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Modelling fertility for national population projections

The case of Belgium

October 2020

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Abstract - This Working Paper presents the methodology that has been applied since 2020 in the model used to draw up the population outlook for Belgium. This outlook is published every year by the Federal Planning Bureau and Statbel. The methodology considers that fertility is not static and is explained by both structural (education, labour market participation, etc.) and cyclical factors (the economic cycle, etc.). Those factors are taken into account through three elements: (1) expert opinion on long-term fertility trends, (2) an explicit trend in the fertility schedule using Schmertmann's model (2003) and (3) the effect of cyclical and structural determinants of fertility using an error-correction model.

Jel Classification - J11
Keywords - fertility projection, demography, age specific fertility rates, total fertility rate

Table of contents

List of tables

List of graphs

Executive summary

The methods for projecting fertility are numerous and varied. They are either based on probabilistic or deterministic methods using explanatory models or based on time series extrapolation. Expert judgment can also be taken into account. Some models simply project births by multiplying the total number of women by an average number of children per woman, but most project fertility by age of mother to take into account the fertility schedule and the age distribution of women of childbearing age. Finally, a choice has to be made on the ways to measure fertility: some models will include the total offspring (longitudinal or cohort approach), while others use the total fertility rate (cross-sectional approach).

Going back to 2008, the year from which the population projection model for Belgium was developed at the Federal Planning Bureau, the fertility projection methodology for national population projections was poorly developed, mainly due to data limitations. It was essentially based on age-specific fertility rates held constant in the projection, assuming no change in future fertility behaviours.

Fertility trends in recent years (described in the third section of the paper), and in particular since 2009, highlight the necessity to improve the methodology used so far, mainly on two issues. First, the *structural determinants of fertility*, in particular the increases in the number of years spent in education and in women's participation in the labour market, which influence both the level and schedule of fertility, were not taken into account. Second, *cyclical factors*, especially the economic situation, which can influence the fertility schedule in the short and medium term, were also barely taken into account in the projection model.

This Working Paper therefore aims to present a new methodology that has been applied since 2020 in the model used to draw up the population outlook for Belgium published every year by the Federal Planning Bureau and Statbel. The methodology considers that fertility is not static and is explained by both structural (education, labour market participation, etc.) and cyclical factors (the economic cycle, etc.). These factors are taken into account through three elements: (1) expert opinion on long-term fertility trends, (2) an explicit trend in the fertility schedule using Schmertmann's model (2003) and (3) the effect of cyclical and structural determinants of fertility using an error-correction model.

By considering the judgment of different experts, the uncertainty surrounding the future evolution of fertility can – to some extent – be taken into account. The inclusion of structural elements can help to determine a relatively stable long-term fertility level. Integrating the cyclical elements of fertility makes it possible to adjust fertility development in the short and medium term depending on the economic environment, in particular the evolution of the unemployment rate. Finally, by integrating demographic parameters (in this case the modal age) into the modelling of the fertility schedule, transparent choices on the future development of this schedule can be made, in particular the continued increase in age at childbirth.

The population projection model developed by the Federal Planning Bureau is deterministic, based on the (demographic) component method. Deterministic projections may be criticized for their lack of information on uncertainty around population projection. One way to address this issue is transparency in assumptions: the results of deterministic population projections are directly linked to the selected

scenario. The user of the projections must be aware of this scenario to interpret correctly the projection results. This Working Paper, which describes in detail the methodology for projecting fertility in the national population projection, contributes to this objective.

Synthèse

Les méthodes de projection de la fécondité sont multiples et variées. Elles peuvent se baser sur des méthodes probabilistes ou déterministes en ayant recours à des modèles explicatifs ou se baser sur l'extrapolation de séries temporelles. Elles peuvent également tenir compte de l'avis d'experts. Certains modèles peuvent encore se limiter à projeter les naissances en multipliant le nombre total de femmes par un nombre moyen d'enfant(s) par femme, mais la plupart projettent la fécondité par âge de la mère afin de tenir compte du calendrier de la fécondité et de la structure d'âge des femmes en âge d'avoir des enfants. Enfin, un choix doit également être fait sur la manière de mesurer la fécondité : certains modèles vont intégrer la descendance finale (approche longitudinale ou par cohorte), alors que d'autres vont baser leur modèle sur l'indice conjoncturel de fécondité (approche transversale).

Si l'on remonte à 2008, année à partir de laquelle le modèle de projection de la population de la Belgique a été développé au Bureau fédéral du Plan, la méthode de projection de la fécondité pour les projections nationales de population était alors peu élaborée. Elle se fondait essentiellement sur l'indice conjoncturel de fécondité qui était maintenu constant en projection, dans l'hypothèse d'une absence de bouleversement dans les comportements futurs en matière de fécondité.

L'évolution de la fécondité depuis plusieurs années (décrite dans la troisième section de l'étude), et en particulier depuis 2009, a mis en évidence les faiblesses de la méthodologie retenue, essentiellement pour deux points. Premièrement, *les déterminants structurels de la fécondité*, en particulier l'augmentation du nombre d'années passées aux études et la progression de la participation des femmes au marché du travail, qui influencent tant le niveau de la fécondité que son calendrier, n'étaient pas pris en compte. Deuxièmement, *les facteurs conjoncturels*, en particulier la situation économique, qui peuvent influencer le calendrier de la fécondité à court et moyen terme, étaient également peu pris en compte dans le modèle de projection.

L'objectif de ce Working Paper est dès lors de présenter la méthodologie appliquée depuis 2020 dans le modèle utilisé pour la projection de population pour la Belgique. Ces perspectives sont publiées chaque année par le Bureau fédéral du Plan et Statbel. La nouvelle méthodologie considère que la fécondité n'est pas statique et est déterminée à la fois par des facteurs structurels (niveau d'instruction, la participation au marché du travail, etc.) et conjoncturels (le cycle économique, etc.). Ces facteurs sont pris en compte par le biais de trois canaux : (1) l'avis d'experts sur l'évolution à long terme de la fécondité, (2) l'évolution du calendrier de la fécondité obtenu à l'aide du modèle de Schmertmann et (3) les effets de déterminants structurels de la fécondité estimés à l'aide d'un modèle à correction d'erreur.

Intégrer l'avis de différents experts permet de prendre en compte – dans une certaine mesure – l'incertitude quant à l'évolution future de la fécondité. En outre, la prise en compte des éléments structurels permet de déterminer un niveau de fécondité à long terme, relativement stable. Intégrer les éléments conjoncturels de la fécondité permet aussi d'ajuster l'évolution de la fécondité à court et moyen terme en fonction de l'activité économique, et en particulier du taux de chômage. Enfin, l'intégration des paramètres démographiques (dans ce cas-ci l'âge modal) dans la modélisation du calendrier de la fécondité permet de poser des choix transparents sur l'évolution future de ce calendrier, en particulier une poursuite de l'augmentation de l'âge à la maternité.

Le modèle de projection de la population développé par le Bureau fédéral du Plan est déterministe, il se base sur la méthode des composantes (démographiques). Les projections déterministes peuvent être critiquées pour le manque d'informations sur les incertitudes entourant les projections démographiques. Une manière d'aborder cette question est d'assurer la transparence des hypothèses : les résultats de la projection de population sont directement liés au scénario retenu. L'utilisateur des projections doit avoir connaissance de ce scénario pour pouvoir interpréter correctement les résultats de la projection. Ce Working Paper, qui décrit en détail la méthodologie retenue pour projeter la fécondité dans les projections démographiques nationales, contribue aussi à cet objectif.

Synthese

Er bestaan tal van verschillende methoden om de vruchtbaarheid te projecteren. Ze zijn ofwel gebaseerd op probabilistische of deterministische methoden die verklarende modellen gebruiken ofwel op de extrapolatie van tijdreeksen. Met de mening van experten kan ook rekening worden gehouden. Sommige modellen projecteren eenvoudigweg het aantal geboorten door het totale aantal vrouwen te vermenigvuldigen met een gemiddeld aantal kinderen per vrouw, maar de meeste projecteren de vruchtbaarheid volgens de leeftijd van de moeder om rekening te houden met het vruchtbaarheidsschema en de leeftijdsverdeling van de vrouwen op vruchtbare leeftijd. Tot slot moet een keuze worden gemaakt over de manier waarop de vruchtbaarheid wordt gemeten: sommige modellen houden rekening met het totale aantal kinderen (longitudinale of cohortbenadering), terwijl andere modellen het totale vruchtbaarheidscijfer gebruiken (transversale benadering).

Als we terugkijken naar 2008, het jaar waarin het bevolkingsprojectiemodel voor België werd ontwikkeld op het Federaal Planbureau, zien we dat de projectiemethodologie voor de vruchtbaarheid voor de nationale bevolkingsvooruitzichten nauwelijks was ontwikkeld, wat hoofdzakelijk te wijten was aan de beperkte gegevens. De projectiemethodologie was hoofdzakelijk gebaseerd op leeftijdsspecifieke vruchtbaarheidsgraden die constant werden gehouden in de projectie, waarbij verondersteld werd dat het toekomstige vruchtbaarheidsgedrag niet zou veranderen.

De vruchtbaarheidstrends van de afgelopen jaren (die in het derde deel van de paper worden beschreven), en in het bijzonder sinds 2009, onderstrepen de noodzaak om de tot nu toe gebruikte methodologie te verbeteren. Dat moet hoofdzakelijk op twee punten gebeuren. Ten eerste werd geen rekening gehouden met de structurele determinanten van de vruchtbaarheid, in het bijzonder het toenemend aantal jaren dat onderwijs wordt gevolgd en de grotere arbeidsmarktparticipatie van vrouwen. Die determinanten beïnvloeden zowel het vruchtbaarheidsniveau als het vruchtbaarheidsschema. Ten tweede werd met de cyclische factoren, in het bijzonder de economische situatie die het vruchtbaarheidsschema op korte en middellange termijn kan beïnvloeden, amper rekening gehouden in het projectiemodel.

Deze Working Paper beoogt daarom een nieuwe methodologie voor te stellen die sinds 2020 wordt toegepast in het model om de bevolkingsvooruitzichten voor België op te stellen. Die vooruitzichten worden elk jaar gepubliceerd door het Federaal Planbureau en Statbel. De methodologie gaat ervan uit dat de vruchtbaarheid niet statisch is en wordt verklaard door zowel structurele (opleiding, arbeidsmarktparticipatie, enz.) als cyclische factoren (de conjunctuur, enz.). Met die factoren wordt rekening gehouden door drie elementen: (1) de mening van experten over vruchtbaarheidstrends op lange termijn, (2) een expliciete trend in het vruchtbaarheidsschema aan de hand van het Schmertmann-model (2003) en (3) de impact van cyclische en structurele determinanten van de vruchtbaarheid op basis van een foutencorrectiemodel.

Door de mening van verschillende experten te beschouwen, kan de onzekerheid over de toekomstige evolutie van de vruchtbaarheid – in bepaalde mate – in rekening worden genomen. Door rekening te houden met structurele elementen kan een relatief stabiel vruchtbaarheidsniveau op lange termijn worden bepaald. Door de cyclische elementen van de vruchtbaarheid te integreren, kan de vruchtbaarheidsevolutie op korte en middellange termijn worden aangepast op basis van het economisch klimaat, in het bijzonder de evolutie van de werkloosheidsgraad. Tot slot, door rekening te houden met de demografische parameters (in dit geval de modale leeftijd) bij het modelleren van het vruchtbaarheidsschema, kunnen transparante keuzes over de toekomstige evolutie van dit schema worden gemaakt, in het bijzonder de stijging van de leeftijd waarop vrouwen kinderen krijgen.

Het door het Federaal Planbureau ontwikkelde bevolkingsprojectiemodel is deterministisch en gebaseerd op de (demografische) componentenmethode. Er kan kritiek worden geleverd op deterministische projecties omdat ze geen informatie geven over de onzekerheid waarmee de bevolkingsprojectie is omgeven. Een manier om deze kwestie aan te pakken is de hypothesen transparant te maken: de resultaten van deterministische bevolkingsprojecties zijn rechtstreeks gekoppeld aan het gekozen scenario. De gebruiker van de projecties moet zich bewust zijn van dit scenario om de projectieresultaten correct te interpreteren. Deze Working Paper, die de projectiemethodologie voor de vruchtbaarheid in de nationale bevolkingsvooruitzichten in detail beschrijft, draagt bij tot die doelstelling.

1. Introduction

The methods for projecting fertility are numerous and varied. They are either based on probabilistic or deterministic methods using explanatory models or based on time series extrapolation. Expert judgment can also be taken into account. Some models simply project births by multiplying the total number of women by an average number of child(ren) per woman, but most project fertility by age of mother to take into account the fertility schedule and the age distribution of women of childbearing age. Finally, a choice has to be made on the ways to measure fertility: some models will include the total offspring (longitudinal or cohort approach), while other models use the total fertility rate (cross-sectional approach).

The aim of this Working Paper is not to provide an overview of the state of the art of the different methods for projecting fertility. It presents the methodology that has been applied since 2020 in the model used to draw up the population outlook for Belgium that is published every year by the Federal Planning Bureau and Statbel. This projection model is deterministic, is based on the (demographic) component method, and provides projections for the Belgian districts (NUTS 3). The population projection for Belgium is thus obtained by summing the projections at the district level.

In the past[1], the fertility projection methodology for national population projections was poorly developed, mainly due to data restriction. In the 2007-2060 population projection, the main assumption concerned the total fertility rate that was kept constant (except for the first years of the projection[2]). The age-specific fertility rates were projected by applying a gamma function that was estimated with available data to the projected total fertility rate.

As from 2012, it has been possible to calculate age-specific fertility rates at the district level (NUTS 3) using the National Register[3]. Updates of these data are available annually. The main assumption was then based on age-specific fertility rates at the district level. They were, however, held constant in the projection, assuming no change in future fertility behaviours.

Fertility developments over the past several years, and in particular since 2009, highlight the necessity to improve the methodology used so far. First, the *structural determinants of fertility*, in particular the increase in the number of years spent in education and in women's participation in the labour market, which influence both the level and schedule of fertility, were not taken into account. Second, *cyclical factors*, especially the economic situation, which can influence the fertility schedule in the short and medium term, were also hardly taken into consideration in the projection model.

This led us to review the method for projecting fertility. To correspond to the population projection model, the revised method remains deterministic and results in a projection of age-specific fertility rates and fertility rates by district. Fertility is measured and projected cross-sectionally. These fertility rates are no longer kept constant, however, but are based on an explanatory model that takes into account:

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1 Going back to 2008, year from which the population projection model for Belgium has been established at the Federal Planning Bureau.
2 See Federal Planning Bureau and Statbel (2008) for more details.
3 Source of administrative data. Main source of data used for the population outlook.

– Expert opinion on long-term fertility trends;
– The evolution of the fertility schedule using Schmertmann's model (2003);
– The effects of cyclical and structural determinants of fertility using an error-correction model.

This Working Paper first describes the general framework of the population projection for Belgium. Secondly, fertility in Belgium is placed in its historical context to highlight the key elements to be included in the revised projection model whenever possible. Then, before concluding, the new fertility projection method is described in detail.

2. The population projection model in a nutshell

Since 2008, population projections for Belgium have been drawn up jointly by Statistics Belgium (Statbel) and the Federal Planning Bureau (FPB). They are updated annually and are founded on a deterministic cohort component projection method, which is based on the components of demographic change. Starting from the latest observation of the population at the beginning of the year t (Pop^t), the births during year t (B^t) are added and the deaths (D^t) are subtracted (including the deaths related to the births occurring in the same year). Internal immigration (InI^t) is then added and internal emigration (InE^t) is subtracted. Finally, the model addresses international migration (adds immigration (I^t) and subtracts emigration (E^t). The resulting population is the *final population* at the end of year t, which becomes the population at the start of year t+1:

$$Pop^{t+1} = Pop^t + (B^t - D^t) + (InI^t - InE^t) + (I^t - E^t) \tag{1}$$

Splitting the total population by age x:

$$Pop_{x+1}^{t+1} = Pop_x^t - D_x^t + (InI_x^t - InE_x^t) + \left(I_x^t - E_x^t\right) \quad \text{for } x \text{ from 1 year old to last projected age} \tag{2}$$

$$Pop_0^{t+1} = Birth^t - D_{birth}^t + (InI_{birth}^t - InE_{birth}^t) + \left(I_{birth}^t - E_{birth}^t\right) \tag{3}$$

Where D_{birth}^t represents the deaths of children born in year t (and the same applies to the other components of the equation (3)).

The official population projections are not only carried out at national level but also at subnational level for regions and also for districts. Consequently, the projection model is based on a bottom-up approach. This allows assumptions to be made on mortality, fertility and migration at district level, whenever possible[4], so as to integrate specific local features. The projection of the population at regional level thus corresponds to the sum of the projected populations at district level, while the population projection for Belgium corresponds to the sum of the population in all the districts.

A distinction by group of nationality (Belgians and foreigners) is used primarily to develop assumptions on fertility, international migration and the change of nationality. The methodology for projecting international migration, internal migration and mortality is detailed in Vandresse (2015), Vandresse (2016) and Paul (2009), respectively. The methodology for projecting fertility is described in the rest of the present document.

[4] It greatly depends on the number of observations required to obtain statistically representative results at district level by gender, age and (groups of) nationality.

3. Historical fertility patterns in Belgium

1960 to 2008 - Decrease in fertility and increase in the age at childbirth

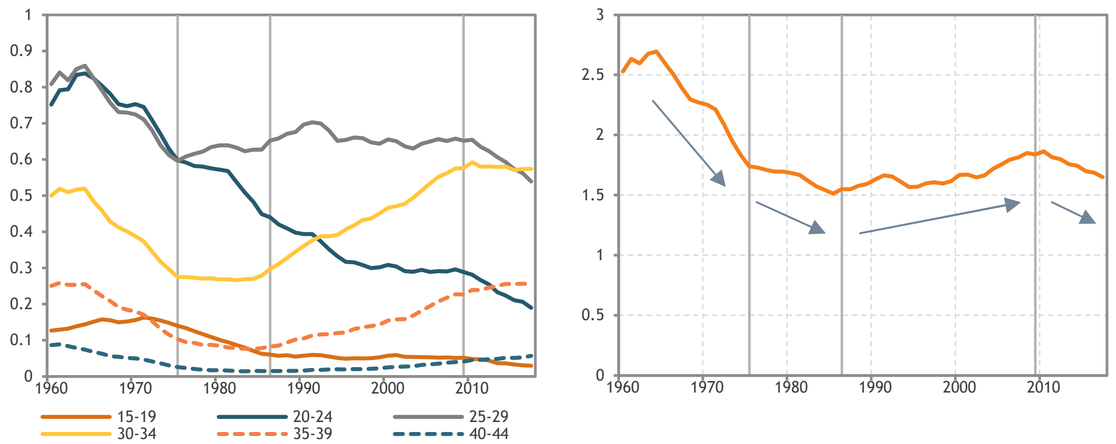
Graph 1 shows the evolution of the fertility rates by age group and the total fertility rate since 1961 for Belgium. The total fertility rate corresponds to the sum of the fertility rates by age and reflects the number of children that would be born per woman if she had the same fertility rates observed in a given year throughout her life.

Between **the mid-1960s and the mid-1970s** the total fertility rate dropped because of a decrease in the desired number of children by couples. Fertility decreases at all ages (from the age of 20). The total fertility rate decreased from 2.53 children per woman in 1960 to 1.74 in 1975.

The period **between the mid-1970s and the mid-1980s** is characterised by the first phase in which age at childbirth increased: fertility of women aged below 25 decreases, whereas it stabilises for women aged 25 and over. This leads to an additional decrease in the total fertility rate (1.5 in 1985).

Next, **until the end of the 2000s**, the delay in the age at childbirth reaches its second phase: a catch-up effect (increase in fertility of women aged 30 and over). The total fertility rate picks up and reaches 1.85 children per woman in 2008.

Graph 1 Fertility rates by age group (left) and total fertility rate (right) - Belgium



Source: Eurostat.

The decrease in fertility and the increase in the age at childbirth can be explained by structural changes in society, namely a rise in the educational attainment of women (and, by extension, the length of education) and an increase in women's labour market participation. Not to mention the impact of the widespread use of contraceptive methods. These make it possible to control for both the fertility level and schedule.

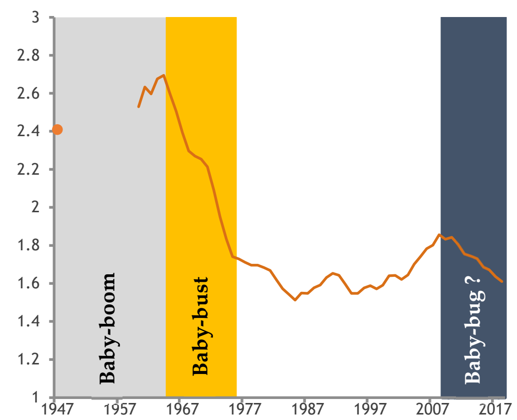
2009 to 2018 - Between certainty and uncertainty

Since 2009 the total fertility rate has decreased again. This decrease is mainly due to a drop in fertility of women under the age of 30 (see graph 1), which had nevertheless been stable since the mid-1990s. This evolution can be partly explained by the financial and economic crisis of 2008 and its consequences that impact especially young families: uncertainty on the labour market, more restrictive conditions for access to home ownership or the rental market. In times of economic crisis, plans to have a child would be delayed until material/financial conditions are met. This argument is particularly relevant at a young age, since the biological limit to procreation is still far off. Several studies show that fertility decreases with a delay during the recession and that this decrease is later partly recovered[5]. Under this assumption this would therefore be a temporary ('cyclical') decrease in fertility. Currently this catch-up effect has not yet been observed and the reasons that could explain this absence of recovery remain unclear. One thing is certain: the decrease in fertility is largely confined to childless women under the age of 30.

Beside its purely economic and financial impact, the 2008 crisis took place in a climate of greater global uncertainty, both geopolitically and in terms of societal developments. We might witness the transition from an *economic crisis* to a more uncertain *global socio-geopolitical-climate-economic context*. Classic indicators, such as the unemployment rate or the consumer confidence indicator, which are often linked to fertility, would no longer be adequate to capture the cyclical developments of fertility[6].

Recent fertility developments are still under debate. The following questions on the underlying causes remain unanswered. Is there a shift in the age at childbirth with a catch-up effect in the coming years? Do societal issues (including those related to the climate) influence the number of children desired by couples? Is a hyper-connected generation aware of all the (un)certainties in the world to be blamed? By analogy with the baby-boom and baby-bust generations (Graph 2), we could today speak of the baby-bug generation, as long as the factors explaining this decline remain uncertain. These factors not only influence age at childbirth, but also the desired number of children.

Graph 2 Total Fertility Rate - Belgium



Source: National Register - Statbel

The decline in fertility observed since 2009 may therefore be explained by both structural and cyclical factors. The importance of each of these factors has yet to be determined. In a recent study, Matysiak et.al. (2020) confirm, with a detailed econometric study, the impact of variables such as the unemployment rate and the long-term unemployment rate on fertility. Their study also highlights a disconnect between the impact of economic factors before and after the Great Recession of 2008. The negative effects of GDP and unemployment rate variables are more pronounced during the Great Recession. However,

5 See, in particular: Pailhé (2010), Sobotka et.al. (2013), Goldstein et.al. (2009), Matysiak et.al. (2020).
6 Comolli (2017).

the authors argue that these more pronounced effects can be explained by the effects of unobserved variables captured by economic variables that are introduced in the model. They mention in particular the risk of poverty or privatisation, structural changes in the labour market (increase in temporary contracts) or increasing uncertainty about future societal developments. In addition to the Great Recession, the COVID-19 pandemic will impact economic activity for a period that is yet to be determined. Generations of child-bearing age could be confronted with both the Great Recession and the pandemic. This does not help in alleviating the climate of uncertainty weighing on our society, nor the uncertainty as to fertility developments.

4. Projection of fertility - methodology

The projection of the number of births involves projecting age-specific fertility rates (ASFRs). Those ASFRs are then applied to the number of women by age (women aged between 15 and 49).

The methodology to project ASFRs by district and citizenship (Belgian – BE – or foreigners – F) consists of three main steps:

1. Making an assumption about the long-term structural fertility level (**SFer**), by district and citizenship.
2. Making a projection of the annual Total Fertility Rate (**TFR)**, by district and citizenship.
3. Making a projection of the Age-Specific Fertility Rates (**ASFRs**), by district and citizenship.

These steps are successively described in this section.

4.1. The long-term structural fertility level

Determining a long-term fertility level by district and citizenship is no easy task. Statistical methods based on the extrapolation of time series could have been used. There are two reasons why these methods were not adopted. The first is strictly statistical: in some districts, observations are not sufficient to achieve a robust estimate[7]. The second reason pertains to the willingness to base the projection on an explanatory model that explicitly describes the selected projection scenario. To do this, we rely on expert advice to determine a long-term fertility level for Belgium as a whole. In a second step, a level per district and per (Belgian or foreign) nationality, which is consistent with this overall level, is determined,

4.1.1. For Belgium as a whole – expert opinion

The long-term fertility level for Belgium was determined by collecting the views of ten experts in the field of fertility and population projections in Belgium. These experts work in academic circles or within federal or regional public bodies.

In view of gathering expert opinion, a first meeting was organised to discuss the historical fertility trend in Belgium and its main structural drivers. After the meeting, the experts received a survey with specific questions about the future of fertility. Among them, the following two are replicated in Box 1.

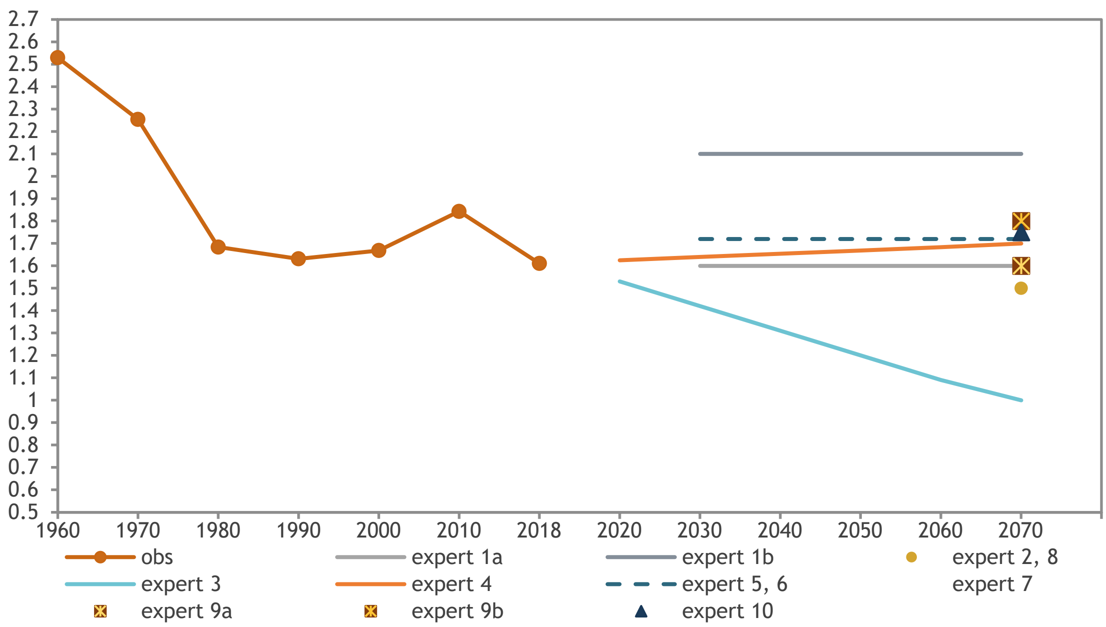
[7] Clustering methods could be used.

Box 1 Questions for the experts

1. What would be the level of fertility in Belgium in 2070?
2. For intermediate years [*tick and specify if necessary*]:
   - Fertility gradually reaches the level of 2070 mentioned in (1).
   - There will be a catch-up at the beginning of the period, following the decline observed since 2009. This catch-up ends in .... [*year to be specified by the expert*]

The experts' answers are summarized in Graph 3. Four experts (2, 8, 9 and 10) mentioned only a level of fertility in 2070. Three experts (experts 1, 5 and 6) mentioned that the level of 2070 should be reached in 2030. Two experts (experts 3 and 4) mentioned that the level of 2070 would be progressively reached. One expert (7) mentions that fertility should know a recovery effect, but without mentioning a specific level.

Graph 3 Long-term fertility - expert opinion



These results were then discussed in a second meeting to come to a common agreement on what the long-term structural fertility level should be in the reference scenario, namely 1.7 children. This level is based on the following two assumptions:

– the number of years spent in education will continue to increase for women;
– the share of women on the labour market will continue to grow[8];
– social issues (health and climate amongst others) or the hyper-connectivity of the younger generations to global (un)certainties could also impact downwards the number of desired children.

[8] This assumption is in line with the assumption adopted by the Study Committee on Ageing.

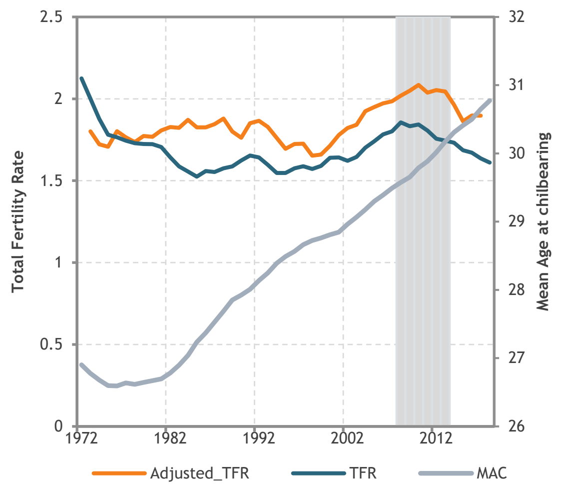
This assumption is made in a context where fertility measured by the total fertility rate has been sharply decreasing since 2009. The experts decided to retain the assumption that this decline can partly be explained by the economic and financial crisis of 2008: uncertainty on the labour market and more restrictive conditions of access to home ownership or the rental market are delaying plans to start a family. Consequently, a partial catch-up effect is expected in the coming ten years, to reach the structural fertility level of 1.7 from 2030 onwards. The partial catch-up effect is explicitly modelled in the second step (see section 4.2).

The recent evolution of the adjusted-TFR (Bongaarts and Sobotka (2012)) supports the assumption retained by the experts. The adjusted-TFR (adj_TFR) corresponds to the evolution of fertility without the tempo-effect[9], or in other words, to the TFR if the mean age at childbearing remains constant. Variation in the adj_TFR can be consequently interpreted as a quantum effect, namely a variation in the number of born children per woman.

The adj_TFR is computed as follows:

adj_TFR(t) = TFR(t) / (1-r(t))   where r(t) =[MAC(t+1) – MAC(t-1)] / 2

Graph 4 TFR, adj_TFR and MAC - Belgium



Looking at its evolution since 2009, the adj_TFR suggests that the decline in the TFR was initially due to a tempo effect, especially in 2010-2013. Indeed, the adj_TFR remains stable during this period, while the TFR decreases. But the adj_TFR starts to decrease in 2014. This can be interpreted as a sign of a gradual decline in fertility level (quantum). This is coherent with the assumption taken by the group of experts: the current evolution of fertility is partly explained by the effects of the 2008 economic crisis (tempo effect) and partly by the evolution of structural determinants – education, societal changes...- (quantum effect). Assuming that structural determinants will continue to affect fertility levels (quantum effect), the long-term fertility will be lower than the current adj_TFR.

4.1.2. At the district level

Since the population projections for Belgium are drawn up using a bottom-up approach, the assumptions must be established at the district level. Yet, the experts ‘assumption concerns Belgium as a whole. It would have been unrealistic to ask the experts for their opinion at the district level. We consequently applied a more practical methodology.

9 The tempo-effect corresponds to the impact of the change in the mean age at childbearing (MAC) on the TFR.

The time series of the TFR by district are available from 1991 to 2018, namely a period where the total fertility rate has been significantly influenced by the childbearing postponement, and where the cohort fertility trends change relatively slowly. For Belgium, the average total fertility rate over this period is 1.7, which corresponds exactly to the long-term structural level recommended by the experts. Hence, a pragmatical way of defining the long-term structural level of fertility at the district level would be to define it as the average TFR observed since 1991 for each district. Further efforts could be made in the future to improve this methodology.

4.2. Projection of the annual total fertility rate

The projection of the annual TFR rate by district *i* (and by citizenship) is based on an Error Correction Model (ECM). ECM is useful for estimating both short-term and long-term effects of covariates on the variable of interest. In the present context, it allows the impact of economic determinants (short-term or *conjunctural* effect) on the TFR to be estimated, taking the structural fertility level in the long run into account. Specifically:

$$\mathrm{dln}(TFR_{i,t}) = \beta_{1,i}*\mathrm{dln}(UR_{i,t}) + \beta_{2,i}*[\ln(TFR_{i,t-1}) - \ln(SFec_{i,t-1})] \qquad (1)$$

Where

- $TFR_{i,t}$ total fertility rate in district *i* and year *t*
- $UR_{i,t}$ unemployment rate in district *i* and year *t*
- $SFec_{i,t-1}$ structural level of fertility in the long run in district *i* and year *t*-1
- t time (year)

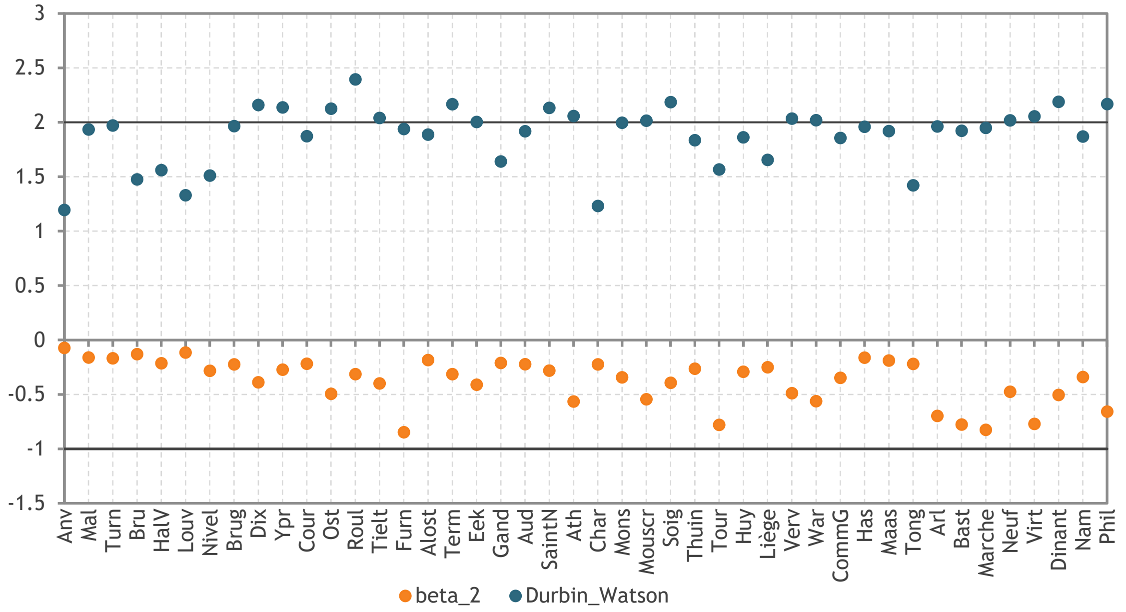
Equation (1) is estimated and then projected by district (and by citizenship). The explanatory variables (UR and SFec) must be available for the observation period (1991-2018) as well as for the projection period (2019-2070):

- The unemployment rate by district is unavailable in the projection. Consequently, each district is assigned the unemployment rate of its region (Brussels-Capital Region, Flemish Region or Walloon Region). For the 2019-2024 period, those data are based on the regional economic outlook published by the Federal Planning Bureau. For the 2024-2070 period, the unemployment rate is assumed to be constant at the level of 2024.
- The long-term structural fertility level for the projection period was described in the previous section. For the observed period, the Hodrick-Prescott filter is applied on the TFR_i and allows a trend to be identified.

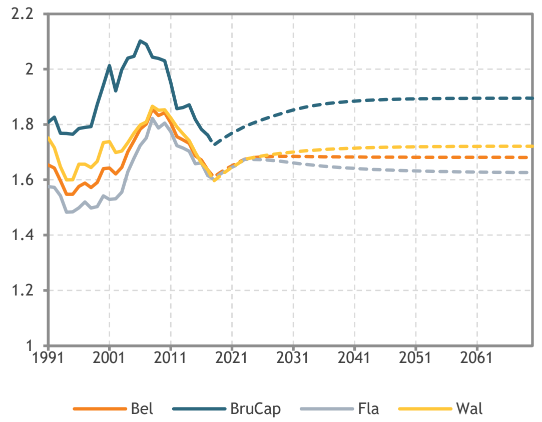
For the robustness of estimates, the following conditions must be met:

- The estimated coefficient $\beta_{2,i}$ must range between -1 and 0. This ensures a convergence of the TFR towards its long-term value, SFec. For each district, the coefficient meets the condition (Graph 5).
- The value of the Durbin-Watson must be near to 2 (no autocorrelation of the residuals). For some districts, the value is less satisfactory (Graph 5).

Graph 5 Error Correction Model (equation 1): values of β_2 and of the Durbin-Watson test by district



Graph 6 Projection of the Total Fertility Rate (TFR)



Source: 1991-2018: Statbel; 2019-2070, Demographic outlooks 2019-2070

By way of illustration, the projection of the TFR for Belgium and its three regions is presented in Graph 6. According to the model, the TFR is expected to rise in the coming few years. This increase is explained by the short-term component of the ECM (equation 1), namely the negative projected trend of the unemployment rate. Then, the TFR converges progressively to the long-term level. The projection at the district level is shown in Table 1 (in the Annex).

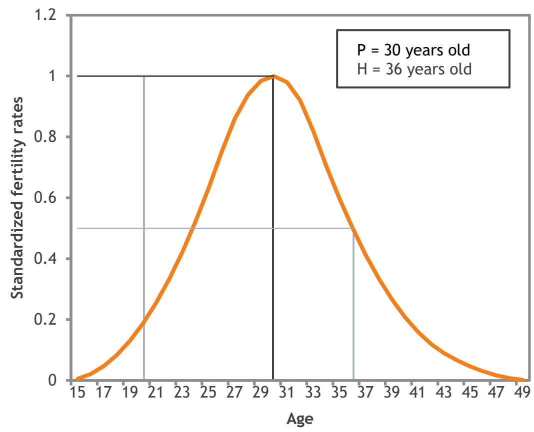
4.3. Projection of the age-specific fertility rates (ASFRs)

The TFR does not give enough information to project the number of births. In the model applied by the Federal Planning Bureau, the number of births is computed by multiplying the number of women by age and the corresponding age-specific fertility rates.

To calculate the age-specific fertility rates from the TFR, the method described in Schmertmann (2003) is applied. The main idea behind Schmertmann's methodology is to build the fertility schedule (or fertility curve) on three demographic parameters (see Graph 7):

- The TFR.
- The age at which fertility reaches its peak level (P).
- The youngest age (H) above P at which fertility falls to half of its peak level.

Graph 7 Illustration of the fertility curve with Schmertmann's (2003) parameters

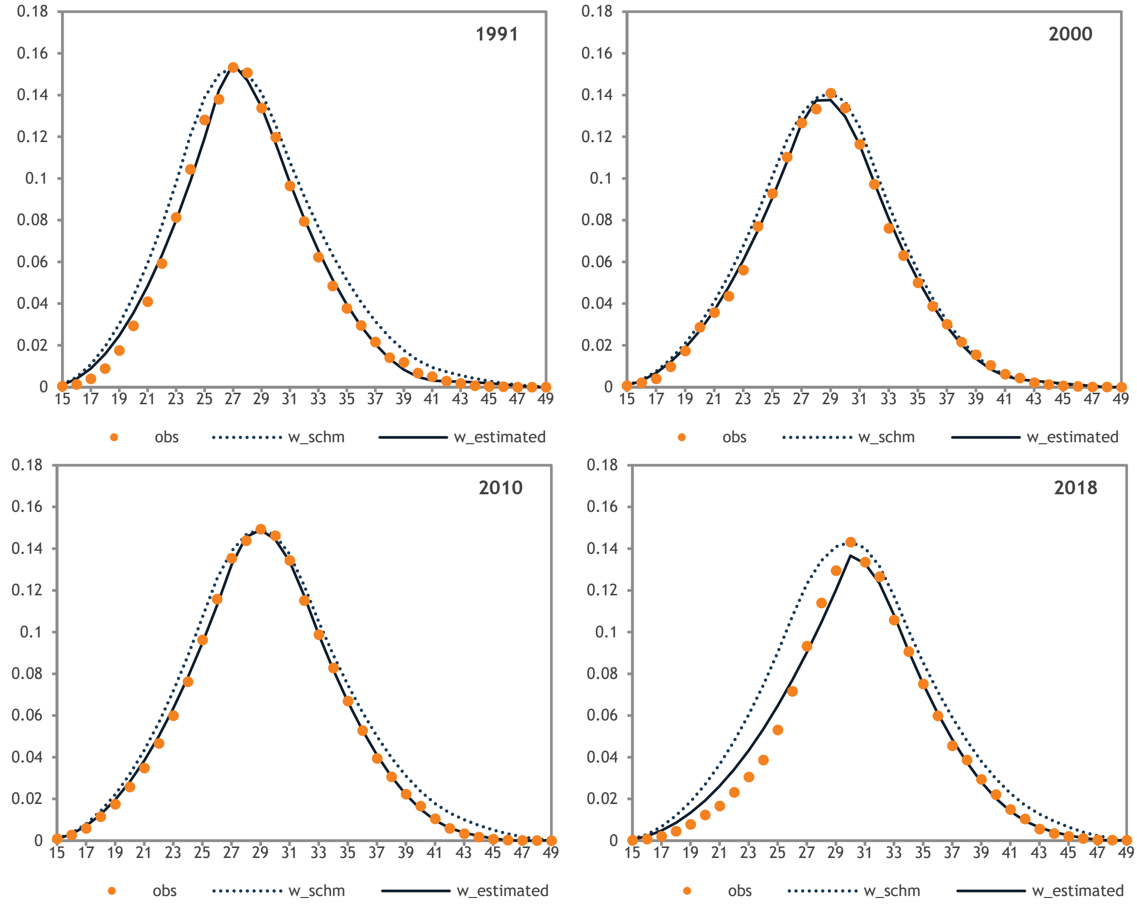


Those parameters allow important indicators of the historical trend of the fertility curve to be taken into account, namely the postponement of childbearing (shift of P to the right) and the control (or stopping) of fertility (post-peak fertility control).

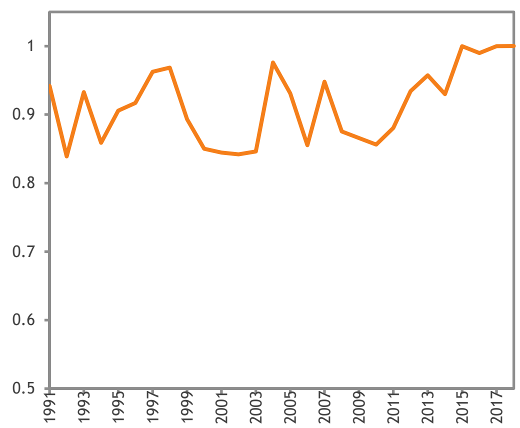
At this stage, we have the TFR in projection (see section 4.2) but we also need the two other parameters (P and H) in projection. Both are projected by district with a logarithmic trend estimated over the 1991-2018 period and projected up to 2070. The logarithmic trend allows the fertility schedule to be kept within plausible range.

Based on those three parameters, the ASFRs can be estimated with a quadratic splines function (see Table 2 in Annex). Note that the parameter *w* of Schmertmann' s model has been adapted (see below). The parameter *w* determines how the fertility curve concentrates around the modal age (P). The comparison of the observed and calculated fertility curves indicates that the value of the parameter *w* as computed with Schmertmann's model (see annexed Table 2) is not optimal. Graph 8 illustrates this issue by showing, for Belgium, the observed curves (obs.) and the fertility curves based on Schmertmann's model (w_schm). Parameter *w* does not seem to sufficiently capture the change (with time) in fertility concentration around modal age (P). The fertility curve is better fitted when parameter *w* is estimated (curve w_estimated).

Graph 8 ASFRs - Belgium - citizenship = BE: a comparison between the observations, Schertmann's model and the adjusted Schmertmann's model



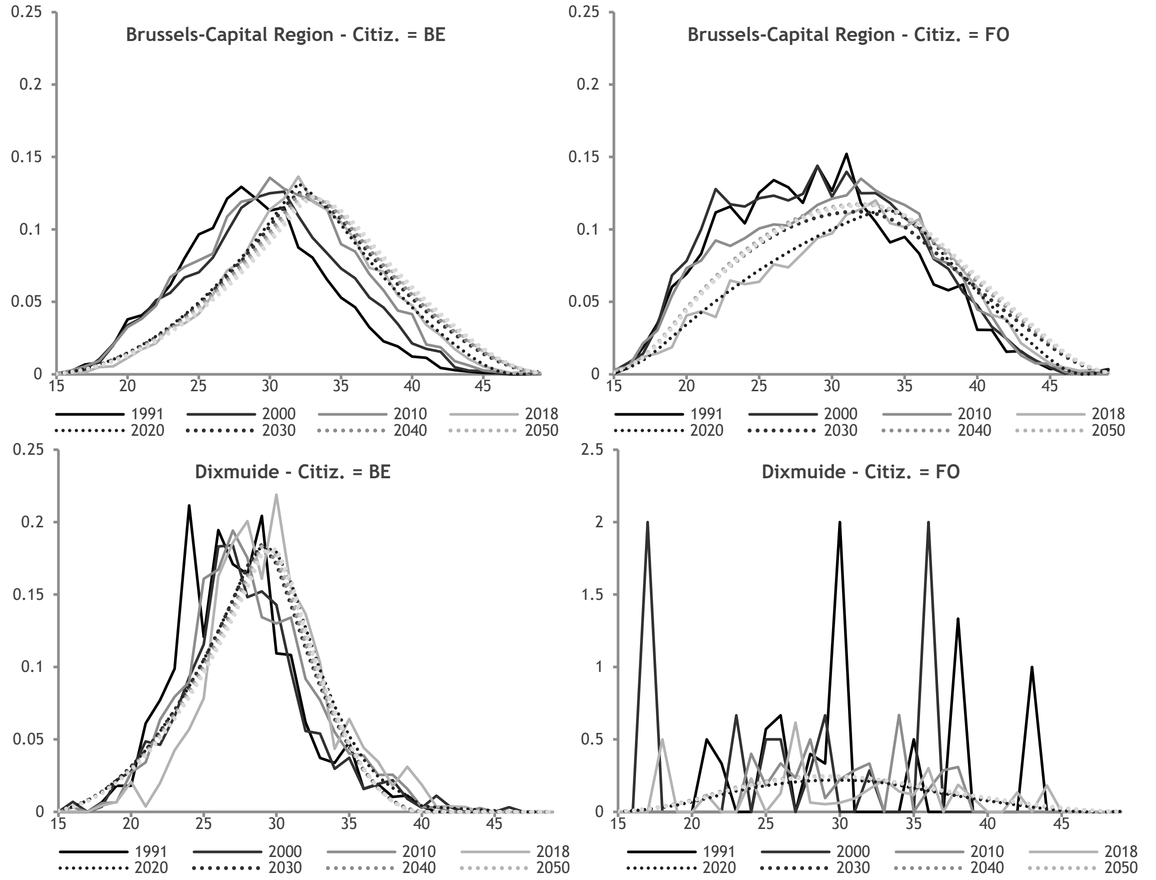
Graph 9 Parameter w for Belgium: estimated values



The estimated value of the parameter w for calculating the fertility curve of Belgian women is presented in Graph 9. Over the 1991-2010 period, the parameter value seems relatively stable, around 0.9. Next, an upward trend seems to develop. This increase is explained by the marked and persistent decline in fertility among women under 30 years of age since 2009. Based on this observation, the value of parameter w, as defined in Schmertmann (2003), is adapted in projection and is determined consistent with the fertility rate assumption. Specifically, in agreement with the expert group, the value of parameter w is defined by the average of the estimated w over a recent period. The increase in the number of education years, the rise in women's participation in the labour market, as well as the possible decline in the number of desired children are expected to maintain fertility more concentrated around the modal age.

Again, it should be remembered that ASFRs are projected at the level of districts, by distinguishing between women of Belgian and foreign nationality. To compensate for the lack of observations at district level for women of foreign nationality, the ASFRs are calculated by applying to their TFR obtained for each district the fertility curve projected for the region to which the district belongs.

Graph 10 Projection of the ASFR by district and citizenship (BE – FO) - illustration

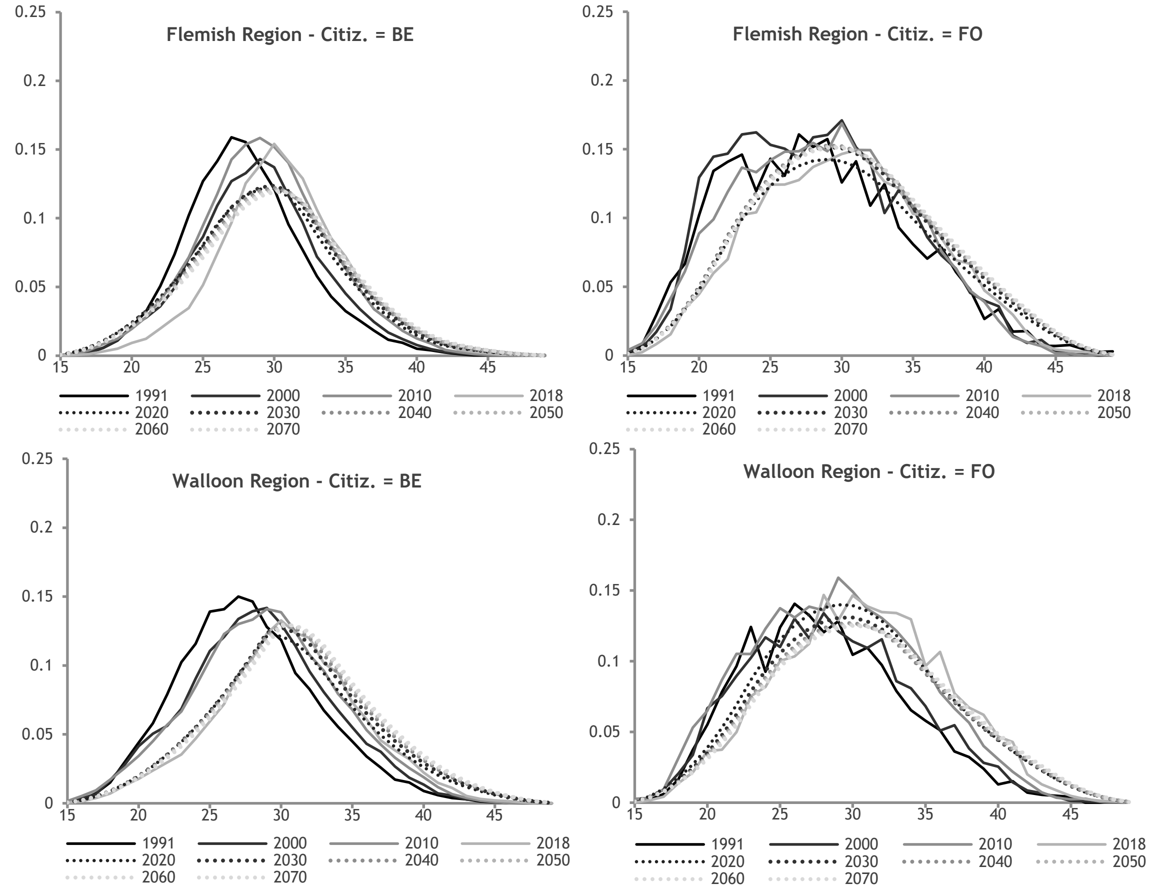


Source: 1991-2018: observations – National Register, Statbel; 2019-2070: demographic outlook, 2020.

The results for two districts are presented in Graph 10. Since these two districts have different demographic characteristics, certain choices made for the projection can be highlighted. Brussels-Capital is the most populated district, it represents 10% of the resident population of Belgium. It overlaps with the Brussels-Capital Region, capital of Europe. 35% of its population has a foreign nationality. The observations are sufficient, both for the fertility curve of Belgian women and for that of women of foreign nationality. Decomposing TFR into ASFRs according to the method of Schmertmann (2003) can be done in both cases.

The district of Dixmuide is home to 0.4% of the resident population of Belgium; 97% of its population holds Belgian nationality. Consequently, the fertility curves observed in the district of Dixmuide are much more erratic for the foreigners. The results obtained with the Schmertmann method for the fertility of foreigners could not be interpreted. The fertility curve of foreign women that is estimated at the level of the Flemish Region (Graph 11) is then applied to the TFR that is projected for women of foreign nationality in the Dixmuide's district.

Graph 11 Projection of the ASFR for the Flemish and Walloon Regions by citizenship (BE – FO)



Source: 1991-2018: observations – National Register, Statbel; 2019-2070 : demographic outlook, 2020.

5. Conclusion

In the context of the annual revisions of the population outlook, the assumption on fertility was – until a few years ago – largely uncontested and widely accepted. The international migration component often monopolised all attention, both because of its increasing impact on population growth in Belgium and because of the uncertainty surrounding its future evolution and the resulting modelling difficulties. Fertility was, however, not static. As mentioned in section 3, fertility has seen a remarkable evolution since the end of World War II that can be explained by both structural and cyclical factors.

Structural factors include, in particular, the increases in both the number of years spent in education and in women's participation in the labour market. These influence both the desired number of children and the fertility schedule (increase in age at childbirth). Developments in economic activity – and in the unemployment rate – are among the *cyclical factors* and impact in particular the fertility schedule.

Since 2009, fertility has undergone a somewhat surprising evolution (see again section 3), marked by uncertainty surrounding the explanatory factors of the trend and, in consequence, its future evolution.

The fertility trend is therefore not a smooth, predictable process. Just as for international migration, a projection methodology was needed that can integrate, as far as possible, the elements explaining its past and future evolution. The new choices made in projecting fertility levels are not neutral for future population growth. Two fertility scenarios have consequently been published in the 2019-2070 population projection published in March 2020 (Federal Planning Bureau and Statbel, 2020).

The methodological choices were based on different criteria:

1. integrating expert judgment;
2. integrating the structural and cyclical determinants of fertility; and
3. modelling the evolution of the fertility schedule based on demographic parameters (hence the choice of Schmertmann's 2003 model).

By considering the judgment of different experts, the uncertainty surrounding the future evolution of fertility can – to some extent – be taken into account. The inclusion of structural elements can help to determine a relatively stable long-term fertility level. Integrating the cyclical elements of fertility makes it possible to adjust the fertility trend in the short and medium term depending on the economic activity, in particular the evolution of the unemployment rate. Finally, by integrating demographic parameters (in this case the modal age) into the modelling of the fertility schedule, transparent choices on the future development of this schedule can be made, in particular a continued increase in age at childbirth.

The question of transparency in demographic projections is often raised to ensure that these projections are interpreted correctly (UNECE, 2018). This transparency can be achieved with the chosen method. It highlights the choices made by experts on the long-term evolution of fertility and the evolution of the parameters that modify the fertility schedule. The importance of the transparency of the assumptions may be particularly relevant since this is a deterministic model: the results of the population projection are directly linked to the selected scenario. The user of the projections must be aware of this scenario to correctly interpret the projection results.

Naturally, this methodology can always be improved upon and other choices could have been legitimately made. It is interesting to note a report published by Statistics Norway (Folkman and Syse, 2020), which compiles the different methods for projecting fertility chosen by the different national statistical offices. With regard to possible improvements that could be made to determine the long-term evolution of fertility, it could be interesting to take into account fertility by age and by birth order, in addition to taking into account expert judgment. Another point that requires attention is the distinction between the fertility of women of Belgian nationality and that of women of foreign nationality. At the present time, a distinction is made as to the current nationality of the women. A distinction as to the nationality of origin might be more relevant. This information is, however, not yet available in the Belgian statistical apparatus. In any case, more research is needed to understand all the determinants of the current fertility decrease. Special attention will also need to be paid to the impact of COVID-19 on fertility in the coming years, adding further uncertainty to the projection.

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7. Annex

Table 1 Fertility level by district

Districts	2018	2030-2070	Districts	2018	2030-2070
Anv	1.74	1.79	Char	1.67	1.77
Mal	1.60	1.64	Mons	1.60	1.68
Turn	1.55	1.54	Mouscr	1.73	1.75
Bru	1.73	1.90	Soig	1.64	1.73
HalV	1.71	1.64	Thuin	1.60	1.68
Louv	1.46	1.54	Tour	1.42	1.65
Nivel	1.55	1.69	Huy	1.55	1.73
Brug	1.53	1.55	Liège	1.57	1.68
Dix	1.85	1.73	Verv	1.68	1.84
Ypr	1.70	1.75	War	1.58	1.62
Cour	1.69	1.68	CommG	1.89	1.58
Ost	1.60	1.61	Has	1.45	1.53
Roul	1.71	1.67	Maas	1.53	1.54
Tielt	1.62	1.67	Tong	1.46	1.47
Furn	1.70	1.60	Arl	1.48	1.65
Alost	1.59	1.51	Bast	1.74	1.93
Term	1.53	1.59	Marche	1.61	1.87
Eek	1.68	1.57	Neuf	1.62	1.88
Gand	1.50	1.60	Virt	1.68	1.85
Aud	1.54	1.67	Dinant	1.68	1.85
SaintN	1.71	1.71	Nam	1.52	1.73
Ath	1.53	1.67	Phil	1.60	1.68

Table 2 Estimation of fertility curve with Quadratic Splines function (Schmertmann 2003)

Function and parameters	Description
x	Age from alpha to Beta (alpha = 15 years; Beta = 49 years)
f(x)	R * $\Phi(x)$where $\Phi(x) = \sum_{k=0}^{4} \Theta_k (x - k_k)^2$
k_0	alpha (the youngest age at which fertility rises above zero)
k_1	(1-w)* αlpha + w*P
	où w = min [0.75,0.25+0.025(P- αlpha)]
	the later P is late, the closer k_1 is to P
k_2	P
k_3	(P+H) /2
k_4	(H+50) /2
f(x) is normalized	TFR = R * $\Phi(x)$
Slope	= 0 at age P and at age 50.
R	Scalar such that f(x) = R * $\Phi(x)$
Θ_k	Parameters