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A duration analysis of housing construction times

Evidence on the role of option values, public involvement and stalled sites

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Abstract
This paper investigates the duration of housing construction projects in the Netherlands. We utilize comprehensive data from the Dutch Land Registry for the period 2013-2022 to investigate the importance of municipal land ownership, building plot price changes, construction costs, development inside areas that are already built-up and competition. The construction process covers the time between issuance of building permits and completion of the project, which can be split in a preparation and construction phase. We find that municipal involvement in projects speeds them up significantly, while increasing building plot prices and especially construction costs have a delaying effect. Construction inside already built-up areas fastens the preparation and slows down actual construction, with an significant net delaying effect on the total duration. Competition decreases the time needed for construction. Our results lend support to real option theory and indicate differences in the objections of private firms and local authorities.

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1 Introduction

In this paper we analyze the time it takes to construct a house after a building permit has been granted. Since requesting a building permit signals the intention to construct, and the permit provides the right to do this,[1] it seems reasonable to assume that the duration of the construction process is primarily determined by the time it necessarily takes to carry out all the steps it takes to transform the raw materials into a house. This suggests that the construction process can be described by a shortest path dictated by the civil engineering challenges at hand. Beyond these technical aspects, factors such as weather conditions, shortage of materials or unforeseen construction issues, e.g. poor soil conditions, could cause delays. Essentially no behavioral aspects are involved. However, existing literature on the topic suggests otherwise. Bulan et al. (2009) study condominium projects in Vancouver using the time at which the government responds to a developer's filing of the condominium plan, typically near the completion of the construction. Their findings reveal that the hazard rate of completing a project is influenced substantially by market circumstances like the volatility in real estate returns, as is suggested by real option theory. Adams et al. (2009) argue that the intense competition for land in the UK means that even a modest deterioration of market conditions during the building permit processing phase can render projects unviable, prompting developers to defer them.. More recently Ball et al, (2022) find that positive demand shocks in general reduce construction times, but less so in areas with more restrictive land use planning, less available land and less competition among developers. This suggests that behavioral aspects *are* important determinants of actual construction times of houses. To phrase it differently, the supply of housing is not solely determined by the number of building permits lagged by the inevitable production time; rather, it is subject to economic forces even in the final stages of the housing development process

Our data refer to the Netherlands where house prices have shown a strong upward trend since the mid-1980s, with an important interruption after the Global Financial Crisis.[2] The construction of new housing appears largely insensitive to price increases, although it reacts quite strongly to price drops.[3] The combination of strongly increasing house prices and lagging construction volumes causes widespread concern in the Netherlands. Dutch housing construction policy relied for a long time on coordination by the national government[4] but was decentralized in recent years. Housing construction also shifted more to projects in existing built-up areas, see Claassens et al. (2020). Although annual construction volumes remained more or less stable, there is an ongoing debate about the desirability of construction through new development of agricultural land or through infill development and densification. Concerns about housing affordability recently resulted in the return of a minister for housing and spatial planning and the goal to build more than 900,000 houses by 2030.

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[1] As will be discussed below, even after the permit has been granted, objections that lead to time-consuming procedures can be made in the Netherlands.

[2] House prices in the Netherlands dropped by more than 20% during the euro crisis, but increased again since 2013. In 2018 pre-crisis levels were reached again (Öztürk, Van Dijk, Van Hoenselaar, & Burgers, 2018) and substantial further increases followed until the end of 2022.

[3] A weak or absent response of supply to fluctuations in demand has been observed in many urban areas (see, e.g., Glaeser, Gyourko & Saks, 2005) and is often been attributed to strong natural and man-made (planning) restrictions (Saiz, 2010).

[4] The main policy documents were a series of white papers of which the so-called Vierde Nota Extra (1991) was the last. It gave rise to the construction of Vinex areas in the 1990s and early 2000s.

Better knowledge of the determinants of housing construction activity is helpful for making realistic plans. A recent overview of the knowledge concerning ways to expedite the construction process highlights a notable absence of a sense of urgency among the actors involved[5], which may contribute to relatively long construction times. Buitelaar and Van Schie (2018) have shown that stalled sites exist in the Netherlands on a limited scale. Korthals Altes (2019) observes that developers in Amsterdam tend to be slow in taking initiatives. Moreover, there exists casual evidence that housing construction projects can be substantially delayed by objections raised against such projects even after building permits have been granted.[6] During the construction process, the discovery of species with protected status (plant or animal) on the site could necessitate a temporary halt to the project.[7] A potentially important difference between the Netherlands and many other countries is the more substantial involvement of the local government in the construction process. As will be discussed in greater detail below, the municipality often plays a pivotal role as a temporary owner of the land on which the new houses will be constructed and by providing the necessary infrastructure. As a result, the considerations emphasized by real option theory may figure less prominently in the Dutch case. This observation is significant, because real option theory is the main explanation for variation in the construction speed that is not associated with the construction process itself, and its relevance has been emphasized by Bulan et al. (2009).

Real option theory has been associated with the possibility to develop a given site in different densities, while the profitability of the alternatives depends on the future evolution of the market (Titman, 1985; Capozza and Li, 1994). Since an issued building permit is associated with one specific density of development, it may appear to be less relevant in the phase of the construction process studied in this paper. However, there is still an option value associated with such permits.[8] The initiator of the project has the possibility to restart the planning process and request a different type of building permit for the same site after one has been granted. Although exercising this option to build in a different density than has already been permitted is clearly costly to exercise, it is used in a non-negligible share of the cases.[9] Moreover, postponing or delaying the actual construction process may be attractive, even at a given density of development, when house prices are increasing. The positive correlation between house price changes in subsequent periods contributes to the value of this option. In fact, when substantial further increases in house prices are expected, this consideration raises the question why developers would be willing to build at all.

There are several possible answers to this question. One is that the owners of the building permits are often firms active in land development that would incur substantial costs when they leave their capital and labor unused. Put somewhat differently, construction firms face substantial adjustment costs and therefore have an incentive to realize a continuous flow of projects. These adjustment costs have to be traded-off against the possible benefits of making use of option values associated with building permits. A second explanation, also explored by Bulan et al. (2009) is

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[5] See Holt et al. (2022) and the summary by Schouwenaars (2023).

[6] It is possible to object against permits during a period of 6 weeks after they have been issued and even if these objections are declined, appeals may cause further delays of several months, or even years. Striking examples are provided in Fokkema and Zandvliet (2022)

[7] See Gedragscode Flora- en faunawet voor de bouw- en ontwikkelsector (rvo.nl) for the code of conduct that is based on the law that protects plants and animals..

[8] Observe that Bulan et al. (2009) also only consider the final stage of the construction process of apartment buildings.

[9] THIS HAS TO BE DOCUMENTED

that the presence of competing projects in the vicinity poses a threat to the realization of the option value. The reason is that local housing demand curves are downward sloping and when good substitutes for the houses permitted in one developer's project can be provided close-by through competitors, it may be more advantageous not to give them this opportunity.

A third explanation is that the public interest, or at least the perception of it by many in the Dutch situation, is to build houses immediately to relieve the existing housing shortage. Since municipalities, who represent this interest, are always involved in housing construction projects they may exert influence on private entities to expedite the process. This seems particularly likely when municipalities are the initiator of the project or otherwise actively involved its realization, for instance by being the temporary owner of the land. In such situations the construction firms to which the land is sold are clearly expected to construct the planned housing and probably have limited possibilities for temporizing the construction process.

In this paper we will investigate the duration of construction projects of new housing using detailed information collected by the Dutch Land Registry. The data allow us to split the period between the issuance of the building permit and the completion of the construction in two phases. The first is preparatory, while the actual construction process in which the building is erected takes place during the second stage.[10] Investment in the building that is under construction is concentrated in the second phase. Our data cover the whole Netherlands in the years 2013-2023. Using duration analysis allows us to take into account completed as well as incomplete projects.

We contribute to the literature in several ways. We provide a detailed picture of the duration of construction processes for the whole of the Netherlands over a prolonged time period covering a depressed as well as a booming market. By non-parametrically estimating the evolution of the baseline hazard we shed light on the time dependence of the production process and on the possibility that sites become stalled once the elapsed construction time exceeds a particular threshold. Relatedly, we find that a non-negligible share of the projects entering the first phase did not switch to the second in the time window covered by our data. Like Bulan et al. (2009) we study the importance of considerations suggested by real option theory. Moreover, we highlight the significant impact of substantial public involvement in a project, which arguably decreases the relevance of considerations associated with real options. Finally, we compare the construction times of building projects within and outside built-up areas.

The paper is organized as follows. In the next section we describe the Dutch context and formulate a number of hypotheses about the duration of the construction process. Section 3 discusses the data and provides some preliminary information about construction times. Sections 4 and 5 present the methodology used and the main results, respectively. Section 6 concludes.

2 The Dutch context

2.1 Spatial planning and residential development

The Netherlands is a densely populated West-European country with a strong tradition in land use planning. The Housing Law (in Dutch Woning Wet) of 1901, which aimed to prevent the construction of low quality and unhealthy housing and obliged municipalities to create a land use plan for new residential quarters is often regarded as its starting point. Currently the whole country is zoned and new construction can only take place within the restrictions imposed by the local land

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[10] Bulan et al (2009) only cover the part of the construction process after the developer's filing of the strata plan, which can only take place near the completion of the construction (Bulan et al., 2009, p. 240) and use a one-year lag in the dependent variable to cover the whole construction process.

use plan (in Dutch: bestemmingsplan). In practice this often implies that this plan has to be amended before building permits can be issued.

Adjusting the local land use plan is not the start of the construction process, but the end of its initial stage at which the planning procedure is closed and the preparation for actual construction can start. The plan can be initiated by local authorities or by private developers. The former occurs often with large scale developments, that historically were often part of a national housing construction program. The latter occurs more frequently for infill developments. However, the distinction is not absolute, as the actual housing construction is invariably carried out by private companies and local authorities are always involved in realizing the street plan, and the connection to public utilities. The municipal council has to determine the local land use plan that enables the construction in all cases.

Until the 1990s developing land for residential purposes implied that the municipality bought the required land, prepared the development plan and, after confirmation by the municipal council, commissioned construction firms to realize it. This changed when emphasis in new construction shifted from social rental to owner-occupied housing and house prices increased substantially in the course of the 1990s. Large construction firms started to speculatively buy land at locations where new (residential) development was expected. Apart from the large gains associated with the much higher price level of residential land, this brought them the advantage of having the right to develop the land they owned. Owning land at a site that would come available for residential construction thus ensured the firm of participation in the construction through what is called a 'construction claim.' For the municipalities the implication was that a higher price for land had usually to be paid and that the firms possessing such claims were inevitable partners in the development process. What usually happened was that municipalities and construction firms agreed upon a development plan. As in the traditional model the land was then sold to the municipality, which then prepared it for construction and sold the plots to developers.

This 'active land policy' proved quite risky when the Global Financial Crisis and the ensuing euro crisis caused house and land prices to decrease substantially. Developers were in many cases unwilling or unable to buy the land from municipalities in the new circumstances. The original development plans had to be adjusted or postponed, implying considerable losses for the municipalities. Since then, alternative models for land development have gained popularity: public-private- partnerships and concessions to private parties are the most common of these. In these new models for residential development the construction firms and their interests play a more prominent role than under active land policy where the municipality is clearly in the lead, even if some developers possess construction claims.

2.2 Housing construction

Housing construction is an engineering process in which many rules have to be taken into account. Part of them are technical in nature and have the purpose of making sure that the houses are of good quality. Detailed construction plans have to be prepared. On top of that there are rules referring to environmental quality. Making sure that these are satisfied often requires further investigations. Moreover, neighbors and other stakeholders may object against construction plans for various reasons. They may do so formally by starting procedures that may result in the necessity to adjust or even abandon the plans, as well as by lobbying members of the municipal council. Going through all the stages and procedures and establishing and keeping good relationships with all stakeholders usually takes much effort and time, and implies that a substantial investment must be made by the initiator of a construction project before a building permit is issued. Note the difference between active and passive land policy of the municipality: with the former many of these costs are realized by this actor, whereas with the latter the private parties are more heavily involved.

The time needed for realization of a plan, after the building permits have been issued, may depend on many aspects of the project concerned, including soil characteristics and dwelling types. One potentially relevant issue is the location of the project inside or outside the existing built environment. In this connection it is important to note that there has been a gradual shift from large scale projects, usually realized outside existing built-up areas, to infill developments, often on green- or brownfields. In the period 2000 to 2017, the share of houses developed within cities increased to a quarter of the total (Claassens et al., 2020). Inner-city (re)developments are generally more expensive and complex than developments outside the built up area (Michielsen, Groot & Veenstra, 2019) and is more likely to involve hindrance from and conflicts with neighboring residents. It therefore seems likely that realization usually takes longer.

In the Netherlands it is common that after receiving the building permits for a project, developers, for housing intended for owner-occupation, offer the proposed dwellings for sale. Only when at least 70% has been sold, actual construction will start. If market conditions have deteriorated since the start of the planning process, realization of this threshold may be difficult or at least time-consuming, which indicates one possible source of delay. Realization of this threshold is, of course, easier when house prices are increasing, or construction costs are declining, which suggests that construction time may be shorter in either of these circumstances.[11]

When the plans for which the building permits have been issued are no longer viable, re-entering the planning stage may be necessary. If this happens, the construction process can start only after changes in the development plan have been made and new or amended building permits have been issued. There is casual evidence that this scenario occurs also in cases when anticipated further house price increases did not fully materialize. [12]

While increasing house prices make it easier to realize the original plan and probably reduce the time needed to sell 70% of the planned dwellings, they also increase the option value of the land. Increasing house prices are usually associated with public concerns about the affordability of housing which put pressure on municipalities to speed up construction. It seems likely that municipalities involved in active land policy have better possibilities to react to this effectively than those engaged in public private partnerships or relying on development concessions for new housing construction. On the other hand, private developers should be expected to focus on overall profitability and be sensitive to larger profits that can be realized through postponement or switching to development opportunities that are more profitable under the improved market circumstances.

3 Data

3.1 Construction projects and their duration

The data on construction times are provided by the Dutch Land Registry (Kadaster). They refer to building permits that have been granted between January 2013 and December 2022. We disregard households commissioning the construction of a private house for their own use by concentrating on projects, that is sets of at least four building permits issued at the same date for dwellings located

[11] However, the option value of postponing development also becomes more important under these circumstances.
[12] Jókovi et al. (2006).

in the same city district.[13] A project may refer to an apartment building, but also to a set of terraced or (semi-)detached houses or combinations of both. Dwellings may be intended for owner-occupation or rent. The houses in a project are usually not all completed at exactly the same time. For each project we calculate the median duration of the construction process of the houses in the project.

Our data allow us to split the construction process (from the issuing of building permits to the completion of construction) into two parts: first there is a preparation phase in which the land is made ready-to-be-built-upon (phase 1), second there is the actual construction phase (phase 2). For each building we know when it proceeds from phase 1 to phase 2 (if it does) and when the construction is completed. We are thus able to analyze these two phases separately and to study the connection between the two.

The database contains information 16,535 projects that entered phase 1 after January 1st 2013. Projects are only observed in phase 2 if they have first been observed in phase 1. Figure 1 shows the distribution of the projects that entered phase 1 and phase 2 over the years 2013 – 2023. It shows that we have a substantial number of observations in each year. Note that the 325 projects we observe in phase 2 in 2013 refer all to projects for which the building permits have been granted earlier in that year and that therefore are also observed in phase 1. The first years of our observation window refer to a period of recovery of the Dutch housing market, which explains the gradual increase in the total number of projects in both phases.

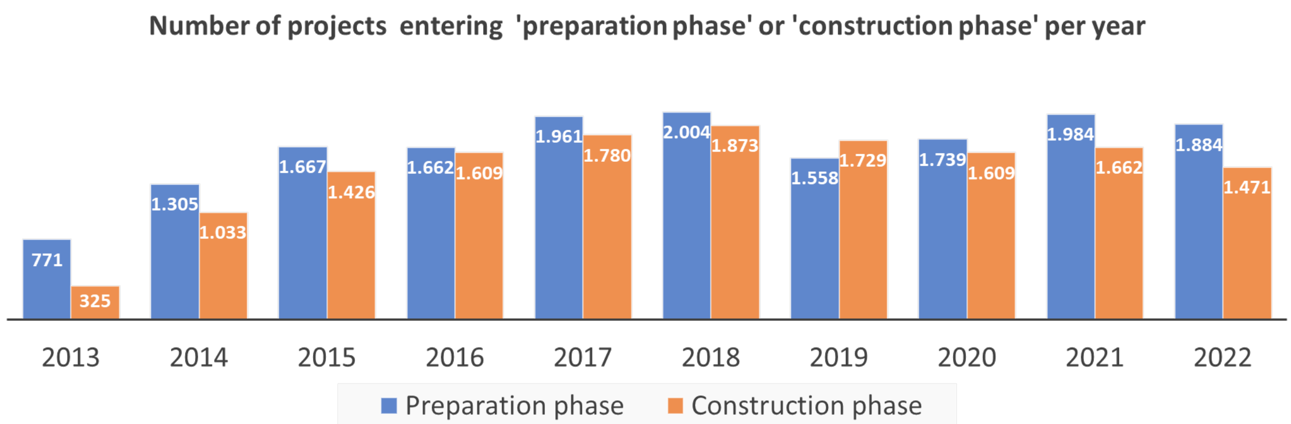

Figure 1: distribution of projects starting phase 1 and phase 2 of the construction process per year. Note: the figure shows the projects entering phase 1 or 2 per year.

It is noteworthy that the number of projects observed in phase 1is larger than that observed in phase 2 in almost every year. The only exception is 2019, when 171 more projects were observed in phase 2. The total number of projects that entered phase 2 equals 14,517, a difference of 2,018 with the number entering phase 1. Since the average duration of phase 1 for projects that completed

[13] This definition may underestimate the size of the project as described in local land use plans, as the issuance of all building permits for such projects might span several years. In our dataset, these larger projects are subdivided into smaller projects, as the number of houses in a project is based on the date of issuance. Concentration on such subprojects is appropriate for the purposes of the present paper, because they realization of the large plan is often subdivided by the parties involved in parts that can be realized more or less independent of each other. Our definition of construction projects is probably close to that of such parts. Note also that we may occasionally overestimate the size of a project as described in a land use plan, if building permits for different (small) projects in the same district are issued on the same day.

this phase is much shorter than a year as we document below, this suggests that some projects remain exceptionally long in phase 1. One possible explanation is the presence of 'stalled sites' (Buitelaar and Van Schie, 2018). Part of the explanation is also administrative. The houses are in use or the permit is no longer valid, but the municipality has neglected to update the registration.

3.2 Control variables

In this subsection we provide information about the covariates we use in the duration analysis. More detailed information can be found in the Appendix.

3.2.1 Municipal ownership of the land

For all project areas, it was determined if the municipality had ownership of the land on which the houses will be realized two years prior to issuance of the building permit. If the municipality had ownership of the land for one of the houses, this is seen as a reasonable indicator of active land policy of the municipality. However it can be that the municipality has legal ownership, while the beneficiary ownership lies with a developer. In the development process, resale constructions are not unusual: the municipality supplies the land to a contractor who in turn resells it to a private individual. Since the municipality does not legally transfer the land to the contractor, this transfer remains outside the cadastral registration. We then see in this study only that the municipality has legal ownership. The contractor remains out of sight.

3.2.2 Property characteristics

As property characteristics, the project size (the number of houses for which a building permit has been issued within the project area), the average surface area of the houses in the project, the composition of the project (single-family, multi-family or mixed) are included.

3.2.3 Location within the built-up area

Based on the topographic map (Top10NL) from 2012, we determine whether the development takes place within or outside the boundaries of the built-up area in 2012. The year 2012 is chosen to depict the situation prior to development.

3.2.4 Building plot price changes

We utilized a dataset sourced from Kadaster, encompassing building plot transactions from 2012 up to 2023, for our building plot prices development variable. Our data captures transactions rather than sales, typically recorded two weeks after the building plot sale. Consequently, the price movements observed exhibit a slight delay compared to the real-time market. Drawing from our literature review, we recognized that building lot price changes influence development more than absolute price levels. Therefore, we opted to compute yearly price changes based on the average price per square meter for each province. The resulting building plot price change variable provides a proxy for housing construction market conditions at the permitting moment.

3.2.5 Construction cost changes

A comparable procedure was used to incorporate construction cost changes. Data for this variable was sourced from the Dutch Central Statistical Office (CBS). We obtained the indexed monthly input prices for material and labor costs at the National level. Since the data was already indexed, we computed the relative change in development costs as follows. The monthly level data was merged with the master dataset based on the timing for the month the building permit was issued and for phase 2 the month construction started. Similar to the building plot prices, this linkage provides us with a proxy for building cost development at the moment of permitting or start of construction.

3.2.6 Risk indicators: GARCH and CAPM

Following Bulan et al. (2009) we separate uncertainty into market risk, which is predicted to reduce investment in a variety of models including the CAPM, and idiosyncratic volatility, which has a negative impact on investment that is more directly tied to the real options model (GARCH). The construction of these variables follows Bulan et al. (2009) closely and is discussed in the Appendix.

3.2.7 Competition

Additionally, we explore how competition influences the connection between volatility and the option value of waiting. Our hypothesis posits that competition should mitigate the impact of uncertainty on investment decisions. The argument posits that competition lessens the influence of volatility on the timing of investments by increasing the cost of delay attributed to the risk of preemption. The insights derived from examining competition also aid us in differentiating between two alternative interpretations of our findings: real options and risk aversion. In periods marked by heightened uncertainty, investors might refrain from engaging in risky real estate investments simply because they struggle to effectively diversify these risks.

We identify competitors within a specified distance of each development site using computer-generated mapping coordinates. For each instance when a project *i* in our sample has not yet been developed, we tally the number of other potential, as-yet-unbuilt projects within a one kilometer

		Obs.	Mean	St. Dev.	Min.	Max.
Duration permit - completed	Days	14.327	550	297	61	2499
Duration permit - start construction	Days	14.327	258	252	1	2484
Duration start construction - completed	Days	14.327	346	208	61	2499
Ownership municipal	Project	14.327	0.54	0.49	0	1
Construction cost change: wages (%)	National, monthly	14.327	2.2	1.11	-0.8	4.6
Construction cost change: material (%)	National, monthly	14.327	3.7	3.2	-1.8	18.9
building lot m² price change (%)	Province, yearly	14.327	7.4	0.82	-22	42.3
Built-up area	Project	14.327	0.75	0.44	0	1
Competition	Number of projects	14.327	11.5	9.8	0	156
GARCH	Return variance	14.327	27	22	12	439
CAPM	Market volatility * Beta	14.327	-0,027	2.1	-25	33

Table 1: Summary statistics of explanatory variables

radius from project *i*. This measure represents the actual number of all future developments that will surround development site i.

3.3 Descriptives

In order to provide insight in the magnitudes of our variables and their standard deviations, which is necessary for the interpretation of our results, the summary statistics of our explanatory variables are demonstrated in table 1.

4 Method

Duration (or survival) analysis is the statistical toolbox for analysis of the time it takes to finish a process. The central concept is the hazard rate, which – in the context of the present paper - can be interpreted loosely as the probability that a construction process that has been active until now will finish in the next time unit.[14] The survival function $S(t)$ gives the probability that the survival time T of a project exceeds a specific time *t*, that is $S(t) = Prob(T > t)$. The hazard rate *h(t)* is a key concept in duration analysis. It is the instantaneous rate of completing the construction process (or one of its phases) and can be formally defined as:

$$h(t) = -\frac{\partial \ln S(t)}{\partial t} \quad (1)$$

The hazard rate can vary over time and its evolution may depend on the characteristics of a project.

A useful starting point for duration analyses is the non-parametric estimate of the survival function provided by the Kaplan-Meier method. The method is non-parametric and therefore able to provide a good first impression of the process, but it is unable to deal with explanatory variables.

Cox' proportional hazard model assumes that the explanatory variables have a multiplicative impact on the hazard rate, while its estimation does not require specification of the baseline hazard. The baseline hazard implied by the estimated model can be recovered non-parametrically way. The proportionality assumption implies, in our application, that project characteristics such as location or the housing types shift the hazard rate at all times by the same multiplicative constant. This model is the workhorse of duration analysis involving explanatory variables.

The standard tool for economic duration analysis is the mixed proportional hazard model, which specifies the hazard rate as the product of three components: a baseline hazard that may change over time, the exponent of a linear function of the covariates and a project-specific random term.[15] The random term, which is absent in Cox's model, is added to take into account that the researcher is imperfectly informed about all the determinants of the duration. Clearly, the effect of the unobserved project characteristics interferes with that of the baseline hazard. For instance, projects with unobserved characteristics that enable fast completion will disappear soon from the sample, and neglecting this effect may lead to the unjustified conclusion that the baseline hazard is initially decreasing, whereas it is in fact constant. The distinction between the impact of unobserved covariates and the baseline hazard is sometimes described as that between spurious and real state dependence. In the context of the present paper the distinction refers to projects taking more time because their characteristics (e.g. complicated nature) imply a longer duration time versus a general decline in the hazard rate once projects have not been completed after a particular threshold duration has passed. The mixed proportional hazard model is nonparametrically identified, meaning that the impact of unobserved characteristics can be

[14] Textbook treatments include Cleves et al. (2010), Kleinbaum and Klein (2020) and Lancaster (1990).
[15] See e.g. Lancaster (1990) or Van den Berg (2001).

distinguished from that of a time-varying baseline hazard under a set of general assumptions (Elbers and Ridder, 1982).

Formally, in the mixed proportional hazard model the hazard rate h of project i is specified as the product of (i) the baseline hazard, specified as a function ψ of time t, (ii) the impact of covariates X, specified as an exponentiated linear function, and (iii) the unobserved characteristics, specified as a random term u, which is sometimes referred to as frailty:

$$h_i(t\ |X, u) = \psi(t)\ e^{\beta\ X_i}\ u_i \tag{2}$$

The impact of the covariates is often expressed as a hazard ratio. For the k-th covariate this ratio equals e^{β_k}, the multiplication factor of the hazard when X_k equals 1 instead of 0.

With the baseline hazard unspecified and the frailty term identically equal to 1, (2) is equal to Cox proportional hazard model. The mixed proportional hazard model is often estimated with a parametric specification of the baseline hazard, for instance the Weibull distribution. However, it is also possible to estimate the model while treating the baseline hazard in a non-parametric way. This partially nonparametric version of the mixed proportional hazard model can alternatively be interpreted as a generalization of Cox'model to situations where frailty is present.[16]

Although the non-parametric treatment of the baseline hazard, as in Cox' model and its generalization, is very general because it avoids the use of a specific and potentially restrictive functional form, it is less efficient than using a parametric specification. One way of dealing with this issue is to start from Cox' approach and inspect the implied nonparametric baseline hazard to investigate its possible compatibility with a parametric specification. For instance, the exponential model specifies the baseline hazard as a constant, while the Weilbull model generalizes this to a power function $\psi(t) = \alpha\ t^{\alpha-1}$, which is less restrictive but still imposes monotonicity on the hazard function. If estimation of Cox' model suggests, for instance, a hazard rate that is initially increasing and later on decreasing, this makes the use of a Weibull model less attractive. A still more general specification that allows the hazard to be first increasing and later on decreasing is the log-logistic one. This model is especially useful when the distribution is characterized by a hazard function that has an S-shaped curve. The survival function in the log-logistic model is $S(t)=1/(1+(t/\sigma)^{\alpha})$. Using (1), we derive $h(t) = (\alpha/\sigma)\ (t/\sigma)^{\alpha-1}[1 + (t/\sigma)^{\alpha}]^{-1}$. α is the shape parameter that determines the slope of the curve and σ the scale parameter that influences the scale of the distribution.

5 Results

5.1 Kaplan-Meier estimates

Figure 2 demonstrate the Kaplan-Meier curves for our observations and provide insights in the distribution of the duration of the various development phases. The estimated survival curves show that 50% of the projects leave phase 1 within 192 days and phase 2 within 318 days. The tow curves cross each other at 529days. Many projects switch to phase 2 relatively soon, but there is also a relatively large share for which it takes much longer to enter the real construction phase. This confirms the discussion of Figure 1 above, in which we noticed that in almost every year more projects enter phase 1 than phase 2 and the associated impression that this may explain stalled

[16] Bulan et al. (2009) use the Weibull distribution for the baseline hazard and ignore unobserved project characteristics.

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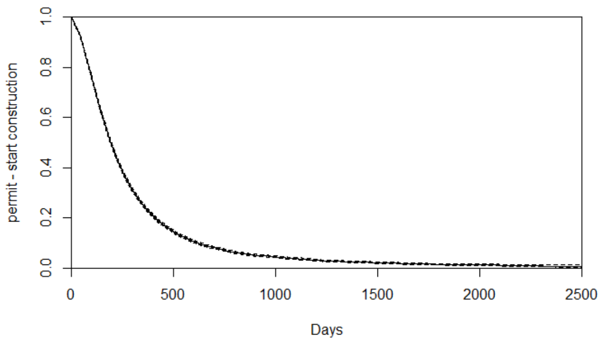

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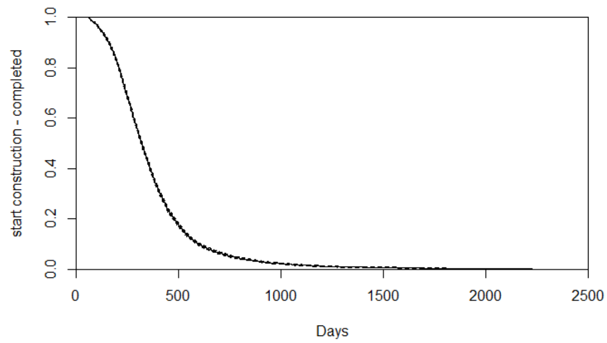

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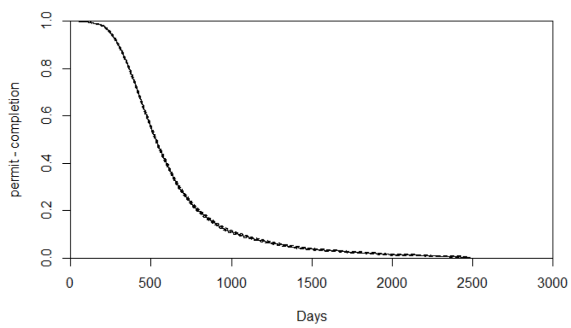


Figure 2: Kaplan-Meier plots
Legend Phase (1) (permit-start) and (2) (start-completion) and total (3) (permit-completion).

sites, that is sites for which building permits have been issued but no construction activity is detected after a considerable amount of time elapsed.

The third panel shows the survival curve of the sum of the durations of the two phases. It is remarkable that this curve is initially much flatter than could be expected by observing the first two panels. The probable explanation is a negative correlation between the duration of phases 1 and 2. It may be the case that the distinction between the two phases is in practice somewhat arbitrary because the order in which all the tasks necessary for completing the house is not fixed.

After this initial phase in which few projects are completed the decline of the survival curve is steeper than would be suggested by horizontally adding the survival curves of the two separate phases. Again, the probable reason is a negative correlation between the durations of the two phases. Finally, there is again the fat tail, which is closely related to the incomplete durations of projects that never left the first phase in the time window to which our data refer.

5.2 Base specification

We start our investigation of the impact of the covariates discussed in section 4 above by estimating Cox' proportional hazard model for the two phases as well as for the whole construction process. For each specification we estimate versions of the model without frailty (that is Cox' original model) and with a gamma-distributed random term covering the unobserved project characteristics. Estimation results are presented in Table 1. The reported figures are hazard ratios.

COX PH models	1 **permit. - completion (no frailty)**	2 **permit. - completion (gamma frailty)**	3 **permit-start construction (no frailty)**	4 **permit - start construction (gamma frailty)**	5 **start construct. - completion (no frailty)**	6 **start construct. - completion (gamma frailty)**
Within built up area of city	0.94*** (0.0222)	0.84*** (0.0437)	0.89*** (0.0206)	0.88*** (0.0208)	1.02 (0.0222)	0.96 (0.0359)
Municipality ownership	1.21*** (0.0194)	1.04*** (0.0390)	1.19*** (0.0181)	1.19*** (0.0183)	1.09*** (0.0194)	1.03*** (0.0315)
Construction cost development: wages	0.98 (0.0207)	0.94 (0.0405)	0.99 (0.0175)	0.99 (0.0177)	0.97*** (0.0148)	0.93*** (0.0235)
Construction cost development: material	0.98** (0.0082)	0.98 (0.0150)	0.99*** (0.0068)	0.98*** (0.0068)	0.97*** (0.0065)	0.92*** (0.0099)
Building lot price development (m²)	0.997** (0.0016)	1.00 (0.0033)	0.997* (0.0014)	0.997* (0.0014)	1.00 (0.0016)	1.00 (0.0026)
Competition	1.005*** (0.0008)	1.00 (0.0017)	1.005*** (0.0008)	1.005*** (0.0009)	1.00 (0.0008)	1.00 (0.0014)
GARCH	*1.00****	*1.00***	*1.00*	*1.00*	*1.00*	*1.00***
CAPM	*1.00*	*1.00*	*1.01**	*1.01*	*1.00*	*0.99*
building types: only appartments	*0.77****	*0.59****	*0.85****	*0.84****	*0.72****	*0.59****
buidling types: only single-family	*1.74****	*2.88****	*1.24****	*1.25****	*1.74****	*2.88****
building types: mixed	*reference*	*reference*	*reference*	*reference*	*reference*	*reference*
project size	*1.00****	*0.99****	*1.00*	*1.00*	*1.00****	*0.99****
Average surface area house	*1.00*	*0.99****	*1.00****	*1.00****	*1.00****	*0.99****
Number of building permits	*1.11****	*1.21****	*1.14****	*1.14****	*1.02*	*1,21****
Year	*x*	*x*	*x*	*x*	*x*	*x*
Province	*x*	*x*	*x*	*x*	*x*	*x*
Number of observations	*14.327*	*14.327*	*14.327*	*14.327*	*14.327*	*14.327*
Concordance index	*0.663*	*0.927*	*0.615*	*0.623*	*0.657*	*0.876*
loglikelyhood	*-102391.5*	*-89738.72*	*-122512.9*	*-122346.3*	*-102001.3*	*-93758.76*

Table 2 Cox'proportional hazard model
Notes: Figures are hazard ratios. The stars refer to differences relative to the value 1.

A value larger than one indicates that the covariate speeds up the process, a value smaller than 1 that it slows it down.

The findings from our estimations reveal that there is a statistically significant difference in the overall duration of the construction process between areas inside and outside the built-up area. We find that the overall process moves significantly more slowly in the built-up area. The columns 3 and 4 show that the preparation phase takes significantly more time for projects inside built-up areas, whereas we find no significant difference during actual construction. These findings do not depend on taking into account unobserved project characteristics.

Increasing wages costs only have a slowing impact on the second phase of the construction process. Rising material costs impede both the preparatory and the construction process. These results remain consistent regardless of considering unobserved project characteristics. Increasing building plot prices slow down the first phase of the project. Since it is probably easier to reach the 70% threshold in periods with strong demand for housing, this is somewhat surprising. However, as noted above, it is consistent with a real option view.

When the municipality owns the land before construction starts, the hazard rate is significantly and substantially higher. This is especially true for the preparation phase of the process. Clearly, the data indicate a very strong impact of municipal involvement through active land policy. The difference in the second phase is smaller, especially when unobserved project characteristics are taken into account.

The control variable capturing riskiness show mixed results. Idiosyncratic volatility exhibits a significant effect at the $p<0.05$ level for the overall process. The hazard rates, mostly surpassing 1, do indicate that heightened risk is correlated with an accelerated pace of development.

We find some evidence that competition speeds up the construction process, but only for the preparation phase. This is not surprising, as.

5.3 Implied baseline hazards

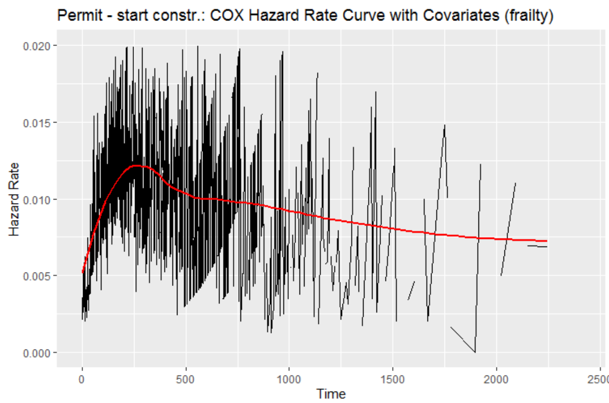
Figure 3 presents nonparametric estimates of the baseline hazards associated with the specifications for which estimation results are reported in Table 2.[17] The smooth (red) line shows the nonparametric estimate. It is obtained by taking the derivative of the cumulative hazard function with respect to time. It provides the instantaneous risk of an event occurring at a specific time, given survival up to that time. Panels 1 and 2 show the hazards of the two phases of the construction process, whereas panel 3 refers to the sum of these two. For all three cases, the diagram on the left-hand side refers to the specification without frailty, and that on the right-hand side to the specification in which unobserved project characteristics are taken into account.

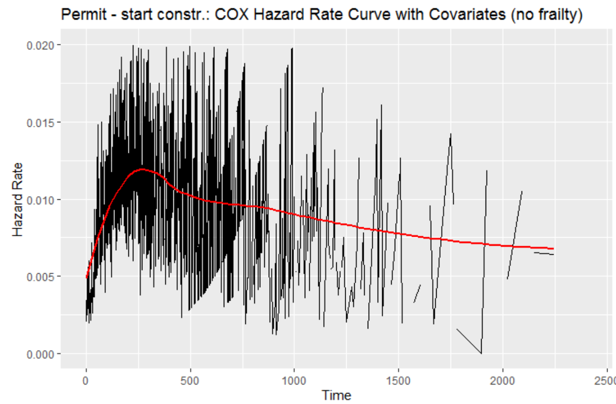
In all three cases we find roughly the same evolution of the baseline hazard, whether or not frailty has been incorporated.[18] In all diagrams the baseline hazard increases initially, as one would expect because there is a minimum amount of time needed to complete each phase of the production process. The curve is initially much steeper for the preparation phase, which confirms the notion that its minimum required duration is much smaller relative to that of the actual construction process (phase 2).

1a 1b

[17] We employ kernel-based methods. The estimation process incorporates global and local bandwidth selection algorithms, along with boundary kernel formulations as outlined in Mueller and Wang (1994). The nearest neighbor bandwidth formulation is adopted from Gefeller and Dette (1992). Hess et al. (1999) provide a comprehensive comparison of the statistical properties of several estimators used in this methodology.

[18] Inclusion of frailty had in all cases an important impact on the likelihood and the estimated coefficient of the gamma distribution was in all cases significant at p=0.01.





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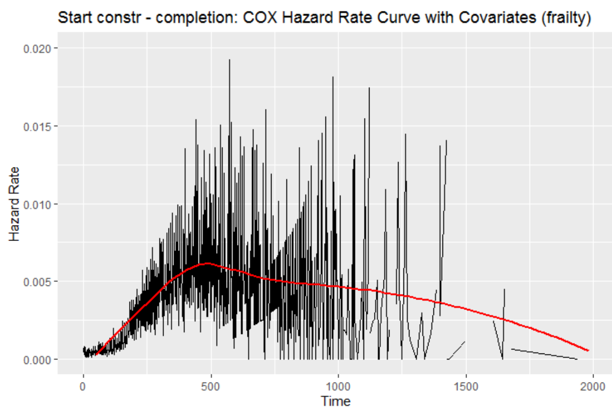

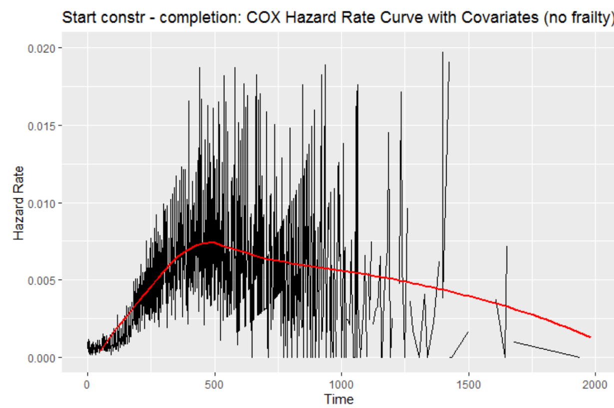

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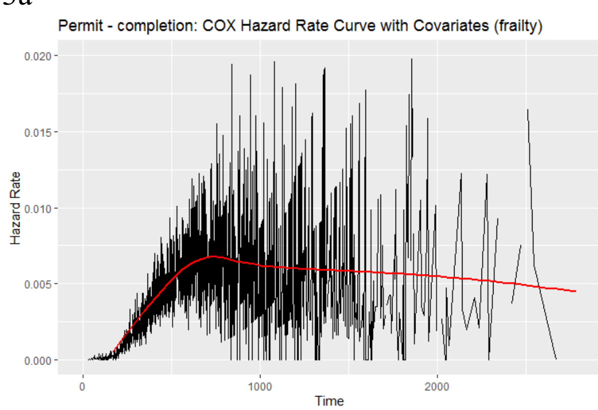

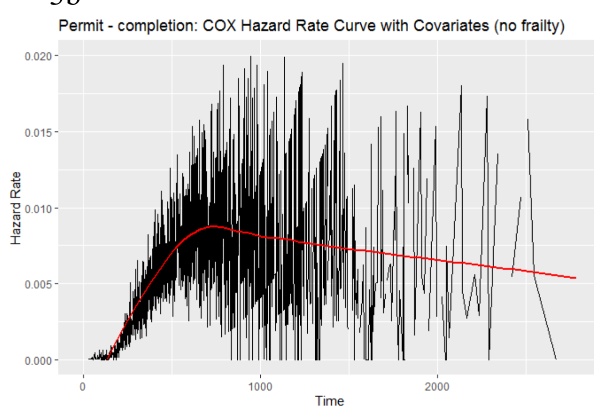

Figure 3: Nonparametric baseline hazard rate plots phase 1a/b (permit-start) and 2a/b (start-completion) and total (3a/b) (permit-completion). A: including covariates and shared frailty. B: including covariates, no shared frailty)

For both phases we find that the baseline hazard reaches a maximum close to the average duration. The diagrams suggest that a monotonous parametric specification of the hazard rate, e.g. the Weibull, is not suitable for the data. The declining baseline hazard for both phases of the construction process implies that the probability that it will soon be finished decreases once a

Log logistic models	1 permit - completion (no frailty)	2 permit - completion (gamma frailty)	3 permit-start construction (no frailty)	4 permit - start construction (gamma frailty)	5 start construct. - completion (no frailty)	6 start construct. - completion (gamma frailty)
Within built up area of city	0.96*** (0.0209)	1.04* (0.0192)	0.90*** (0.0185)	0.88*** (0.0202)	0.99 (0.0101)	1.05** (0.0224)
Municipality ownership	1.04*** (0.0235)	1.14*** (0.0164)	1.10*** (0.0162)	1.21*** (0.0171)	1.01 (0.0087)	1.06*** (0.0185)
Construction cost development: wages	0.99 (0.0202)	0.995*** (0.0083)	0.98 (0.0154)	0.96*** (0.0084)	0.98*** (0.0066)	0.93*** (0.0102)
Construction cost development: material	0.98*** (0.0081)	0.996*** (0.0033)	0.98*** (0.0059)	0.96*** (0.0034)	0.98*** (0.0028)	0.96*** (0.0039)
Building plot price development (m²)	1.00 (0.0016)	0.997** (0.0013)	1.00 (0.0013)	1.00* (0.0011)	1.00 (0.0007)	1.00 (0.0016)
Competition	1.00 (0.0008)	1.005*** (0.0007)	1.00 (0.0007)	1.005*** (0.0008)	1.00 (0.0004)	1.00 (0.0009)
GARCH	*1.0005****	*1.00*	*1.00*	*1.00*	*1.01**	*1.00*
CAPM	*1.00*	*1.01*	*1.01*	*1.00*	*1.00*	*0.99**
building type: appartments	*0.83****	*0.85****	*0.86****	*0.89****	*0.78****	*0.76****
buidling type: single-family	*1.22****	*1.28****	*1.15****	*1.13****	*1.25****	*1.19****
building type: mixed	*reference*	*reference*	*reference*	*reference*	*reference*	*reference*
project size	*1.00****	*1.00****	*1.00*	*1.00*	*1.00*	*1.00*
Average surface area houses project	*1.00****	*1.00****	*1.00*	*1.00**		
Number of building permits	*1.11****	*1.00*	*1.25****	*1.09***	*1.05****	*1.41****
Year	*x*	*x*	*x*	*x*	*x*	*x*
Province	*x*	*x*	*x*	*x*	*x*	*x*
Scale parameter	*0.25*	*2.70*	*0.55*	*1.50*	*0.27*	*2.70*
Number of observations	*14.327*	*14.327*	*14.327*	*14.327*	*14.327*	*14.327*
loglikelyhood	*-102391.5*	*-122.436.266*	*-92337.7*	*-100.906*	*-78286.85*	*-84024.19*

*** p<0.01, **p<0.05,*p<0.10

Standard errors in parentheses

Table 3 Log-logistic proportional hazard model

Notes: Figures are hazard ratios. The stars refer to differences relative to the value 1.

particular threshold in the elapsed duration has been passed. The decline is gradual and suggests that completion becomes increasingly problematic when the elapsed time is longer. This confirms the reports on stalled sites that have been published earlier (Buitelaar and Van Schie, 2018, for the Netherlands).

5.4 Log-logistic regressions

We will now estimate regressions using a log-logistic model, To account for unobserved heterogeneity we include random effects in a number of the models. Estimation results for the log-logistic models both excluding (model 1,3,5) and including gamma frailty (at the COROP-level, model 2,4 and 6)) are shown in Table 3.

The changes, relative to those reached when the baseline hazard is estimated semi-parametrically are limited. Values and significance of the estimated coefficient typically remain the same. We again identify a significant impact of the built-up area, especially during the preparation phase. The findings related to the development of construction costs are also consistent across all our models. Similar to the observations in the Cox models, we observe a delaying effect. In the log logistic models we more often find an effect of increasing wage costs. The influence of square meter price development attains significance solely in the sum process including frailty. Once again, we observe that municipal involvement correlates with a notably accelerated progression in the preparation phase and the overall process. But we also find it in the construction phase, when including frailty. Results for the control variable capturing riskiness are mostly not statistically significant. Conversely, competition exerts a positive influence on the speed of the preparatory phasein our model with frailty.

6 Conclusion

This paper has provided a detailed duration analysis of more than 10,000 residential construction projects in the Netherlands started between 2013 and 2022. The construction process takes place between the issuance of the building permit and the completion of construction. Moreover, the data allowed us to separate the construction process into two phases, the first one referring to preparation and the second to the actual construction process. We specified a duration model that allowed for a more flexible treatment of the baseline hazard than what was possible in previous studies and included unobserved project characteristics through a random effects specification.

Like Bulan et al. (2009) we found clear evidence of the relevance of real option theory for the duration of construction projects. This suggests that even after the building permits have been issued, developers take into account market circumstances when deciding on the speed with which investments take place. We found in some of our models that increasing building plot prices tend to have a delaying effect on the overall construction process. This may be due to developers postponing the sales of the houses after receiving the building permits as well as to upgrading of the proposed houses to more luxury versions that are covered by the available permits. We found stronger evidence of the impact of construction costs. Increasing material costs tend to delay all phases of the construction process. Increasing wage costs also have an effect, but most profoundly in the construction phase. This is not surprising. When construction costs increase it may be needed to reevaluate the original design and specifications to find cost-effective alternatives or make adjustments to accommodate the increased material costs. This process takes time and may delay the process. Higher costs may be associated with unavailability of materials and personnel, leading to project delays.

Exploratory analysis of the number of projects in our data entering the two phases provided preliminary evidence of stalled sites, as the number of projects entering the first phase exceeded that entering the second stage, although there is no clear upward trend in the total number of projects started annually. This was confirmed by the Kaplan-Meier plots which show that the survival curve of the first phase declines much stronger for the preparatory phase than for the actual construction phase, while this changes for longer elapsed durations and ultimate the two curves cross each other.

Related to this we find strong positive duration dependence of both phases for short elapsed durations, implying that the probability that the phase will be completed soon increases when is has been in that phase for a longer time, whereas there is negative duration dependence for longer elapsed durations. This suggest that once a particular threshold has been exceeded, it becomes increasingly difficult to complete a construction project. Our analysis suggests that phenomenon occurs for all types of projects and is not due to unobserved project characteristics.

We also found some evidence that competition, that is the (almost) simultaneous construction of similar housing on sites in the vicinity tends to speed up the production process. Contrary to the suggestions of real option theory (and the findings of Bulan et al., 2009) volatility on the local housing market appears to increase the speed of construction somewhat.

Perhaps the most important finding of the paper is that active land policy of the municipality in which the project is carried out, meaning that the land is owned by that municipality before the building permits are issued, tends to fasten the completion of the project significantly. This effect is mainly due to a shorter preparatory phase. A possible explanation is that the public involvement implies stronger pressure on construction speed as more housing supply is perceived to be in the general interest. This may be formalized in contractual agreements that included the data of completion of the project (about which we do not have direct information) or through informal mechanisms such as the municipality proceeding immediately with making public infrastructure available to the project site.

Finally, a notable finding of our analysis is that projects located within existing built-up areas tend to be completed somewhat sooner than others, which contradicts the *communis opinio* of developers in the Netherlands. This is mainly caused by a shorter preparatory phase, that is likely facilitated by the availability of public infrastructure close to the project site.

We conclude by briefly mentioning some issues that the current paper was unable to address. One is the importance of selling the required 70% of te the planned dwellings for construction projects intended for owner-occupation. This interferes with the common practice of municipalities to sell the land at the ‘residual value’ that is at the difference between the expected sales price of the housing to be constructed and the estimated construction costs. In the absence of active land policy, a similar effect may be due to the developers valuing the land involved in the project at this value. The implication may be that a failure to realize the expected sales price of the houses results first in delay and potentially later in stalled sites. Second, it would be interesting to connect the current analysis to the earlier phases of the planning process, that is those preceding the issuing of the building permits. It is possible that building plot prices changes have a different impact on the number of projects that are made ready for inclusion in a local land use project and the willingness of municipal boards to pass such proposals. Proceeding to such a more comprehensive analysis of the process could lead to insights that differ from those offered by the present paper.

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Appendix Market risk and idiosyncratic volatility

We compute a monthly repeat sales index of condominium and single family home prices between 2011 to 2021 using data obtained from the Dutch Land Registry and Mapping Agency (Kadaster). The repeat sales index has the advantage of controlling for changes in the quality of units sold over time. We compute the index using the geometric repeat sales methodology outlined in Shiller (1991). Shiller (1991) argued that changes in house prices include components whose variance increases with the interval of sales, so that the assumption of a constant variance of the errors is violated. He proposed a Weighted Least Squares (WLS) approach to correct for this type of heteroskedasticity. The weights are derived by regressing the squared residuals from the standard (OLS) repeat sales regression on an intercept and the time interval between sales. To estimate a repeat transactions model we therefore make use of a weighted OLS model. Jansen et al. (2008), using data from Kadaster, found that houses resold within a 12 month period showed relatively strong price increases. To ensure that these 'flips' are excluded we only include those sales a year or more apart in our analyses. In the event of more than two transactions of the same property, only sequential transactions are used, i.e. sales 1 to 2 and 2 to 3, for example, but not 1 to 3. For months where there are not enough data to estimate a value, the missing period is imputed. For missing internal periods (those with estimated periods both before and after) a 'stine' interpolation is used and for those missing at the end a 'last observation carried forward' (LOCF) approach is used.
To measure uncertainty, we compute a time-varying measure of the volatility of monthly returns using a GARCH (1,1) estimate for the variance of residuals from an AR(2) first stage equation. For the standard GARCH model, we specify a constant to mean ARMA model, which means that arma0rder = c(2,0). We consider the GARCH(1,1) model and the distribution of the conditional error term is the normal distribution.

The repeat sales indexes will have higher estimated variance during periods when the underlying index has fewer transactions. We believe that this pattern captures an important source of uncertainty faced by developers. If there are fewer transactions in the market, the more difficult it is for developers to extract a signal from the noise. To test for robustness we examine two additional measures of uncertainty. The first is the simple variance in returns over the previous two years. The second is a GARCH specification with a correction for the component of volatility caused by differences in the ratio of repeated sales of the same unit to total transactions in a month. This latter GARCH measure adjusts for possible differences in the volatility observed by a developer who considers all transactions in the market compared with the volatility measured by a repeat sales index that only includes sales of units that transact at least twice in the sample. The three series of return volatilities are presented in Figure 3. We believe that the transactions-adjusted GARCH volatility measure is the appropriate measure to use in the regressions that follow, although the same basic results hold for the other measures as well.

Finally, systematic market volatility, is modeled via a Capital Asset Pricing Model (CAPM). Capital Asset Pricing Model (CAPM) describes the relationship between systematic risk, or the general perils of investing, and the expected return for an asset, in this case the condo market. It is calculated by multiplying monthly Dutch stock market (AEX) returns by a time varying measure of β, the covariance between excess returns in the condo market and the AEX stock market. Time variation in the CAPM beta is smoothed using locally weighted regression (Figure 4).

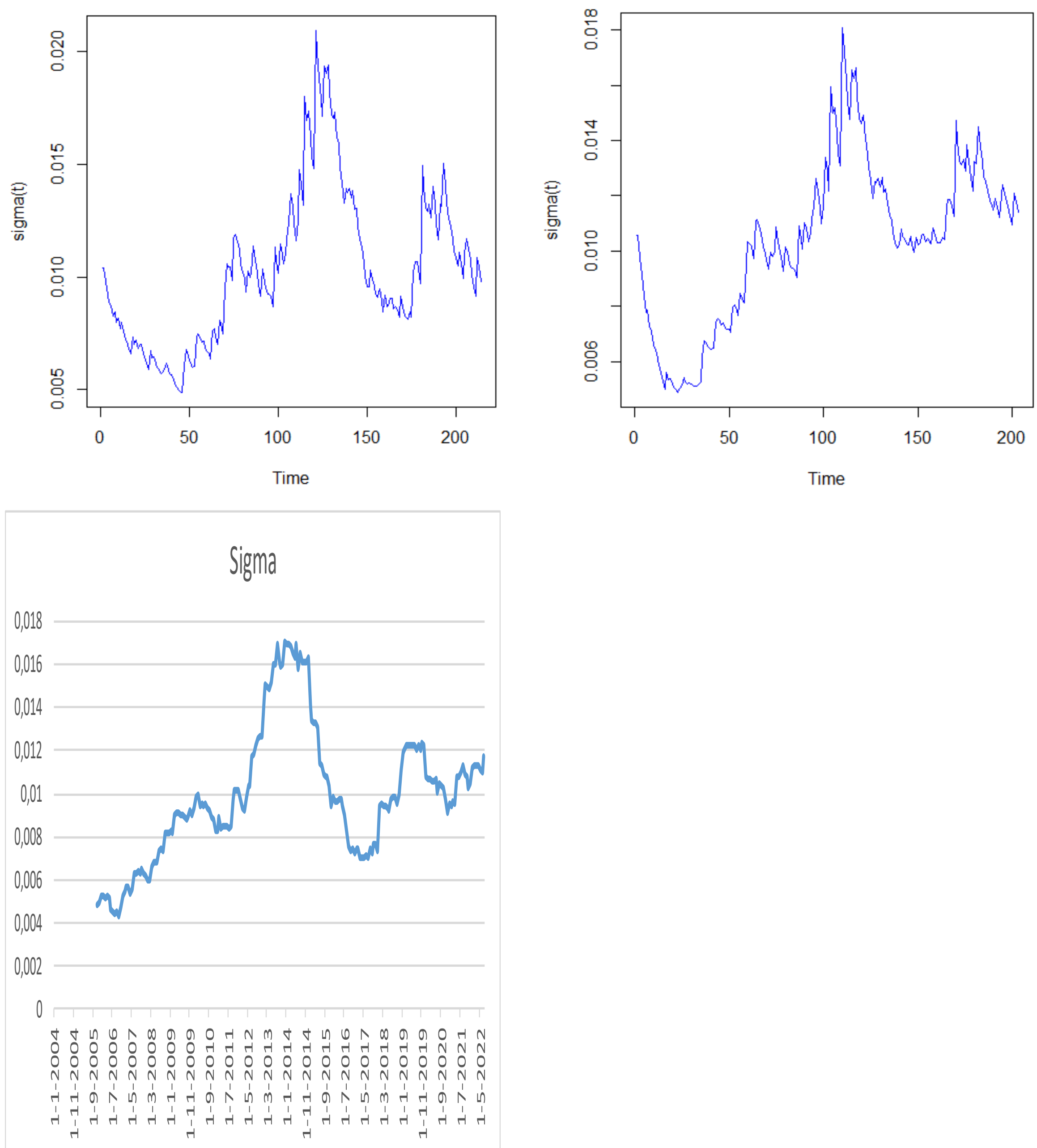

Figure A.2: return volatilities

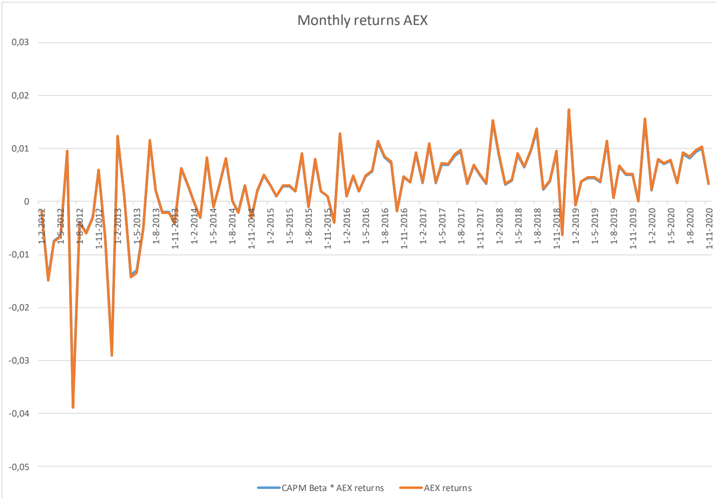

Figure A.3: Time variation in the CAPM smoothed using locally weighted regression