discussed how the time lags between them are incorporated.

Per variable, this section will explain the data gathering process.

4.3.2.1. Public procurement

Information about public procurement is, as mentioned earlier, publicly available, to promote transparency in government expenditures. In Europe, public procurement documents (contract awards, award notices, etc.) are collected in the Ted database (Tender electronic daily, at ted.europa.eu).

Public procurement documents are categorized by business sector, then subsectors within it, etc., with many levels to allow for very detailed classifications. This system is called the common procurement vocabulary (CPV), and works with codes for categories. From the level of subsectors onwards, every category has a code. “Construction work” for example, which is a subsector within the category “Construction and Real Estate”, has the code 45000000. This means that all instances of procurement that start with “45” are part of this subsector. One of the “subsubcategories” within this subsector starts with 452 and is called “Works for complete or part construction and civil engineering work”. This still includes infrastructure and other irrelevant types of construction. The CPV code that is finally used in this research is 4521, which is “Building construction work”. The EU offers .csv datafiles that can be used for statistical analysis of the years 2007-2019 (TED, 2021).

After downloading the datasets, they were filtered on CPV codes starting with 4521 and on the Netherlands as the relevant country. Filtering on location in this database is possible in two ways: the location of the public authority that publishes the tender, and the location of the party that is awarded the contract. It was decided to filter both to the Netherlands: The contract winner should be Dutch, as this research is focussed on innovative output in the Dutch economy. The public authority should however also be Dutch, as the conclusions of this report will be targeted at the Dutch government that is not responsible for e.g. German procurement that has Dutch contract winners.

After cleaning and combining the resulting data and removing the irrelevant columns, the result was a database with a row for every award notice, with as columns the year, the location of the award winner, and the procurement volume. Via several Excel tools, the names of the cities of the award winners could be isolated into a separate column. Because this database consisted of too many observations to manually fill in the province of each city, this process was automated. This was done by downloading a CBS database (the Dutch Bureau of Statistics) that includes every city and town in the Netherlands and connects it to its province. Via an Excel “vlookup” function, the city names in the procurement databases could thus be used to create a column with the corresponding provinces.

The result is a database with the columns: year, province, and procurement value. Via a “sumifs” function, the “procurement volume” column of the main dataset could be filled. E.g., for the observation in the main database in which the year is 2007 and the province is Groningen, the procurement column was the sum of the values of all contract awards in the procurement database where the year is 2007 and the province is Groningen. In this way, the procurement variable of the main dataset is defined.

4.3.2.2. Number of patents

For the number of patents, international patent databases could be used. The one used in this research is espacenet.com, which contains the patents from all over the world over more than 100 years. Patents are classified via internationally recognized classification systems. One of them is the CPC: the Cooperative Patent Classification system (European Patent Office, 1970), which is also used by Espacenet.

The classification system uses levels: there are firstly main classifications, after which there are subcategories per main classification, and many levels below it, so that categories can become very specific. The main classification that is relevant to this research is E: fixed constructions. This includes everything that is constructed, including infrastructure, water supply, buildings, etc. Because this report is more focussed on the lack of innovation in the context of buildings rather than e.g. infrastructure, the subcategory E04, that is specifically targeted to buildings, will be used in this analysis. In Espacenet, “cpc=E04” is thus used as a search term, so that all of these patents appear as results. Other filters need to be applied as well. As the aim of this report is to make conclusions about Dutch innovativeness, the filter will be applied that the applicant for the patent (which is the name of the company in question) must be Dutch.

Furthermore, a time filter is needed. Because of the time lag between procurement and patent applications, and because the data availability of procurement is 2007-2019, the relevant years for the patent applications could be 2007-2022, to allow for delays of 0, 1, 2, and 3 years. However, the patent data unfortunately imposes further limits. As the desired dependent variable in this analysis is the number of patent applications, not patent awards, the patents are not filtered on publication date, but on their earliest priority date. This is the date at which the very first document relating to a patent reaches a patent office.

The reason for this choice is that the priority date is the earliest possible data, meaning that it is closer to the date of the contract award of a public tender that eventually led to a patent application. This reduces the time lag between independent and dependent variable to a minimum, so that a potential significant relationship between the two has the highest probability of not getting lost in the data noise.

When it comes to data availability, however, this choice limits the available data further than filtering on publication data would, as the patents published so far in 2021 are already available, but those with the earliest priority in 2021 are not available yet, as they will only become available after they are published.

A second restriction appeared in the process of determining the location of each Dutch E04 patent. Espacenet does not offer a feature to export databases with exact locations of each patent. The location of each patent can be found and linked to a province manually, but this was not possible because of the number of observations. Therefore, it was necessary to use the EPO (European Patent Office) database, which can link patent codes to a location. However, the EPO database did not have as many records in the most recent few years as Espacenet does. From 2017 onwards, there were significant deviations. Therefore, the timespan for patent data was limited to 2007-2016.

With help of the EPO database, the result was a dataset with the columns Year, Patent code, and Location, containing all patents for which a location could be found. As certain patents had several locations, duplicate patent codes needed to be removed. With the same CBS database as was used for the procurement locations, the applicants' locations of the patents were translated to provinces. The patents column in the main dataset was filled via an Excel "countifs" function, so that for each combination of year and province, the patents were counted. In this way, the number of E04 patents per year and province was defined.

4.3.2.3. Control variables

After the above, the result is a balanced panel with the number of applications for e04 patents and the total volume of 4521* public procurement award notices per year and province. A regression could be run on this dataset, to see if these two variables are significantly related, while controlling for potential influences of the provinces and the years. However, it is more useful to include some other control variable before the regression. One assumption of regression analyses is namely that all relevant predictor variables for the outcome variable are included. If this is not the case, there might be confounding variables that make it appear like there is a significant relation, while another omitted variable might have had an influence on both variables, influencing their mutual relationship. Conversely, confounding variables can also hide a significant relationship. When controlling for the confounding variables by including them as predictor variables in the regression, it is guaranteed that these fluctuations over time and space do not influence the relationship between procurement and patents.

The following control variables were identified:

- The sectoral GDP of the construction sector in a province. The size of the sector in a province could be predicted to have an influence on the absolute number of patents applied for by the sector.
- Net population growth in absolute units in a province. Population growth can be expected to be strongly related to demand for new buildings in a province, and therefore also to the number of patents the sector applies for.
- The total number of all patents applied for in a province in a given year, wider than the E patent classification. This variable could indicate the propensity of a province to apply for patents, which could be strongly related to the number of E04 patent applications.

Each of these control variables are reported per year and per province. It is also relevant to mention the time lag between these variables and the outcome variable. The sectoral GDP and population growth are time-wise both linked to the year of procurement. These three variables are namely mostly relevant at the time when the innovative process starts: Procurement is at the start of this process by definition. Population growth can be seen as another metric for the demand for the construction sector, just like public procurement.

Population growth can also lead to new projects in the sector, and can therefore also be linked to the start of the innovative process. Lastly, the provincial GDP of the construction sector can be seen as the "supply" of the construction sector: how large the sector is at this moment. This stands for the economic capacity that currently exists for innovating in the sector. A larger sector means more capacity for starting up (innovative) projects. Therefore, this variable is also linked to the start of the innovative process.

As mentioned, results will be reported for a time lag between procurement and patent applications of 0, 1, 2, and 3 years. To maintain overview over the results, the predictor variables of procurement, sectoral GDP and population growth are placed in the same year. For example, in the case of a delay of 1 year, the 2007 values for these three variables will be linked to the 2008 number of E04 patents.

The third control variable of the above enumeration, the total number of patents per province, will in this case be reported in 2008, alongside with the E04 patents. The propensity of the province to apply for patents can namely be expected to bet predict the number of E04 patent applications in the same year, rather than a later year. The lag between this control variable and the outcome variable is thus zero years.

Now that the control variables and the rationale for including them has been discussed, it still needs to be explained how the data gathering to retrieve them was executed. This will be done underneath.

Sectoral GDP

Via CBS StatLine, a public program for retrieving CBS databases, a database was found that reports several metrics of economic activity per economic sector, year, and province in the Netherlands (CBS, 2021). Results were combined for the required years and incorporated in the main dataset via the “vlookup” command.

Population growth

Similarly to the above, CBS Statline was used to find values for population growth as well (CBS, 2021). A database was found that report amongst others the absolute population growth per year and province. Via a “vlookup” command, these values could be incorporated in the main dataset.

Total number of patent applications

The process behind this control variable was very similar to the process of retrieving the data for the E04 patent applications. Rather than filtering on “cpc=E04”, all categories of patents were included. Because of the very large number of observations and the technical limitations of Espacenet, it was not possible to export a list of all patent codes per year.

Therefore, sampling was needed as a solution. Per priority year, 500 patent codes of patents were exported. For these patents, locations were retrieved from the EPO database. Via the same procedures as for the E04 patents, these data were cleaned, the numbers of patents were counted per year and province, and these were then incorporated in the main dataset. After counting the patents per year and province, however, all found values were multiplied again with the sampling factor. If there were in reality 4000 patents in 2007 and 35 out of the 500 patent applications were in the province of Groningen, then the final number of 2007 patents for Groningen will be *35 * (4000/500) = 280*.

4.3.2.4. Result

After the above, the main dataset for analysis in Stata was completely filled in. In Excel, several columns were shifted one or several years to incorporate the time lags, so that in the case of e.g. a one-year delay, the 2007 procurement volumes are in the same rows as the 2008 patent numbers.

The result is a balanced panel with one outcome variable, one predictor variable that reflects the analysed policy, the years and provinces that will serve as categorical control variables, and three continuous control variables.

4.3.3. Data analysis

Now that the data gathering stage is finished, the completed balanced panel can be analysed using Stata. The available data consists of a numerical dependent variable, and multiple independent variables, some of which are categorical and some of which are numerical. In broad terms, there are two types of analysis in statistics to test the relation between the dependent variable and the independent variables in this case: regression and ANOVA. Since ANOVA is used primarily for finding differences between groups with different experimental conditions in experiments, and regressions are used primarily for finding the relationship between independent and dependent variables in social sciences and many other fields, it is clear that the panel data needs to be analysis with a regression analysis.

There are many kinds of regression analyses. Which one to choose depends firstly on the type of dependent variable. In this research, this is the number of E04 patent applications in a province and year, which is a count variable; the variable is numerical, but discrete rather than continuous.

4.3.3.1. Count regression models

Regressions with count data often use the Poisson regression. However, an important assumption behind this model is that the count data follow a Poisson distribution, which means that the mean of the dependent variable is equal to the variance in the dependent variable. In Stata, it can be seen if this is the case.

In order to be able to follow the Stata output that will follow below, the variable names will first be explained in the table below.

ID	Identification number for each observation in the database
ProcYear	Year of the reported public procurement volume, and thereby also the year of the population growth and the sectoral GDP
ProvNr	The number of a province
RegionNr	The number of a province
ProcVolume	The 4521* public procurement volume
PopGrowth	Population growth in absolute numbers
SectGDP	Sectoral GDP of the construction sector
NrPat	The number of E04 patent applications
PatYear	The year of the E04 patent applications
NrPatTot	The total number of patent application

The Stata output to check the Poisson distribution for the NrPat variable is the following:

```
. sum NrPat, det

                           NrPat
-------------------------------------------------------------

      Percentiles      Smallest
 1%            0              0
 5%            0              0
10%            0              0       Obs                 108
25%            1              0       Sum of wgt.         108

50%          2.5                      Mean           4.296296
                        Largest       Std. dev.      4.646895
75%            6             16
90%           11             16       Variance       21.59363
95%           15             16       Skewness       1.434782
99%           16             21       Kurtosis       4.496113
```

As can be seen, the mean is ~ 4.30 and the variance is ~ 21.59. The variance is approximately five times as high as the mean, which means the data do not follow the Poisson distribution. When the variance is higher than the mean, this is called “overdispersion”. In the case of overdispersion, a negative binomial regression can be used. (Statistics By Jim, 2021)

Lastly, zero-inflated models could be used to analyse count data with many zeroes. However, these models are targeted at situations in which the zeroes in the day have been generated by two separate processes: one in which an activity (e.g. fishing) was undertaken with zero “events” (zero fish caught) as a result, and one in which no activity was undertaken, which therefore results in zero events as well (no fish as the person in question did not go fishing). However, the data in this analysis is not generated by two distinct processes: the economic processes that could result in patents took place in all combinations of provinces and years, and sometimes the number of patents this led to was coincidentally zero. Therefore, zero-inflated models will not be used. (Statistics By Jim, 2021)

4.3.3.2. Data checking

Before running a regression, it is always best to check the data, e.g. for coding errors.

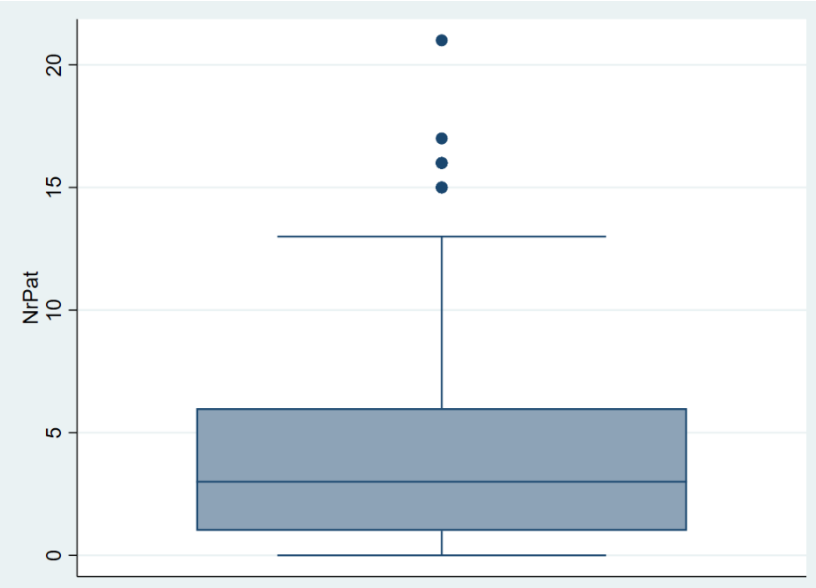
```
. summarize ProcVolume PopGrowth SectGDP NrPat NrPatTot
```

Variable	Obs	Mean	Std. dev.	Min	Max
ProcVolume	120	2.31e+07	4.56e+07	0	4.15e+08
PopGrowth	120	6029.292	7400.201	-4100	27919
SectGDP	120	2426.767	2078.743	328	8843
NrPat	120	4.266667	4.648544	0	21
NrPatTot	120	294.075	453.7896	0	2032

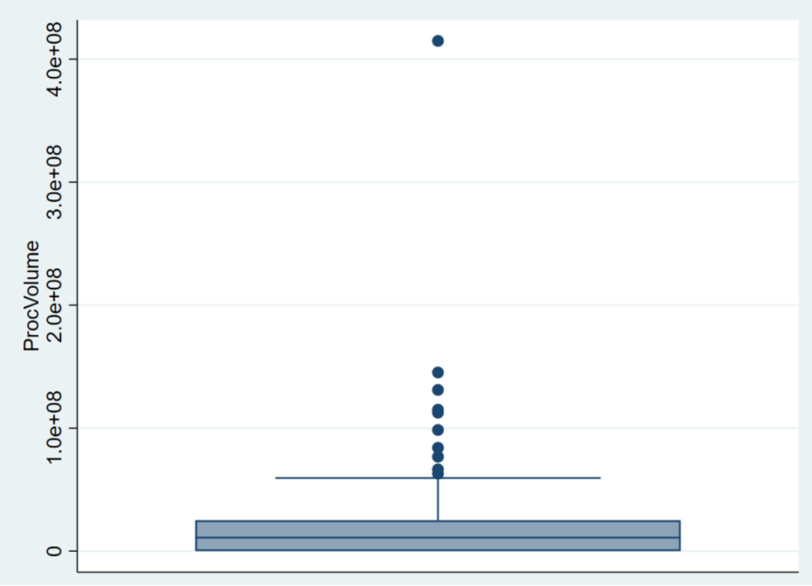
The table above shows some descriptive statistics for the variables. ProcVolume ranges from zero to 415 million euros. It might be the case that in some combinations of year and province, there were no contract awards for the construction of buildings, and it might be the case that in some combinations, several hundreds of millions of euros were spent. This volume might have included one or several large projects. The mean value is 23.1 million euros, and the standard deviation is quite high, which seems logical as some values can become very high. All in all, the ProcVolume values seem logical.

PopGrowth ranges from -4100 tot about 28 thousand. Indeed, the value can be negative, as the population of a province might decrease in a certain year. An increase of 28 thousand in several provinces could also be plausible. The sectoral GDP's are reported in millions of euro's. Construction sector GDP's in different provinces ranging from 328 million to 8.84 billion seems plausible, as the total Dutch GDP of the production sector, averaged over 2007-2016, was approximately 29 billion. A minimum value of 0 for NrPat is plausible, as not every province produces building-related patents every year. A maximum of only 21 is plausible as well, as the E04 classification is quite specific. Finally, the minimum of zero patents for NrPatTot shows that not every province applies for a patent every year, which could as an exception be plausible for some provinces of the Netherlands that have a smaller economy. A maximum of 2032 patents in a provinces in one year also seems plausible. Furthermore, the reported mean and standard deviation values for the variables also seem in proportion with the minimum and maximum values.

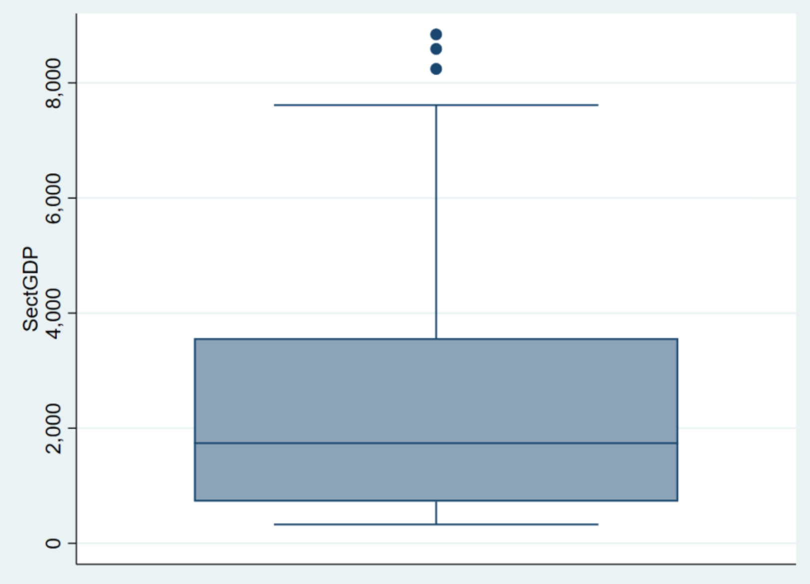
Now that the extreme values of these variables have been considered, the distribution of values between these extremes can best be shown with the use of boxplots.



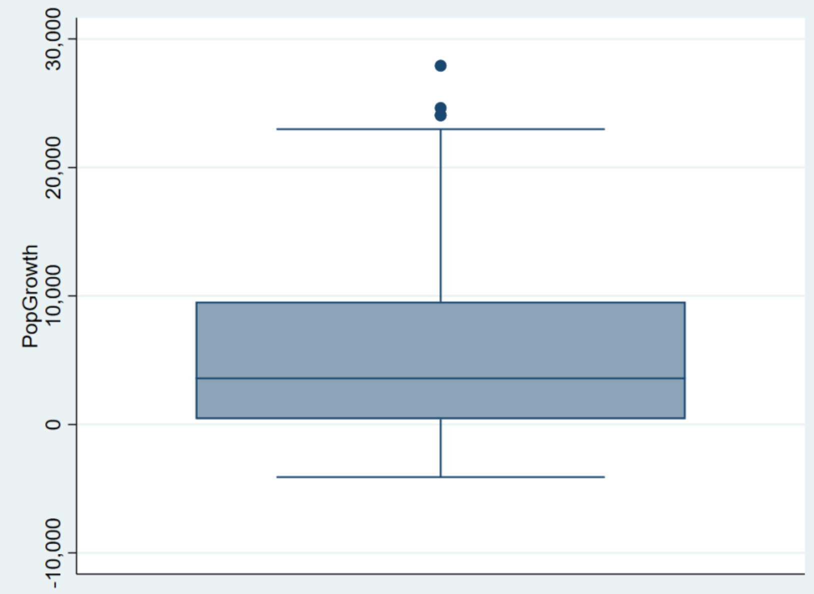
NrPat has a few outliers, but they are not far from the boxplot, so they do not require special attention.



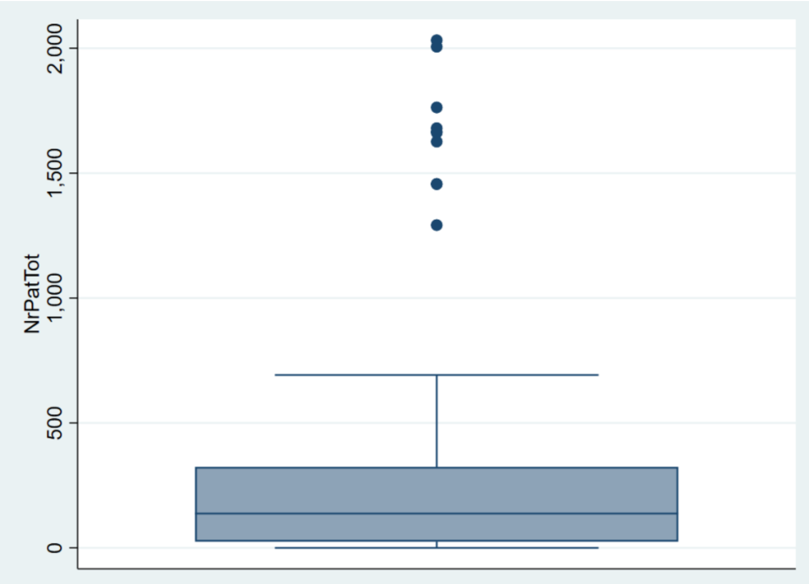
ProcVolume has several outliers relatively close to the boxplot that do not require attention, and one outlier significantly further away, which therefore does need some attention. It turned out that this value is from the most populous province of the Netherlands (Zuid-Holland). As a value of just above 400 billion is only a few times as much as the values below it at around 150 billion, it was decided to keep this value in the dataset, as the value is plausible, and because removing it would make it necessary to remove all values of this province, as otherwise the panel would not be balanced anymore.



SectGDP only has some outliers close to the boxplot, which do not require attention.



For PopGrowth, the same holds as for SectGDP.



NrPatTot has some outliers, but they are not in a complete other order of magnitude. As the values seem plausible, none of the outliers were removed from the dataset.

Overall, the conclusion of the data inspection step is that all data is considered to be of sufficient quality to use for statistical analysis. Coding errors do not seem to be present.

4.3.3.3. Regression

The basic form of the regression to be run is the following:

```
. nbreg NrPat ProcVolume i.ProvNr i.ProcYear SectGDP PopGrowth NrPatTot
```

ProvNr and ProcYear are also included as control variables, because outside of the other three control variables, there might still be explanatory power left in ProvNr and ProcYear; the province of Noord-Brabant might consistently have a higher number of E04 patent applications than other provinces, because of factors that are not taken into account in the model. They are included as categorical variables. For ProvNr, this is logical, since the variable is not even ordinal, but strictly nominal. ProcYear is an ordinal variable, but it still makes more sense to include it as a categorical variable. It is namely unknown what the potential trend of NrPat over the years looks like, and if it is strictly linear. By including the variable as a categorical one, more flexibility is offerded to incorporate time trends, and the statistical results of i.ProcYear do not need to be interpreted anyway; i.ProcYear is only included as a control variable.

4.3.3.4. Regression assumptions

Before showing and interpreting the output of this regression, however, it is necessary to check the assumptions behind regressions first. In principle, there are eight assumptions to check for a regular linear regression model:

1. No multi-collinearity between predictor variables
2. Linear relationships between predictor variables and outcome variable
3. Homoscedasticity
4. Independent errors
5. Errors have a normal distribution
6. All relevant predictor variables are included
7. Not too many non-significant predictors are included
8. Do not include unwanted outliers in the data

Firstly, the Poisson and negative binomial regressions are not normal linear regressions. Rather, they are log-linear regressions, meaning that the log-transformed outcome variable is predicted with non-transformed (linear) predictors. Therefore, assumption 2 of the list above now means that the non-transformed predictors are linearly related to the log-transformed outcome variable, rather than to the non-transformed outcome variable. All information about the assumption of Poisson and nbreg models comes from Stack Exchange (2013).

Assumption 1 is still present. Predictors cannot be too strongly correlated to each other. Assumption 3 is no longer made, while assumptions 4, 5, and 6 are. Assumption 7 is not made in this analysis. It is not common practice in economic science to omit non-significant predictors, as even insignificant control variables still control for minor confounding behaviour that might not be significant because of e.g. the number of observations in the dataset. The statistical results of these control variables is not interpreted, as the variables are only included to isolate influences that these policies could have. Lastly, assumption 8 is also still made.

The Poisson regression would add the Poisson distribution to the list of assumptions, but by using negative binomial rather than Poisson, this assumption is not included anymore.

This results in an updated list of assumptions for negative binomial regression. Each of them will now be tested and/or solved. Some assumptions must be tested separately for each time lag scenario, as the scenarios with a higher lag can incorporate fewer years of the basic dataset.

1. No multi-collinearity between predictor variables

Multi-collinearity can be checked in two ways that complement each other. Firstly, the Stata command for pairwise correlation can be used to check for the correlation between all pairs of predictor variables. For a delay of 1 year, the output looks as follows:

```
. pwcorr ProcVolume SectGDP PopGrowth NrPatTot
```

	ProcVo~e	SectGDP	PopGro~h	NrPatTot
ProcVolume	1.0000			
SectGDP	0.4704	1.0000		
PopGrowth	0.3871	0.8010	1.0000	
NrPatTot	0.3554	0.6232	0.3888	1.0000

A value of 1 means perfect correlation; as can be seen, every variable logically correlates perfectly with itself. Between the pairs of variables, the rule of thumb is that the correlation should not exceed 0.8. This happens very slightly in one instance above, but since this excess is so small, this does not need to be considered a problem. For all time lag scenarios, this process was repeated, and pairwise correlation was never too high, although SectGDP and PopGrowth were always close to 0.8.

Secondly, the command vif can be run after running a regression model. This works only after reg and not after nbreg. For the assumption of no multi-collinearity, however, this does not matter, as only the correlation between the predictors is of importance, which appear in the same format in the reg and nbreg commands. Therefore, it is needed to first run:

```
. reg logpatplus1 ProcVolume SectGDP PopGrowth NrPatTot
```

After this, vif can be run, with the following results:

```
. vif
```

Variable	VIF	1/VIF
SectGDP	4.26	0.234822
PopGrowth	2.96	0.337816
NrPatTot	1.75	0.572187
ProcVolume	1.30	0.771028
Mean VIF	2.57	

For these results, individual VIF values should not exceed 10, while the mean VIF should not exceed 3. This is not the case, and therefore this is an extra check to rule out multi-collinearity between the predictors. This assumption is thus met, and it turned out to be for all other time lags as well.

2. Linear relationships between predictors and log-transformed outcome variable

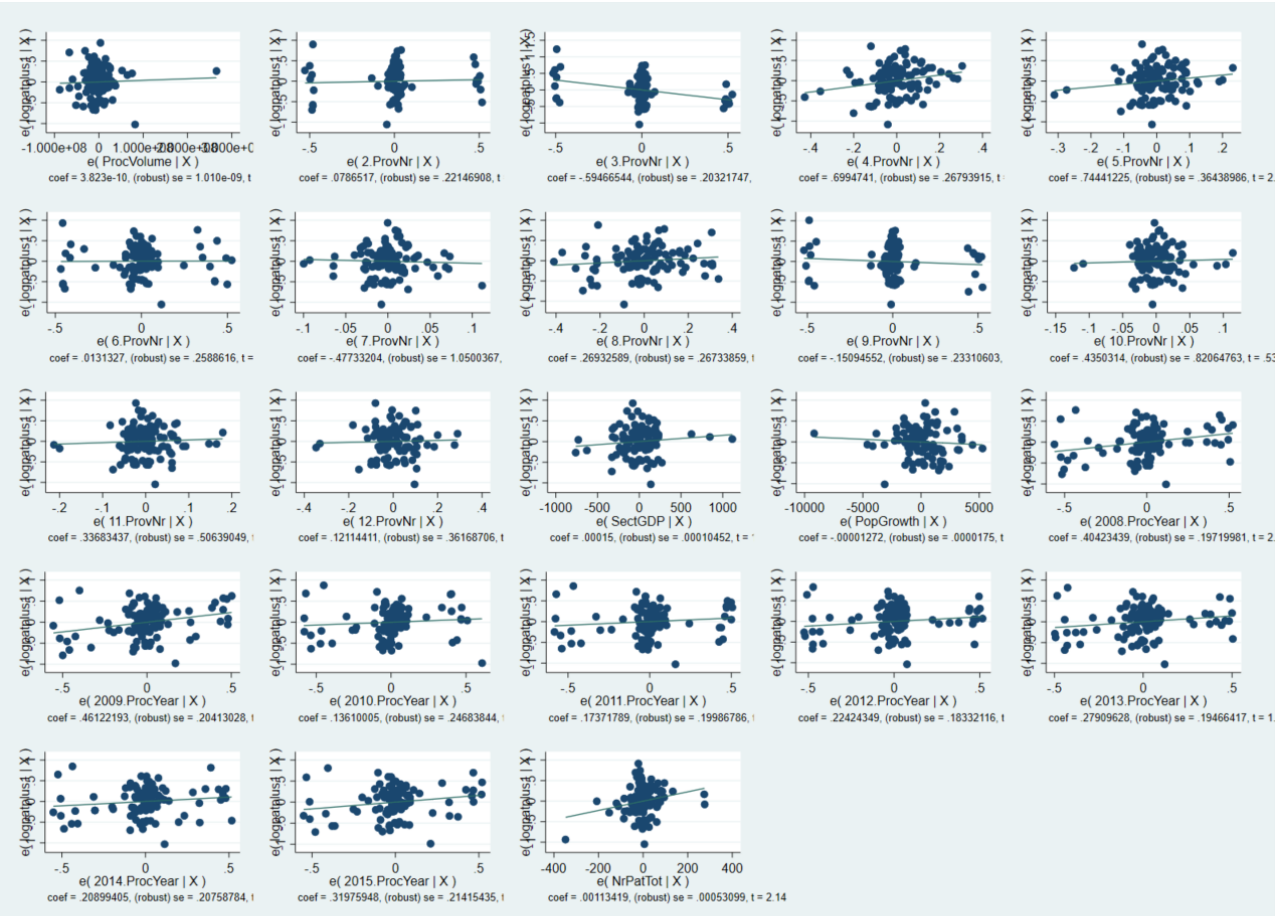
The combination of linear predictor variables should be able to predict the log-transformed outcome variable. Therefore, the relationship between the non-transformed predictor variables and the outcome variable should be linear. There is no Stata command to check if this is the case, but there is a command that makes a plot for each independent variable, plotting the exponent of their values against the exponent of the log-transformed outcome variable. This creates a plot similar to a scatter plot. If the graphs show that another relation than a linear one better fits the shown distribution, the predictors cannot be considered to be linearly related to the outcome variable. This command is called “avplots”. Similarly to the above assumption, this command can be run only after running a regular linear regression.

Contrary to the regression required to run “vif” for assumption 1, for this assumption the transformation of the outcome variable does logically alter the outcomes. Therefore, NrPat has to be log-transformed. Before applying the logarithm to NrPat, each count is increased by one, so that even the observations with zero patents will have a value in the to-be-created “logpatplus1” variable. Log(0) is namely not possible, which would lead to missing values in logpatplus1. Log(1) is possible, and returns 0.

Now that the data have been transformed, it is first required to run the following regression:

```
. reg logpatplus1 ProcVolume i.ProvNr SectGDP PopGrowth i.ProcYear NrPatTot, robust
```

After this, “avplots” could be run. The following is the output:



None of the relations shown above perfectly follow a line, but also none of them shows another relationship to fit the graph better than a linear one. Therefore, the assumption that all predictor variables are linearly related to the log-transformed outcome variable is justified. This was the case for all other time lag scenarios as well.

3. Independent errors

The residuals or errors of one observation should be independent of those of other observations, so that knowledge about the errors of one observation does not have any value in predicting the errors in other observations. This assumption is not justified when working with e.g. time series data, repeated measures from the same individual, etc. Since the balanced panel is both of these ("individuals" being the provinces), this assumption is not justified. With knowledge of the errors of province 4 in the years 2007-2013, it is possible to make a better prediction of the errors in 2014. Once again, there is no way to test this in Stata; the assumption needs to be justified or rejected using logical reasoning.

The assumption is thus rejected for the balanced panel. Fortunately, there is an easy solution for this. By including the option ", robust" after the nbreg command, Stata will use robust standard errors. From this point onwards, the regression analysis thus becomes: "nbreg NrPat ProcVolume i.ProvNr i.ProcYear SectGDP PopGrowth NrPatTot, robust".

4. Normally distributed errors

Besides errors being assumed to be independent, they are also assumed to be distributed normally. However, the robust option is also a solution for errors that are not normally distributed. Therefore, this assumption is not made anymore.

5. All relevant predictor variables are included

All relevant predictor variables seem to be included. An attempt was made to also include the total yearly GDP per province, as the total size of the economy of a province could also be predictive of the number of E04 patent applications, even after controlling for the sectoral GDP per province. In reality, economic sectors are namely not strictly isolated and firms in the construction industry work together with firms in other industries. Therefore, the total provincial GDP could say something about the total economic capacity available, which can amongst others be used for innovative projects.

However, this variable correlated too strongly to SectGDP, and therefore could not be included, as SectGDP was thought to have even more predictive power of NrPat, because of its higher specificity. Therefore, no more predictor variables were added to the regression.

6. Not too many non-significant predictors are included

As explained above, this assumption is not very relevant in economics, as the statistical results for the control variables will not be interpreted and will not be used for prediction. Therefore, in economics all control variables that are included on theoretical grounds can be kept in the regression, even when they are non-significant.

7. Do not include unwanted outliers in the data

In the data checking phase above, boxplots were used to find outliers in the data. It was concluded that all of the values can be expected to be accurate and plausible. Furthermore, it would be difficult to remove individual outliers, as this would make the panel unbalanced. Lastly, a robust regression already ensures that the results are not overly sensitive to outliers (https://en.wikipedia.org/wiki/Robust_regression). Therefore, it was decided to run the regressions on the datasets including all observations in the relevant time windows.

Conclusion
The conclusion of the above is that most assumptions are justified for a regression analysis on the balanced panel, and the solution for the assumptions that are not justified is to include the option “, robust” in the regression command. Now that it is known that running this regression is allowed, the results of it will be shown underneath. They will be translated to conclusions in the conclusion section of this report.

4.4. Results

4.4.1. Regression output

The full results of one of the time lag scenarios (1 year of delay) are presented below as an example, in order to explain which values are relevant to interpret. The picture underneath shows the Stata output concerning the iterative computational procedures used to arrive at the final regression model. There is no need for interpreting these values, as it just shows how Stata arrived at the final model, which is outside the scope of this report.

```
. nbreg NrPat ProcVolume i.ProvNr i.ProcYear SectGDP PopGrowth NrPatTot, robust

Fitting Poisson model:

Iteration 0:   log pseudolikelihood = -185.21705
Iteration 1:   log pseudolikelihood =  -178.1276
Iteration 2:   log pseudolikelihood = -178.03795
Iteration 3:   log pseudolikelihood = -178.03754
Iteration 4:   log pseudolikelihood = -178.03754

Fitting constant-only model:

Iteration 0:   log pseudolikelihood =  -277.1309
Iteration 1:   log pseudolikelihood = -277.13013
Iteration 2:   log pseudolikelihood = -277.13013

Fitting full model:

Iteration 0:   log pseudolikelihood =  -244.4523  (not concave)
Iteration 1:   log pseudolikelihood = -213.84731
Iteration 2:   log pseudolikelihood = -193.80736  (not concave)
Iteration 3:   log pseudolikelihood = -183.20351
Iteration 4:   log pseudolikelihood = -179.05785
Iteration 5:   log pseudolikelihood = -178.22207
Iteration 6:   log pseudolikelihood = -178.07991
Iteration 7:   log pseudolikelihood = -178.04593
Iteration 8:   log pseudolikelihood = -178.03902
Iteration 9:   log pseudolikelihood = -178.03789
Iteration 10:  log pseudolikelihood = -178.03761
Iteration 11:  log pseudolikelihood = -178.03755
Iteration 12:  log pseudolikelihood = -178.03754  (not concave)
Iteration 13:  log pseudolikelihood = -178.03754  (backed up)
```

The picture underneath shows the final regression model. Discussion of the results continuous below the picture.

```
Negative binomial regression                         Number of obs =     108
                                                     Wald chi2(22) =       .
Dispersion: mean                                     Prob > chi2   =       .
Log pseudolikelihood = -178.03754                    Pseudo R2     = 0.3576
```

NrPat	Coefficient	Robust std. err.	z	P>|z|	[95% conf.	interval]
ProcVolume	1.57e-09	6.63e-10	2.37	0.018	2.71e-10	2.87e-09
ProvNr						
2	.0359732	.3433851	0.10	0.917	-.6370493	.7089957
3	-2.408161	.9783303	-2.46	0.014	-4.325653	-.4906689
4	1.02153	.3304185	3.09	0.002	.373922	1.669139
5	1.155853	.388094	2.98	0.003	.3952026	1.916503
6	-.0483563	.4179857	-0.12	0.908	-.8675933	.7708807
7	-.0825838	.9019632	-0.09	0.927	-1.850399	1.685232
8	.4471536	.3316816	1.35	0.178	-.2029304	1.097238
9	-.4497663	.3827982	-1.17	0.240	-1.200037	.3005044
10	.9905011	.699347	1.42	0.157	-.3801938	2.361196
11	.9900009	.5040037	1.96	0.049	.0021717	1.97783
12	.4819181	.4137812	1.16	0.244	-.3290782	1.292914
ProcYear						
2008	.5978173	.1779035	3.36	0.001	.2491328	.9465018
2009	.7207832	.2239933	3.22	0.001	.2817644	1.159802
2010	.5669045	.2543732	2.23	0.026	.0683422	1.065467
2011	.4278791	.1877261	2.28	0.023	.0599426	.7958155
2012	.3337813	.151521	2.20	0.028	.0368055	.630757
2013	.408977	.1761539	2.32	0.020	.0637216	.7542324
2014	.2702632	.2273094	1.19	0.234	-.1752551	.7157815
2015	.471223	.2351088	2.00	0.045	.0104183	.9320278
SectGDP	.0001679	.0000816	2.06	0.040	7.92e-06	.0003278
PopGrowth	-.0000352	.0000135	-2.60	0.009	-.0000617	-8.69e-06
NrPatTot	.0011947	.0004538	2.63	0.008	.0003054	.0020841
_cons	-.3660879	.3841463	-0.95	0.341	-1.119001	.386825
/lnalpha	-17.35949	.1413311			-17.63649	-17.08248
alpha	2.89e-08	4.08e-09			2.19e-08	3.81e-08

4.4.2. Explanation of results

The values above the table with coefficients are mostly outside the scope of this research. The number of observations speaks for itself, while the Pseudo R2 requires explanation. Ordinary Least Squares linear regressions have a standard method of defining the R2, which is a measure for the total predictive power of the model. For other types of regression, like nbreg, there is not one standard measure, as many versions of Pseudo R2 measures have been developed by different researchers (UCLA, n.d.). Pseudo R2 values cannot be interpreted in the same way is the regular R2, and have to be interpreted with more caution

in general because of the relative lack of scientific consensus on the best Pseudo R2 measure.
Stata reports the McFadden's pseudo R-squared, which is ~ 0.358 in this case. McFadden (1977) himself states that a value between 0.2 and 0.4 indicates an excellent fit of the model. Therefore, the Pseudo R2 values suggests that the used model is a good fit to the balanced panel data, at least in the scenario of a one-year time lag. The other values above the coefficients table are outside the scope of this research.

In the coefficients table, NrPat (or rather the log-transformed version of it) is predicted with a function of linear predictors. In other words, Stata attempts to find the best coefficient values to fill into the following equation:

*Log(NrPat) = beta1 * ProcVolume + beta2 * ProvNr2 + … + beta23 * NrPatTot + _cons*

For beta1 e.g., Stata arrived at a coefficient of 1.57e-9, meaning that every extra euro of procurement volume results on average in an increase of 1.57e-9 in log(NrPat). All betas are defined, and for categorical variables, they are separately defined for each category. The variables that represent the categories are called dummy variables, which can only take values of 0 (when the province for which to predict log(NrPat) is not the province number in question) and 1 (for when it is). For example, ProvNr2 in the above equation is 1 when predicting log(NrPat) for a province with ProvNr 2, and zero for all other provinces. In this way, each province has its own beta value. The same holds for the years.

For each of the coefficients, the level of statistical significance is defined in the "P > |z|" column, also called the "p-value". In social sciences, a value is normally considered as being statistically significantly different from zero when the P-value is below a so-called alpha level of 0.05. For these values, it can be concluded they are likely different from zero and thereby "meaningful", while this cannot be concluded for the other values.

It could be interesting to discuss the significance of some of the control variables. However, in the scope of this research, it is only relevant to discuss the significance of the independent variable that represents the policy of interest, which is ProcVolume. As explained earlier, the control variables are included to control for several other (possibly confounding) factors, but they are not the focus of the analysis.

Therefore, it can be concluded that the positive relationship between log(NrPat) and ProcVolume is statistically significant, as its p-value of 0.018 is smaller than the alpha value of 0.05. This is the case after controlling for differences between provinces and years, and for differences in sectoral GDPs, Population growth, and the total number of patents per year and province.

Although not relevant to the aim of this research, interesting findings of the report also include that the sectoral GDP of the construction sector in a province, population growth in a province, and the total number of patents applied for in a province are all statistically significant predictors of the number of E04 patents applied for in that province one year later (for population growth and sectoral GDP) or in the same year (for the total number of patents). Furthermore, after controlling for these three variables and for procurement

volume, there are still provinces and years that show significantly different numbers of E04 patent applications than other years or provinces.
The last values that are relevant to explain are the last two rows: /lnalpha and alpha. /lnalpha is used by the model to calculate alpha, and alpha is a measure of the dispersion parameter (UCLA, n.d.). A positive value means that there is overdispersion, while a value of zero would mean that the mean is equal to the variance, following the Poisson distribution. In this last scenario, the nbreg regression is in effect just a normal Poisson regression.

If the value of alpha is statistically significantly higher than zero, this means there is overdispersion, justifying the choice for the negative binomial regression rather than the Poisson regression. The value given for alpha is 2.89e-08, which is positive, and the difference from zero is also significant, as the 95% confidence interval only includes values above zero. This means that the overdispersion has been statistically verified, which is a stronger justification for the choice for the negative binomial regression than only checking for overdispersion via descriptive statistics, as was done earlier in this report.

4.4.3. Summary of results

The above results only apply to the scenario of 1 year of time lag between the procurement award notices and the patent applications. The table below will summarize the relevant values of the regression for each of the scenarios.

Time lag	Number of observations	Coefficient of ProcVolume	P-value of ProcVolume	Pseudo R2	Alpha	Alpha significant?
0 years	120	1.75e-09	0.001	0.351	3.43e-08	Yes
1 year	108	1.57e-09	0.018	0.358	2.89e-08	Yes
2 years	96	2.43e-10	0.668	0.362	8.92e-11	n.a.
3 years	84	-5.53e-09	0.000	0.381	2.15e-24	n.a.

The above table shows that the relationship between ProcVolume and NrPat is significant in three out of four analyses. However, in the 3-year time lag scenario, the coefficient seems to become negative rather than positive.

More generally, the model seems to show unexpected behaviour from the 2-year scenario onwards. From the 0-year to the 1-year lag, the coefficient of ProcVolume decreases, the p-value increases, the pseudo R2 increases, the alpha decreases, but they all do so in a relatively gentle way. These trends continue from the 1-year scenario into the 2-year scenario and then into the 3-year scenario, but in an increasingly dramatic way.

The p-value reaches extreme values (either high or low), the pseudo R2 increases increasingly steeply, and the alpha seems to asymptotically move towards zero. This is also expected to cause the alpha confidence interval to not be reported anymore either.

After checking for all possible mistakes that could have taken place in the modification of the datasets to incorporate lags, no causes of these trends could be found. It might be the case that the number of observations becomes too low to successfully perform the analysis in the multiple-year time lag scenarios.

One trend that has a practical meaning is the fact that alpha is decreasing towards zero. As explained earlier, this implies that the overdispersion of the data is disappearing, in which case the Poisson regression is the more logical choice over the negative binomial regression. Therefore, the Poisson regression was attempted for the 2-year and 3-year lag scenarios. The results in terms of coefficients and level of significance were however exactly the same.

Therefore, it was decided not to consider the results of the 2-year and 3-year lag scenarios, as they do not seem to be plausible and rather seem to be based on factors that are too complicated to analyze in the scope of this research.

4.4.4. Size of results

The 0-year and 1-year time lag results can also be used for predictions of the outcome variable, to retrieve more insights from them.

After running the nbreg command, the following command can be used to create a table that predicts values of the outcome variable for several values of a predictor variable. As this is the independent variable of interest, ProcVolume is chosen as the predictor variable. Based on the nbreg results, Stata predicts the outcome variable NrPat, taking several values of ProcVolume as input and keeping the rest of the variables at their means. Categorical variables are in this case all kept at a value between 0 and 1, depending on the number of categories. In the command underneath, the extreme values of ProcVolume were taken as extreme values of the prediction, and the interval is chosen such that there are five levels of ProcVolume for which NrPat is predicted.

```
. margins, at(ProcVolume=(0(100000000)400000000))
```

The outcome for the 0-year scenario is the following:

```
Predictive margins                                  Number of obs = 120
Model VCE: Robust

Expression: Predicted number of events, predict()
1._at: ProcVolume =        0
2._at: ProcVolume = 1.00e+08
3._at: ProcVolume = 2.00e+08
4._at: ProcVolume = 3.00e+08
5._at: ProcVolume = 4.00e+08
```

	Margin	Delta-method std. err.	z	P>|z|	[95% conf.	interval]
_at						
1	3.953229	.162982	24.26	0.000	3.63379	4.272668
2	4.710216	.224351	20.99	0.000	4.270496	5.149936
3	5.612155	.5275457	10.64	0.000	4.578184	6.646125
4	6.686802	.9782397	6.84	0.000	4.769487	8.604117
5	7.967229	1.592774	5.00	0.000	4.84545	11.08901

For the 1-year scenario, it is:

```
. margins, at(ProcVolume=(0(100000000)400000000))

Predictive margins                                      Number of obs = 108
Model VCE: Robust

Expression: Predicted number of events, predict()
1._at: ProcVolume =        0
2._at: ProcVolume = 1.00e+08
3._at: ProcVolume = 2.00e+08
4._at: ProcVolume = 3.00e+08
5._at: ProcVolume = 4.00e+08
```

	Margin	Delta-method std. err.	z	P>|z|	[95% conf.	interval]
_at						
1	4.013411	.2045887	19.62	0.000	3.612425	4.414398
2	4.695932	.2089618	22.47	0.000	4.286374	5.105489
3	5.494521	.553644	9.92	0.000	4.409399	6.579644
4	6.428919	1.05868	6.07	0.000	4.353945	8.503894
5	7.522221	1.729683	4.35	0.000	4.132105	10.91234

Following from the above tables, the number of E04 patent applications in a province and year increases 17.2% (from 4.01 to 4.70) when increasing the procurement volume from 0 to 100 million euros in the 1-year scenario, and 19.2% when doing the same for the 0-year scenario. However, the maximum value of 400 million is based on the one outlier in this variable identified earlier. It is not reasonable to expect that the average province in the average year will spend 100 million euro's more on building construction tender in order to increase innovation. Therefore, it is more useful to make these tables at values closer to the mean of ProcVolume.

This mean value is 21.3 million euros, as shown earlier in the descriptive statistics. In order to keep the mean levels of procurement realistic, while also showing the potential effects of increasing it more substantially, a table will be created ranging from zero to twice this mean value, with intervals of 25% of this mean.

```
. margins, at(ProcVolume=(0(5325000)42600000))

Predictive margins                              Number of obs = 108
Model VCE: Robust

Expression: Predicted number of events, predict()
1._at: ProcVolume =        0
2._at: ProcVolume =  5325000
3._at: ProcVolume = 1.07e+07
4._at: ProcVolume = 1.60e+07
5._at: ProcVolume = 2.13e+07
6._at: ProcVolume = 2.66e+07
7._at: ProcVolume = 3.20e+07
8._at: ProcVolume = 3.73e+07
9._at: ProcVolume = 4.26e+07
```

	Margin	Delta-method std. err.	z	P>|z|	[95% conf.	interval]
_at						
1	4.013411	.2045887	19.62	0.000	3.612425	4.414398
2	4.047117	.1959421	20.65	0.000	3.663077	4.431157
3	4.081106	.1876608	21.75	0.000	3.713297	4.448914
4	4.11538	.1798443	22.88	0.000	3.762891	4.467868
5	4.149942	.1726087	24.04	0.000	3.811635	4.488249
6	4.184794	.1660869	25.20	0.000	3.85927	4.510318
7	4.219939	.1604273	26.30	0.000	3.905507	4.534371
8	4.255379	.155789	27.32	0.000	3.950038	4.56072
9	4.291117	.1523343	28.17	0.000	3.992547	4.589687

The above table corresponds to the 1-year time lag. Row 5 represents the current mean. If, hypothetically, the average province in the average year decides to increase their 4521* procurement spending with 25% by increasing it from 21.3 million to 26.6 million euros, this will increase patent applications one year later in this province with 0.84% (from 4.150 to 4.185). Doubling the volume from 21.3 to 42.6 million euro results in an increase of patent applications of 3.4% one year later. These calculations will lead to similar results when using the 0-year database.

This seems like a relatively low result. To increase innovation in the Dutch construction sector with 3.4%, a crude estimate for the extra needed procurement spending is 12 * (42.6 million – 21.3 million) = 256 million euros. It needs to be considered, however, that the results of this regression can be used in a broader sense. Procurement-induced innovation can be expected to happen mostly in procurement contracts with many requirements that require innovation to be met, or by contracts that actively attempt to promote innovation by demanding an innovative solution with certain characteristics. In other words, it is plausible that the innovation-inducive effect of public procurement depends not only on the volume of procurement, but also on the degree to which the contract requirements require innovation to take place.

4.4.5. Wider interpretation of results

It could almost be hypothesized that the innovation-conduciveness of public procurement is a function akin to the following:

$I = R * V$,

with
I = the Innovation-conduciveness of procurement
R = the average extent to which the requirements of the procurement contracts require innovation to take place
V = the procurement Volume

This function is simple, but important to be aware of. *I* is namely not only increased by increasing *V*, but also by increasing *R*. As the data included in the balanced panel in the analysis did not consider the level of *R* of contracts, it can be expected that these values were randomly distributed above and below the average level of *R*. Therefore, *R* can be assumed to have been constant in the above analysis, so that only the relationship between *V* and *I* was considered. Data on the level of *R* per year and province is probably not readily available, making it difficult to incorporate it into a statistical analysis.

However, assuming the above relation to be true, this implies that innovation in the Dutch construction, assuming the 1-year lag, can also be increased with 3.4% by doubling *R* rather than *V*. Furthermore, doubling *R* does not mean that requirements are doubled in every contract. It might namely well be the case that most 4521* procurement contracts at present do not specifically target innovation significantly at all. Assuming a percentage of 10% of contracts that currently require some significant level of innovation, this means that an increase to 50% of contracts having these requirements would already be a five-fold increase of *R*.

With a combination of increasing the percentages of contracts that require innovation, increasing the average level of innovation that these contracts require, and possibly some modest increases in procurement volume as well, it could be imagined that the multiplied effects of these factors might result in an increase in *I* of several tens of percentages. In other words: by combining the tools that governments have to promote innovation via procurement, a very significant contribution could be made to increasing the level of innovation in the Dutch construction sector.

4.5. Conclusion

In conclusion, the empirical part of this report showed that there is a statistically significant positive relationship between the total volume of 4521* procurement in a province and year and the number of E04 patent applications in that province and year. This relationship exists in the period 2007-2016 and 2007-2015 when assuming a time lags of zero years and one year, respectively. This relationship was found after controlling for the differences between provinces, the differences between years, the population growth, the total number of patent applications, and the sectoral GDP in a province and year. All control variables were values of the same year as the procurement year, except for the total number of patents, which consisted of values of the same year as the patent year.

The size of the results were in a strict sense rather small: a large amount of additional procurement volume would increase the number of patents in a minor way. When interpreting the results in a wider sense, however, it turns out that governments could significantly increase innovation via a combination of increasing the share of public tenders that demand an innovative outcome, increasing the level of innovation-inducing contract requirements in these contracts, and potentially modestly increasing the total volume of public procurement.

5. Conclusions and discussion

5.1. Summary and conclusions

In this report, the lack of innovation was analysed using two complementary methods: a theoretical discussion and an empirical analysis. The aim of the research was to answer the following four subquestions using the insights from both methods. Underneath, a summarized version will be given of the answer to each subquestion. A more elaborate answer to each question is provided in the partial conclusions throughout the report.

"Which market failures exist in the Dutch construction sector, and how do they impact innovation in the sector?"
Market failures in the Dutch construction sector involve negative externalities and the positive externality of innovation. The negative externalities themselves have no impact on innovation, while the positive externality would lead to a lack of innovation in a market without government intervention.

"How does the Dutch government address these market failures, and how does this impact innovation in the sector?"
The negative externalities are addressed with policies that do limit them, but that can also have a negative influence on innovation. The positive externality of innovation is addressed with innovation stimuli, such as public procurement.

"Are there further policies that impact innovation in the sector?"
Many other restrictions on the construction of buildings could have a negative influence on innovation as well.

"Are efforts by the Dutch government to promote innovation in the sector effective?"
The total volume of public procurement contract awards related to the construction of buildings in a Dutch province and year is significantly and positively related to the number of building construction related patents and that same province and year, after controlling for several control variables. This relation applies for time lags of zero years and one year between the two variables. The size of this effect can become very significant if governments included more requirements in procurement contracts that induce innovation, and if they would make a larger share of the tenders innovation-related in general.

With the above answers, it is possible to answer the main question of this report:
"Which factors are responsible for the current lack of innovation in the Dutch construction sector, and which regulatory changes would help this situation?"

The short answer to this question would be: "The combination of innovation being a positive externality and the existence of many regulatory restrictions in the construction industry together cause a lack of innovation in the construction sector. The second of these two causes might be the reason why the lack of innovation is more pronounced in the construction sector than in other sectors. Innovation stimuli tools appear as the main regulatory answer to this lack of innovation, amongst which public procurement can be a very effective tool, especially when increasing the level of innovation-related expectations of procurement contracts.

By increasing the innovation-conduciveness of public procurement in the way suggested above, this report could thus provide value to pol

5.2. Discussion

Overall, the research retrieved the desired types of results. It was possible to retrieve all the data necessary for answering the subquestions, and eventually this made it possible to answer the main research question.

However, some parts of this research could have produced better results. The most important factors was the analysis of the balanced panel, which did not produce realistic results for the time lag scenarios of 2 and 3 years. A data availability of more years could have increased the number of observations, which would potentially have enabled the regressions for larger time lags to behave as expected as well.

Alternatively, the panel data could have included more geographic regions, thereby increasing the number of observations. The regions could be parts of provinces, or even municipalities. To have more patent applications per observation, it could be considered to widen the patent classification filters to include all patents of the classification E, for example.

Overall, however, it was possible to answer the research question in a satisfactory way. It was especially valuable to see how the three years of Sustainable Innovation education provided a combination of technical skills and knowledge of social sciences that facilitated the analysis of a socio-technical issue such as the topic of this report. Data analytics (technical skill) and knowledge of economic policy and market mechanisms (social science knowledge) made it possible to engage in both a critical theoretical discussion and well as a full data analysis cycle.

Concerning the value of the results of this report, the insights about the proposed changes to public procurement could definitely help policymakers make decisions that will increase the level of innovation in the construction sector, which is an important step in making buildings more sustainable, as well as allowing a growing population to have sufficient housing for everyone at reasonable price.

It is unclear if the practical implications of this report also hold for other countries than the Netherlands, and for other time lags between policy and innovative outcome than zero years and one year. Lastly, it is uncertain if the relationship that existed in the 2007-2016 also holds in the future.

5.3. Recommendations

There are two types of recommendations to make in this report: policy recommendations and research recommendations.

Policymakers are recommended to:

- Evaluate whether some of the regulatory restrictions analysed in this report could be modified in such a way that the negative effect on innovation is limited
- Allow mixed-use buildings at more locations
- Evaluate the societal costs and benefits of several specific urban planning restriction that might have more societal costs than benefits
- Increase the number and volume of building construction related public tenders that would require innovation from the contract winner

Researchers are advised to:

- Replicate the data analysis, to see if the retrieved results are the same
- Replicate the data analysis for other countries where the construction sector also experiences a lack of innovation
- Empirically analyse the effectiveness of more innovation stimuli than only procurement in increasing innovation specifically in the construction sector, in the Netherlands or in other countries
- Perform social cost benefit analyses on several specific regulatory restrictions analysed in this report

6. Bibliography

Bouwend Nederland. (2021). *Feiten en cijfers*. https://www.bouwendnederland.nl/service/feiten-en-cijfers

CBS. (2021). *CBS Statline*. https://opendata.cbs.nl/statline/#/CBS/nl/

Cobouw. (2015, October 30). *Omgevingswet: op tijd dialoog aangaan*. Cobouw.nl. https://www.cobouw.nl/marktontwikkeling/blog/2015/10/omgevingswet-op-tijd-dialoog-aangaan-10121941

Cobouw. (2019, 10 april). *Innovatie stimuleren of realiseren?* Cobouw.nl. https://www.cobouw.nl/aanbesteden/artikel/2019/04/innovatie-stimuleren-of-realiseren-101271747

Cobouw. (2020). *Largest construction companies of the Netherlands*. https://form.cobouw.nl/sites/default/files/downloads/cobouw50_ranglijst_2020.pdf

Corporate Finance Institute. (2021, February 2). *Neoclassical Economics*. https://corporatefinanceinstitute.com/resources/knowledge/economics/neoclassical-economics/#:%7E:text=Assumptions%20of%20Neoclassical%20Economics&text=People%20are%20rational%20in%20making,(full%20and%20relevant)%20information

de Vries, H. J., & Verhagen, W. P. (2016). Impact of changes in regulatory performance standards on innovation: A case of energy performance standards for newly-built houses. *Technovation*, *48–49*, 56–68. https://doi.org/10.1016/j.technovation.2016.01.008

Dewulf, G., Van Egmond, E., & Mohammadi, M. (2014). The Netherlands - innovations in the Dutch construction industry. In *R and D Investment and Impact in the Global Construction Industry* (pp. 185–206). Taylor & Francis/ Balkema. https://doi.org/10.4324/9781315774916

Dutch social housing. (2018). [Photograph]. https://logicfreezone.wordpress.com/tag/sociale-woningbouw/

Dinopoulos, E., & Syropoulos, C. (2006). Rent Protection as a Barrier to Innovation and Growth. *Economic Theory*, *32*(2), 309–332. https://doi.org/10.1007/s00199-006-0124-4

European Patent Office. (1970, 22 augustus). *EPO - Cooperative Patent Classification (CPC)*. Copyright © 2007 European Patent Office. All Rights Reserved. https://www.epo.org/searching-for-patents/helpful-resources/first-time-here/classification/cpc.html

Georgakellos, D. A. (2010). Impact of a possible environmental externalities internalisation on energy prices: The case of the greenhouse gases from the Greek electricity sector. *Energy Economics*, *32*(1), 202–209. https://doi.org/10.1016/j.eneco.2009.05.010

Galindo, M. Á., & Méndez-Picazo, M. T. (2013). Innovation, entrepreneurship and economic growth. *Management Decision*, *51*(3), 501–514. https://doi.org/10.1108/00251741311309625

García-Quevedo, J. (2004). Do public subsidies complement business R&D? A meta-analysis of the econometric evidence. Kyklos, 57(1), 87-102.

Guerzoni, M., & Raiteri, E. (2015). Demand-side vs. supply-side technology policies: Hidden treatment and new empirical evidence on the policy mix. *Research Policy*, *44*(3), 726–747. https://doi.org/10.1016/j.respol.2014.10.009

Hagmann, D., Ho, E. H., & Loewenstein, G. (2019). Nudging out support for a carbon tax. *Nature Climate Change*, *9*(6), 484-489.

Hall, B. H. (2020). Tax policy for innovation. In Innovation and Public Policy. University of Chicago Press.

Han, S., Lerner, J. S., & Keltner, D. (2007). Feelings and Consumer Decision Making: The Appraisal-Tendency Framework. *Journal of Consumer Psychology*, *17*(3), 158–168. https://doi.org/10.1016/s1057-7408(07)70023-2

Innova58. (2019). *De A58: een slimme en duurzame snelweg*. https://www.innova58.nl/default.aspx

IVBN. (2020, October 22). *Verhoging overdrachtsbelasting beleggers heeft ernstige negatieve effecten voor de woningmarkt* [Press release]. https://www.ivbn.nl/persbericht/verhoging-overdrachtsbelasting-beleggers-heeft-ernstige-negatieve-effecten-voor-de-woningmarkt

Kahneman, D., & Thaler, R. H. (2006). Anomalies: Utility Maximization and Experienced Utility. *Journal of Economic Perspectives*, *20*(1), 221–234. https://doi.org/10.1257/089533006776526076

Koenen, I. (2011, 23 november). *Bouw vraagt veel patenten aan*. Cobouw.nl. https://www.cobouw.nl/innovatie/artikel/2011/11/bouw-vraagt-veel-patenten-aan-101175846

Martin, S., & Scott, J. T. (2000). The nature of innovation market failure and the design of public support for private innovation. *Research Policy*, *29*(4–5), 437–447. https://doi.org/10.1016/s0048-7333(99)00084-0

McFadden, D. (1977). Quantitative Methods for Analyzing Travel Behaviour. *n.a.* Published.

Ministerie van Infrastructuur en Waterstaat. (2020, February 7). *Bouwvoorschriften*. Bouwregelgeving | Rijksoverheid.nl. https://www.rijksoverheid.nl/onderwerpen/bouwregelgeving/bouwvoorschriften

Pries, F., & Dorée, A. (2005). A century of innovation in the Dutch construction industry. *Construction Management and Economics*, *23*(6), 561–564. https://doi.org/10.1080/01446190500040349

Raiteri, E. (2020). *Monopoly mark-up pricing* [Graph]. https://canvas.tue.nl/courses/10707/files/2447655?module_item_id=184242

Rouwendal, J. (2007). Mortgage interest deductibility and homeownership in the Netherlands. *Journal of Housing and the Built Environment*, *22*(4), 369–382. https://doi.org/10.1007/s10901-007-9090-9

RVO. (2021). *Innoveren in de bouw*. https://www.rvo.nl/onderwerpen/duurzaam-ondernemen/gebouwen/technieken-beheer-en-innovatie/innoveren-de-bouw

Stack Exchange. (2013, 3 juni). *What are the assumptions of negative binomial regression?* https://stats.stackexchange.com/questions/60777/what-are-the-assumptions-of-negative-binomial-regression

Statistics By Jim. (2021). *Choosing Regression Analysis*. https://statisticsbyjim.com/regression/choosing-regression-analysis/

Stiglitz, J. E. (1999). Knowledge as a global public good. Global public goods: International cooperation in the 21st century, 308, 308-325.

Tangkar, M., & Arditi, D. (2000). INNOVATION IN THE CONSTRUCTION INDUSTRY. *Civil Engineering Dimension*, 96–103. https://www.researchgate.net/publication/26843965_INNOVATION_IN_THE_CONSTRUCTION_INDUSTRY

TED. (2021). *data.europa.eu*. data.europa.eu. https://data.europa.eu/data/datasets/ted-csv?locale=en

UCLA. (n.d.). *Negative Binomial Regression | Stata Annotated Output*. Retrieved 20 June 2021, van https://stats.idre.ucla.edu/stata/output/negative-binomial-regression/

Vastgoed Business School. (2019). *Dutch residential neighborhood* [Photograph]. https://www.vastgoedbs.nl/nieuws/leefbaarheid-nederland-is-danken-aan-gemengde-woonwijken/

VolkerWessels. (2019). *Notulen AVA VolkerWessels N.V.* https://www.volkerwessels.com/dynamics/modules/SFIL0200/view.php?fil_Id=369365#:~:text=Op%20een%20totaal%20van%20ca,VolkerWessels%20heeft%20hoger%20beroep%20aangetekend.

Wikipedia contributors. (2006). *Economic surpluses* [Graph]. https://upload.wikimedia.org/wikipedia/commons/thumb/d/d7/Economic-surpluses.svg/1200px-Economic-surpluses.svg.png

Wikipedia contributors. (2020a, december 5). *Fixed effects model*. Wikipedia. https://en.wikipedia.org/wiki/Fixed_effects_model

Wikipedia contributors. (2020b, december 12). *Panel data*. Wikipedia. https://en.wikipedia.org/wiki/Panel_data#:%7E:text=A%20balanced%20panel%20(e.g.%2C%20the,person)%20is%20observed%20every%20year.&text=An%20unbalanced%20panel%20(e.g.%2C%20the,is%20not%20observed%20every%20period.)

Wikipedia contributors. (2021, 24 mei). *Random effects model*. Wikipedia. https://en.wikipedia.org/wiki/Random_effects_model

Xue, X., Zhang, R., Yang, R., & Dai, J. (2014). Innovation in construction: A critical review and future research. In *International Journal of Innovation Science* (Vol. 6, Issue 2, pp. 111–125). Multi-Science Publishing Co. Ltd. https://doi.org/10.1260/1757-2223.6.2.111