Is the twin-boom in developed countries coming to an end?

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Abstract

The twinning rate has increased dramatically over the last four decades in developed countries. Two main factors drive this increase: delayed childbearing, as older women tend to have twins more frequently, and the expansion of assisted reproductive technology (ART), which carries an increased risk of multiple births. We document the twin boom in developed countries with data from civil registration systems. We estimate the share of the increase in twinning rates due to the increase of the age at childbearing and, by implication, the share due to other causes, mainly infertility treatments. A major aim of the paper is to find out whether the twin boom is coming to an end. Negative health outcomes associated with multiple deliveries have – at least in some countries – led to changes in ART regulations and practices, which may or may not have influenced the upward trend. We find that in one out of four developed countries the twinning rate reached a plateau around the early 2000s and decreased afterwards. We examine the reasons for this reversal, in particular changes in ART policies and practices, and discuss the future trends in twin frequency.

1. Introduction

The twinning rate has increased dramatically over the last four decades in nearly all countries for which we have information from vital statistics (Hoekstra et al. 2008; Pison and d'Addato 2006). For example, it has increased in the United States from 9.5 twin deliveries per 1,000 deliveries in 1975 to 16.9 in 2011 (Martin et al. 2012). It has more or less doubled in many developed countries over the same period, increasing for example from 9.9 to 16.1 in England and Wales, 9.2 to 17.2 in Germany, 9.3 to 17.4 in France, 9.6 to 21.2 in Denmark, and from 5.0 to 14.6 in South Korea.

This increase is an important public health issue because twin babies are more fragile than singleton ones, due to their low birth weight, their tendency to be born premature, and complications at birth. In all parts of the world, the risk of giving birth to a stillborn twin is three to four times as high as that of giving birth to a stillborn singleton (Pison 1992). Also infant mortality is much higher among twins than among singletons (Guo and Grummer-Strawn 1993; Pison 1992). The birth of twins (compared to a singleton) may have negative impacts on the parents too. There is evidence suggesting twin births are associated with higher post-partum depression in mothers and with a small increase in divorce rates (Choi, Bishai and Minkovitz 2009; Jena, Goldman and Joyce 2011).

A major reason for the increase of twinning rates is the strong rise of fertility treatments since the 1970s. Techniques like ovulation stimulation and assisted-reproductive technology (ART) are associated with a highly increased risk of multiple births. However, in the same period also the average age of the mother at first birth has increased considerably and the incidence of multiple pregnancies is known to increase with the mother's age. Since the turn of the century, raising concerns about the high number of twins (and even triplets) with the associated health risks for mother and child, have led to changes in ART practices in some countries, including a reduction of the number of embryo's transferred to the uterus (Hazekamp et al. 2000). However, at the same time the number of treatments is still increasing, and the group of women undergoing these treatments is getting older (Kupka et al. 2014).

These developments raise a number of questions regarding the trends in twinning rates in developed countries. To what extent is the increase of the twinning rates since the 1970s due to an increase in the maternal age at birth and to what extent to the rise of ART and other fertility treatments? Will twinning rates continue to increase or will they reach a plateau or even start to decrease under influence of changing ART practices? Can we predict in which countries which developments will are more likely to take place?

This paper aims to answer these questions on the basis of a compilation of all available statistical information on twin births in developed countries. In the next section (2) we describe how twinning rates have changed in developed countries over the last century. In section 3 we examine whether the increase over the last 40 years was caused by changes of age at childbearing or diffusion of infertility treatments, and propose estimates of the share of increase due to each. The fourth section focuses on the reversal of the trend which we observe for some countries and discusses the reasons for this. In this preliminary version of

the paper, this fourth section is only a draft. It will be expanded in the final paper. For the conference paper, we will also explore possible future changes under various demographic and social scenarios.

2. How have twinning rates changed in developed countries (since we have data)?

To gain a proper perspective, the changes in the frequency of twin maternities in developed countries over the recent decades should be seen in their historical contexts. In Figure 1, we selected six European countries for which long historical series of the twinning rate are available, going back in the past to 1900 or near that year (one exception in figure 1 is Greece for which the series start in 1956). We added four non-European countries: the USA, for which we could go back to 1915, and three East-Asian countries or territories for which the series start in the 1970s (Japan, Hong Kong, Singapore).

The twinning rate is the proportion of twin deliveries out of the total number of deliveries, expressed per 1,000 deliveries. It was computed for each given year using the total number of confinements as the denominator and the annual number of twin confinements as the numerator. There is no unique database providing statistics on births by multiplicity and by year for all countries for which such information exists. We collected data from the civil birth registration systems of the different national statistical offices and from earlier studies where data from official registers had been collected and compiled[1].

<Figure 1 about here>

Several insights can be drawn from Figure 1. First, twinning rates have changed considerably over the last 100 years in these countries, with overall range of variations from 1 to 2 in many of these countries, from 1 to 2.5 in some cases (Denmark, Singapore) and even from 1 to nearly 3 in the most extreme ones (Greece, Hong Kong).

Second, in all the European countries and in the USA, since the end of Second World War, there has been a decrease followed by a marked increase, with a minimum in the 1970s. For most East-Asian countries, no data are available to examine the trend before the 1970s, but a similar trend as in the European countries and in the USA is observed since the 1970s. Compared to the 1970s, the twinning rate has more or less doubled in most countries, and nearly tripled in Greece and Hong Kong.

Third, in some countries, the twinning rate seems to have reached a plateau after 2000 and to have diminished afterwards. This is the case for Denmark, the Netherlands, Norway and

[1] The statistics published by the statistical offices do not always refer to the same definition of a twin delivery. For example, in some countries, in case of multiple deliveries, only deliveries in which at least one child was born alive are included. In other countries, all deliveries are included including those in which all children were born dead (still-born). However, such variations of the definition have only a very small effect on the estimates.

Japan in Figure 1. In some other countries, the increase seems to have decelerated, but it is not clear whether the twinning rate reached a plateau.

Finally, this pattern of changes is observed regardless of the general level of twinning in the country. As is well known, the twinning rate varies across regions and countries. In particular, it is much lower in East-Asia compared to Europe (Bulmer 1970; Smits and Monden 2011), as is also illustrated in Figure 1.

3. Age at childbearing or infertility treatments?

3.1 Mean age at childbearing and twinning rates

The probability that a woman who conceived spontaneously or "naturally", i.e. without the help of medical assistance, delivers twins is determined by various factors. The most important factors are maternal age, birth rank, and region or country[2](Bulmer 1970). We first examine the role of changes in age at childbearing for twinning rates before we move on to the role of medically assisted reproduction (MAR)[3].

Figure 2 shows twinning rates by age of the mother in the period 1965-1969 in four countries: the USA[4] and three European countries: England and Wales (in the North of Europe), France (in the Middle) and Italy (in the South). We selected the 1965-1969 period because it precedes the diffusion of MAR and thus shows us twinning rates under spontaneous conception.

<Figure 2 about here>

The frequency of twin deliveries varies considerably with the mother's age group. We observe similar patterns in the four countries. From 6 per thousand before the age of 20, the frequency increases steadily until 35-39 age-group where it reaches a maximum of around

[2] Differences between regions, countries and races reflect partly genetic differences (Hoekstra et al., 2008).

[3] The term "medically assisted reproduction" (MAR) is wider than the often-used term "artificial reproductive technology" (ART). ART consists of treatments in which both sperm and oocytes (eggs) are handled outside (i.e., in vitro) of the woman's body and embryos are transferred for the purpose of establishing a pregnancy. This includes, but is not limited to, in vitro fertilisation (IVF) and its variant, intracytoplasmic sperm injection (ICSI). MAR includes ART and more simple techniques, like ovarian stimulation, that also increase the likelihood of twin births.

[4] In France and in the USA, the national statistical office publishes statistics on multiples births by age of mother with the detail by type of plural delivery: twin delivery, triplet delivery, etc., so the rates of twin deliveries by age-group can be calculated; in England and Wales, and in Italy, the detail by plural delivery is not provided, so only rates by age-group of multiple deliveries can be calculated. The inclusion of deliveries with more than two babies (triplets, quadruplets, etc.) does not change however much the estimate since these have represented a maximum of 1% of all multiple deliveries during the period 1965-59. The proportion increased in the 1980s and 1990s up to a maximum of 4% of all multiple deliveries, when there was a triplet boom; more recently, the proportion decreased to 2% or less.

15 per thousand. After ages 35-39 it diminishes rapidly to around 7 per thousand for age-group of 45 and over. At all ages, the twinning rate is slightly higher in England and Wales than in France, the maximum at age 35-39 years being respectively 16.4 and 13.8. The rates for Italy and the USA take an intermediate position.

Given this relationship, we may expect changes in the overall twinning rate of a country when the distribution of the age at childbearing changes. Let us take the case of France as an example. Figure 3 shows the evolution of the mean age at childbearing in this country since 1900, and in parallel, the evolution of the twinning rate. In the beginning of the 20th century, the mean age of mothers was close to 29.5 years in France and it followed a downward trend over the first three quarters of the century to around 28 years in the middle of the century and falling to a minimum of 26.5 in 1977. A rapid increase then followed and by the beginning of the 2010s, the average age was over 30 years.

<Figure 3 about here>

Twinning rate changes are partly linked to modifications in childbirth schedules. The twinning high of World War I is thus partly due to the rise in the mean age of women at childbirth during wartime. Between 1910 and 1914, the average was close to 29; the outbreak of the war prompted a sudden increase, up to almost 30, between 1915 and 1919. After the war, the rate dropped back to prewar levels. Conversely, when the mean childbearing age fell, as in the 1960s and 1970s, the twinning rate declined as well. Similarly, when the mean age at childbirth increased at the end of the 1970s, the twinning rate rose as well[5].

<Figure 4 about here>

The trend towards later childbearing since the 1970s is observed in nearly all the developed world as illustrated by figure 4 with a selection of countries. This trend is associated with the

[5] However, early or late childbearing only accounts for part of the variations in twinning incidence. For instance, the peak level of the twinning rate during WWI is also due to the fact that couples who conceived during war years were among the more fertile (Pison, G. 2000. "Nearly half of the world's twins are born in Africa." *Population & Societies*(360):1-4, Pison, G.and N. Couvert. 2004. "The Frequency of Twin Births in France. The Triple Influence of Biology, Medicine and Family Behaviour." *Population-E* 59(6):765-794.). Many men were fighting at the front, and a high proportion of conceptions occurred during leaves. These leaves were very short, and the couples that did manage to conceive were the most fertile. Children born to hyperfertile women thus represented a larger proportion of births than they did in peace time, and hyperfertile women are probably those who are more at risk to have fraternal twins (ibid.).

From the opposite angle, the drop in the twinning rate observed in the 1960s was not only due to the fact that mothers had their children at a younger age; the age factor being equal, the twinning rate also decreased (cf figure 8 after). An overall decline in the fertility rate occurred at that time, and large families were fewer. Women whose first children were twins reached upon the first pregnancy–or the second, for those who wanted three children–the desired number of children. These women were less likely to have subsequent pregnancies than those who had had the same number of pregnancies, but no twins. Thus, women predisposed to having twins were less and less represented in birth orders following the first, since they were more likely to control their pregnancies: as a result of this selection, the twinning rate declined. The selection effect associated with fertility control is probably the true mechanism of what has long been described as the effect of parity (ibid.).

lengthening of time spent in education, the increase in female labour force participation and the growing desire among women to wait until they are well settled in life, with qualifications, a stable job, a place to live and a lifetime partner before starting a family (Frejka et al. 2008; Lesthaeghe and Van de Kaa 1986). The spread of modern contraception has contributed to this trend by reducing the frequency of unplanned pregnancies, notably at young ages. The difficulty of reconciling work and family life has also played a role, especially in countries where family policies are limited (Thévenon 2008).

3.2 How much of the increase in twinning rates can be attributed to the delay in child bearing and how much to other factors?

Delayed childbearing since the 1970s has pushed up the twinning rate but other factors like MAR have had also an influence. One method to separate the two effects is to estimate what would have been the increase of twinning rate if age distribution of mothers had not changed. We can compute a "standardized" twinning rate based on a constant age distribution of mothers equal by convention to that of a particular year. To make this calculation we need estimates of the twinning rate by age of the mother for each year. Such age-specific twinning rates are available only for a minority of developed countries. The USA, England and Wales, and France, are in this case, and Figure 5 shows the trends in standardized twinning rate since 1970 based on the age distribution of year 1970 (1971 for the USA since data are missing for 1970), and compares it to the observed trend in the three countries.

<Figure 5 about here>

In France, the actual twinning rate increased from 9.4 in 1970 to 16.3 in 2005, so it was multiplied by a factor of 1.73. If the age distribution of mothers had not changed and had remained that of year 1970, the increase would had been less, from 9.4 to 13.6, a multiplication by 1.45. If we consider that delayed childbearing and other factors are independent and combine their effects, we can conclude that delayed childbearing alone would have multiplied twinning rate by 1.20 (1.73/1.45).

In England and Wales, similarly, the actual twinning rate increased from 10.4 in 1970 to 14.9 in 2005, so it was multiplied by a factor of 1.43. If the age distribution of mothers had not changed and had remained that of year 1970, the increase would had been less, from 10.4 to 12.5, a multiplication by 1.20, so delayed childbearing alone would have multiplied twinning rate by 1.19 (1.43/1.20).

In the USA, the actual twinning rate increased from 8.9 in 1971 to 16.4 in 2005, so it was multiplied by a factor of 1.84. If the age distribution of mothers had not changed and had remained that of year 1971, the increase would had been less, from 8.9 to 13.9, a multiplication by 1.54, so delayed childbearing alone would have multiplied twinning rate by 1.19 (1.84/1.54).

Unfortunately, the method used for France, England and Wales, and the USA, cannot be applied to all developed countries. We would need age-specific twinning rates and age distribution of deliveries for the different years, or, if not available for all the years, at minimum, for the first year and the last year of the period. Although age distributions of deliveries are available for nearly all countries, this is not the case for age-specific twinning rates.

As an alternative, we propose a simple method to assess how much of the increase in twin rates can be attributed to delayed childbearing and how much to other factors (i.e. MAR). We calculate seven age-specific twinning rates (<20, 20-24, 25-29, 30-34, 35-39, 40-44, 45+) on the basis of the distribution of deliveries by mothers' age and status of delivery (twin or not) for the years 1965-1969 from vital statistics in Italy, USA, England and Wales, and France (Figure 2). We chose 1965-1969 because the twin rates in these years were not yet affected by MAR. A further assumption we are making is that the average of these four countries can be reasonably applied to other North-American and European countries. **[For the PAA presentation we will extend the model by taking into account more countries, total fertility and parity]**

Next we extract the number of births by mothers' age for the years 1970-2005 from the Human Fertility Database (HFD) (Jasilioniene et al. 2012) or national statistics if no HFD data are available. We apply the average age-specific twinning rate to the observed number of births to predict the overall twinning rates by country by year if only the age distribution of mothers had changed. Figure 6 shows the observed and predicted twinning rates for England and Wales, France, the Netherlands and the USA. The difference between the predicted twinning rate in 1970 and the predicted figure for 2005 reflects the increase in twinning rates due exclusively to delayed child-bearing. The difference between the observed twinning rate and the predicted twinning rate thus reflects the contribution of all other factors, primarily MAR.

<Figure 6 about here>

This method has been applied to all developed countries for which we have estimates of the total twinning rate (without distinguishing age-group of mother) since 1970. We used the age distribution of deliveries as available in the Human Fertility Database. The countries are listed in table 1 and, for each one are indicated the twinning rate in 1970, the twinning rate in 2005, the observed increase over the period 1970-2005 (expressed by the multiplication factor), the predicted multiplication factor if only childbearing had been delayed, the estimated multiplication factor if only other factors had played a role (mainly MAR), the ratio between the increase due to delayed childbearing and that due to other factors, and the estimated fraction of the overall increase due to other factors (in %). Figure 7 shows the share of increase due to each factor.

<Table 1 about here>

<Figure 7 about here>

[For the PAA presentation, we will add countries in Table 1 and Figure 7, and we will show in an appendix similar trends to those shown in Figure 6, for all developed countries for which the method can be applied.]

For the countries for which age-specific twinning rates are available, the estimates obtained using the model can be compared to that one obtained through computation of age-standardized twinning rates. For example, in the case of France, where twinning rate was multiplied by 1.73 from 1970 to 2005, age-standardized twinning rates indicate that it would have been multiplied by only 1.45 if the distribution of mother ages had not changed. Using the model, we find 1.50, which is not too different. Similarly, in England and Wales, where twinning rate was multiplied by 1.43, age-standardized twinning rates indicate that it would have been multiplied by only 1.20 if the distribution of mother ages had not changed. Using the model, we find 1.26, which is close also. And in the USA, where twinning rate was multiplied by 1.84 between 1971 and 2005, age-standardized twinning rates indicate that it would have been multiplied by only 1.54. Using the model, we find 1.61, which is also close. With this method, contrasts between countries are conserved.

If age at childbearing had not changed and only other factors had been in action, the twinning rate would have increased only by 40% to 50% on average from 1970 to 2005 in the 13 countries considered in Table 1 and Figure 7, with large differences between countries, the lowest increase being in Estonia (22%) and the highest in the Czech Republic (64%). If, on the contrary, only age at childbearing had changed and in particular MAR had not developed, the increase of the twinning rate would have been only 15% on average, with differences between countries, the lowest increase being again in Estonia (5%) and the highest again in the Czech Republic (22%). The effect of MAR is twice as important as the effect of delayed childbearing on average, with again large differences between countries: in Estonia the effect of MAR is four times that of delayed childbearing ; in Sweden, both effects are similar.

3.3 Medically assisted reproduction (MAR)

By the end of the 1960s, doctors began to prescribe hormonal treatments to stimulate ovulation to women who had difficulties to get pregnant. While these treatments allowed hypofertile women to conceive, they also significantly increased the risk of multiple pregnancies. When ovarian stimulation alone does not produce results, assisted reproductive technology (ART) is proposed. Its first success dates back to 1978 with the birth of the first “test-tube baby”. To increase the chances of success, doctors who practice ART often implant several ova or several embryos, so this practice also increases the risk of multiple pregnancies[6](Vitthala et al. 2009).

Both types of treatments, only ovulation stimulation, or ART (including in-vitro fertilization), have become more and more frequent in the developed world. This is reflected by statistics on ART which are compiled and published yearly by more and more countries. They are

[6] The twin pregnancies resulting from several embryos transfer are dizygotic ones, so ART influence the dizygotic (DZ) twinning rate (the difference between dizygotic (DZ) and monozygotic (MZ) twins and the factors which influence their frequencies are presented in Appendix 2).

based on reports sent by clinics. These reports are used also for international comparisons. Comparative tables are published yearly, for Europe by the European Society of Human Reproduction and Embryology (ESHRE) (the last report is for year 2010 (Kupka et al. 2014)), and for the World, by the International Committee for Monitoring Assisted Reproductive Technology (ICMART) (the last report is for year 2005 (Zegers-Hochschild et al. 2014)). The average number of ART cycles per 1,000 women of reproductive age has increased by about 50% during the 2000s in European countries which have complete (or almost complete) statistics (Ferraretti et al. 2013; Kupka et al. 2014). There are large differences between countries with high rates observed in the Nordic countries (around 12 ART cycles per 1,000 women of reproductive age in 2009-2010), half less in France and in the Netherlands (around 6) and three times less (around 4) in UK, Germany and Italy. Denmark has the highest rate in the last report published by ESHRE for Europe (18 ART cycles per 1,000 women of reproductive age in 2010), and Belgium is second (14.5) (Kupka et al. 2014).

The share of live-born children conceived through ART was around 2% in 2000 in European countries which have almost complete statistics, with large differences between countries: 1% in UK, 1.5% in France, nearly 4% in Denmark (Ferraretti et al. 2013; Kupka et al. 2014; Mills et al. 2014). This share of ART children has increased since to 2% in UK and France and 4.5% in Denmark in 2009. The share of children conceived through ovulation treatments alone (non-ART treatments), which add to that conceived through ART, is unknown. In the United States, it has been estimated indirectly as 4 times greater than the ART contribution in 2005 (Schieve et al. 2009). But the share of children conceived through ART is relatively low in this country compared to Europe (around 1% in 2005), which explains partly why non-ART ovulation treatments have a stronger influence on the total number of births than ART (Mills et al. 2014).

The multiplication of fertility treatments pushed up the twinning rate over the past fourty years, combining its effect to that of delayed childbearing. As infertility is increasing with age of the woman (Leridon 2004), couples with a relatively aged woman (more than 30 years) are over-represented among those who seek such treatments compared to all couples who have babies. As a result, the pushing up of the twinning rate by MAR has been more pronounced in older age groups that younger ones.

This can be illustrated by examining the trends in twinning rates by age-group in countries where age-specific twinning rates are available over a long period of time. Figure 8 shows the trends in three countries yet taken as examples: France (over the period 1901-2012), England and Wales (1938-2011), and the USA (1949-2011).

<Figure 8 about here>

In France, age-specific twinning rates declined during the first three quarters of 20th century at all ages over 25 years to attain a low level in the 1970s[7]. This secular trend was more

[7] The trends have not been regular in France: the twinning rate peaked during World War I for all age-groups, showing that the temporary rise in the age at motherhood is not the only factor in play as explained above. Following the World War I twinning peak, the twinning rate returned to a lower level in 1920 and then

pronounced at higher ages (for age-groups 30-34, 35-39 and 40-44). After the low point in the 1970s, the rates started rising at almost every age, but it was also more pronounced for older age-groups than younger ones. The increase has been highest for the last two groups (40-44, 45-49). The twinning rate more than doubled for the 40-44 age-group and increased tenfold in the 45-49 age-group.

In England and Wales, the secular trends follow a similar pattern for the period starting in 1939 – the figures are missing before. In the USA, the pattern seems the same although only the end of the trend can be observed (the series starts only in 1949). For England and Wales, as in figure 2, the age-specific rates correspond to all multiple births and not only twin ones. The inclusion of triplet births, quadruplet ones, etc. does not change however sensibly the rates, as yet explained above, so the comparison with France and the USA remains valid. The differences of twinning rates between age-groups are a bit more pronounced in England and Wales than in France and in the USA during the period of downward trend before the 1970s – we have yet observed this concerning the particular period 1965-1969 (cf figure 2). For the period since the 1970s, twinning rates in older age-groups, particularly in age-groups 40-44 and 45-49, started to increase in the USA and in England and Wales about ten years earlier than in France, and reached still higher levels in the recent years. In England and Wales the twinning rate increased 2.5 fold for age-group 40-44 and 15 fold for age-group 45-49, and in the USA, respectively 3 fold and 20 fold.

4. Have we reached the peak in twinning rates?

4.1 An overview of peaks, plateaus and reversals

Our data make clear that in some countries the twinning rate has reached a peak or a plateau recently and has diminished afterwards. Table 2 list 46 countries for which twinning rate could be estimated yearly over the recent decades with enough certainty and indicate whether a peak or a plateau was attained in each one, and if it is the case, in which year or period? (see also Figure A1 in appendix). Such a reversal is observed in one out of four countries (26%), the peak or plateau occurring usually after 2000 - Finland and Sweden are exceptions with a peak or plateau attained respectively in 1998 and 1999 (Iceland is probably also a forerunner but it is more difficult to date the reversal in this country because of the uncertainty of the yearly estimates due to the small size of the population).

<Table 2 about here>

Restricting the analysis to the European countries only, the proportion of those with a reversal remains the same on the whole (26%). However, there are contrasts by region of

began a steady decline among women between the ages of 25 to 44, all the more pronounced at higher ages. This secular downward trend was interrupted in 1945. The rate then increased again slightly for several years, at approximately every age. It corresponds to the higher fertility period, from 1946 to 1966. The slightly higher twinning rate at each age during that period is most likely tied to the baby-boom episode – the selection mechanism mentioned above to explain the lowering of twinning rate when fertility is more controlled diminish on the contrary when control is less tight (Pison et Couvert 2004). The downward trend took over in the 1960s until rates reached a low point in the 1970s.

Europe: among the 11 countries of Northern Europe, half of them (6) had a reversal (all the Scandinavian countries plus Scotland, considered here separately from England and Wales since their statistics are provided separately). By contrast, the reversal occurred in only one country out of 6 in Western Europe (in the Netherlands), two countries out of 10 in Eastern Europe (in Czech Republic and Hungary), and in no country out of 8 in Southern Europe.

Among the six developed countries outside Europe listed in table 2, a reversal occurred in half of them (Australia, Japan and New Zealand), and not in the other half (Canada, Israel, United States).

In some countries where no reversal has yet occurred, the increase of the twinning rate seems to have decelerated recently, and in a few of them, a plateau seems to have been attained, as in Europe, in Belgium, Greece and Slovenia, and outside Europe, in Canada. However we have to wait still a few years to verify whether the twinning rate reached actually a maximum or has increased still afterwards.

4.2. Reasons for a reversal in twinning trends

As discussed above, twinning rates have been pushed up in developed countries mainly by two phenomenon: the increase of the age at childbearing, and the diffusion of medically assisted reproduction (MAR). The reversal of the trend or its deceleration may come from a stop or a reversal in the delay of childbearing – women having their children younger – and/or changes in MAR practices. Actually, the mean age at childbearing has continued to increase during the recent period in the developed world, continuing to push up the twinning rate. Thus, the observed reversal has to be attributed to changes in other factors.

Pregnancies obtained through MAR result much more frequently in multiple births compared to pregnancies obtained naturally. While we lack estimates for non-ART treatments, we do have statistics on ART practices and consequences for some countries. For example, “in 2000 over two thirds of women in the United States undergoing ART had three or more embryos transferred into their uterus, around 35% of ART pregnancies resulted in multiple delivery and 53% of all ART infants were born as twins or triplets. In Europe, the most typical ART transfer at that time involved two embryos (44% of women), multiple delivery rates after ART amounted to 26% and the share of ART infants from multiple pregnancies reached 43%. In other words, the DZ twinning rate[8] following ART was about 20-30 times higher in Europe and in the US than the ‘natural’ DZ twinning rate.” (Mills et al. 2014).

Very high rates of multiple deliveries after ART were labeled as problematic because of negative outcomes for infants and mothers’ health. As a consequence, medical professionals proposed new criteria for evaluating the success of ART, centered on successful singleton live birth delivery. Single embryo transfers became favored by health authorities and legislation, and ART multiple delivery rates started declining gradually in most of the developed countries during the 2000s, reaching 30% in the USA in 2009 and 20% in Europe

[8] Appendix 2 provide information on dizygotic (DZ) and monozygotic (MZ) twin rates.

in 2010 (Kupka et al. 2014; Mills et al. 2014). However, as shown in table 2, this did not result in a reversal of the twinning rate trend among the total population of all these countries because of the continuing increase in ART and non-ART ovarian stimulation and the continuing shift of childbearing to later ages. In countries where there has been a reversal, the decline of twinning rate has been more modest until now than one would expect from ART statistics.

This is well illustrated by the example of Sweden. Changes have been fast in this country: ART expanded early and was associated with a rapid rise in multiple deliveries. The share of ART multiple deliveries was around 23% in the late 1990s (Mills et al. 2014). Following changes in ART regulations and practices it fell to around 12% in 2003 and 7% in 2004. Twinning rate among the total population declined more modestly however, from 17 per 1,000 (the highest level observed in the country) in 1999 to 14 per 1,000 in 2004.

Most developed countries have moved to more stringent regulations regarding the transfer of embryos overtime. But they started to reduce the number of transfers more or less early. In Europe, for example, in the mid-2000s, Scandinavian countries were transferring the least and Southern and Eastern countries the most as illustrated by the map of Europe showing average number of embryos per embryo transfer cycle in 2006-2007 (Figure 9) (Mills et al. 2014).

<Figure 9 about here>

4.3. The role of transnational ART

An unknown, but probably substantial, number of individuals or couples travel to another country in order to obtain fertility treatments (Shenfield et al. 2010). This phenomenon has had several names over the last years, in particular “reproductive tourism” or “cross border reproductive care”. We will call it here “transnational ART”.

There are several reasons to explain such movements, among which the most frequent are law evasion, difficulty of access because of either restrictive legislation or long waiting lists, and expected quality of care.

Transnational ART has become an important activity in some countries like Denmark, Belgium, Switzerland, Spain, the Czech Republic, Greece, and Israel, with foreign patients representing a significant share of all patients. Foreign patients from Europe are often from nearby countries: in Denmark, they come often from Norway or Sweden, in Belgium, from the Netherlands and France, in Switzerland, from Italy, in the Czech Republic, from Germany and the United Kingdom, in Spain, from Italy and the United Kingdom (Shenfield et al. 2010).

After becoming pregnant, these “medical tourists” return to their country of residence and deliver there. The birth is included in the vital statistics of the country of residence. The treatment they received is included in the ART statistics of the country of treatment. These statistics are used to produce standard indicators for international comparisons of ART, for example the number of treatment cycles per 1,000 women of reproductive age per year.

Such an indicator is calculated as the ratio of the number of treatments yearly in the country and the number of women resident in the country, as provided by the census data. Foreign patients are not counted in the denominator, but the treatments they received are counted in the numerator. This indicator is thus inflated by transnational ART in "treatment countries" and depressed on the contrary in "origin countries", which makes it difficult to properly assess the impact of ART on births in individual countries. This problem might be particularly important in countries with a relatively small population and a sizeable ART activity serving foreigners, such as Belgium and Denmark. This may explain partly why these countries rank first and second in the European comparisons of the number of cycles per 1,000 women of reproductive age.

In some of the countries providing treatments for foreigners, clinics might also have different practices than in the origin country and might, in particular, transfer a higher number of embryos (McKelvey et al. 2009). This phenomenon represents an additional difficulty when one examines, for a particular country, the links between changes in regulation policies, practices, and trends in twinning rate.

One solution to partly overcome these difficulties would be for national and international reports to specify ART statistics by nationality or country of residence of patients. It would improve international comparisons, make the differences between countries more meaningful, and help monitoring policies and regulations in each country.

[This section will be expanded in the PAA presentation with an attempt to link rules and regulation to transnational ART .]

5. Scenarios for the future

[Section to be added for the PAA presentation.]

6. Preliminary discussion and conclusion

We have compiled all available statistical information on the frequency of twin births in developed countries to document the twin boom and examine whether it is coming to an end.

The present paper is preliminary and will be completed before the PAA conference. However, the first results indicate that:

- the twinning rate has practically doubled over the last forty years in many developed countries for which we have data,

- around one-third of the increase is due to delayed childbearing and two thirds to other factors, mainly the development of medically assisted reproduction (MAR),

- in one out of four developed countries the twinning rate reached a plateau around the early 2000s and decreased afterwards,

- this reversal is linked to new regulations affecting assisted reproductive technology (ART), in particular regarding the number of embryos transferred, with new criteria for evaluating the success of ART centered on a successful singleton live birth delivery,

- the association between regulatory changes, new practices and trends in the twinning rate is not straightforward, however, for several reasons among which 1) the continuing increase in recourse to MAR procedures, 2) the influence of non-ART ovarian stimulation, whose frequency and trends are unknown, 3) the development of transnational ART, which is also not accurately measured,

Three recommendations can nonetheless be formulated from our study:

- given the lack of reliable statistics on MAR to monitor policies and practices and evaluate their effects, twinning rates are a useful proxy indicator; moreover, this measure is produced by many national statistical offices routinely, rapidly, and at no extra cost; it should be used more frequently,

- estimates of twinning rates broken down by mother's age and year are needed; however only a minority of national statistical offices publish such data. We therefore recommend that all national statistical offices publish routine statistics on deliveries by plurality of birth, age of mother and year,

- we also recommend that in the ART reports submitted by clinics and compiled by national and international groups, statistics be produced by women's nationality or country of residence; it would help to properly assess the impact of ART on births in individual countries and improve international comparisons.

[7. To be added in the final version

- **Overview of the policies regulating multiple embryo transfers and their role,**

- **Overview of transnational ART and its influence,**

- **Scenarios for the future]**

Figures

Figure 1. Evolution of the twinning rate in a selection of European and other developed countries or territories, 1900 to 2013

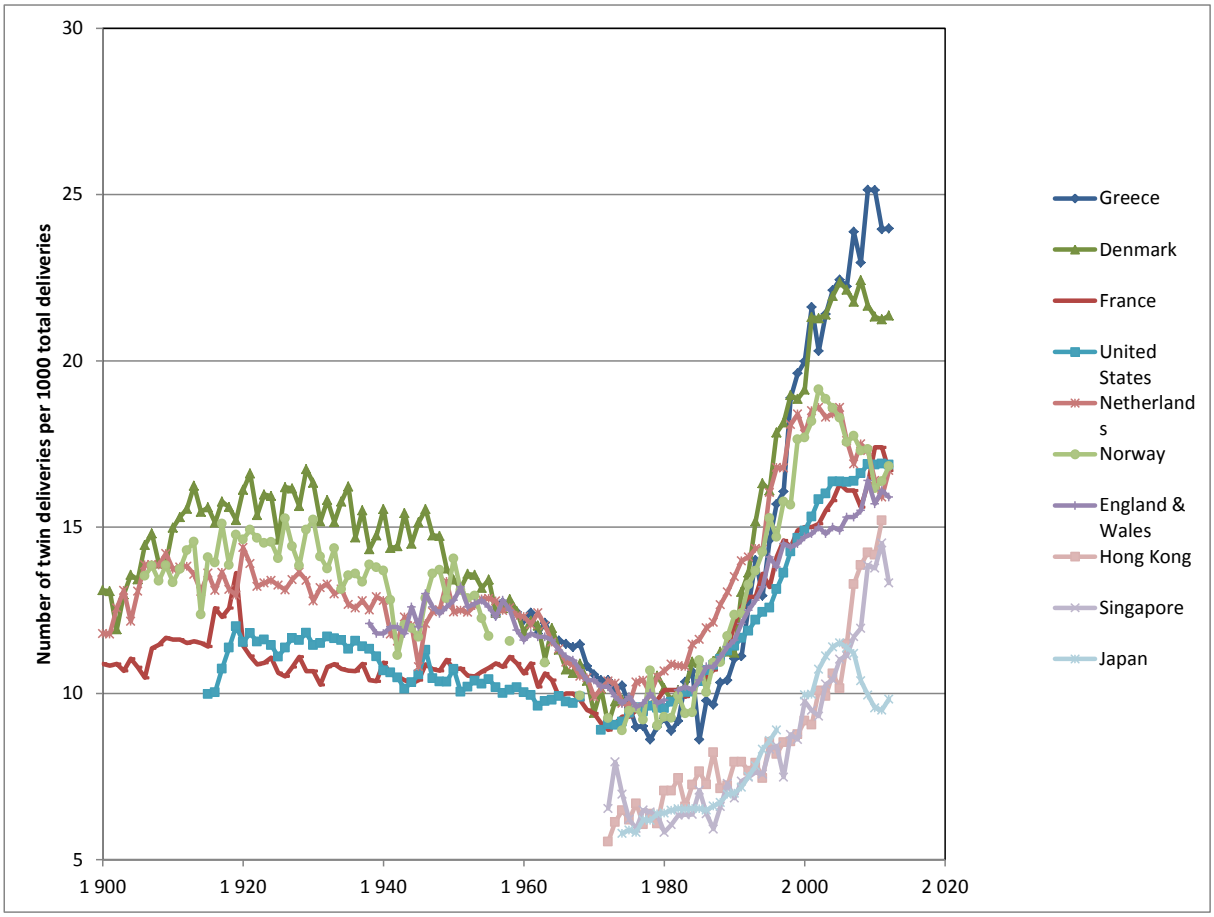
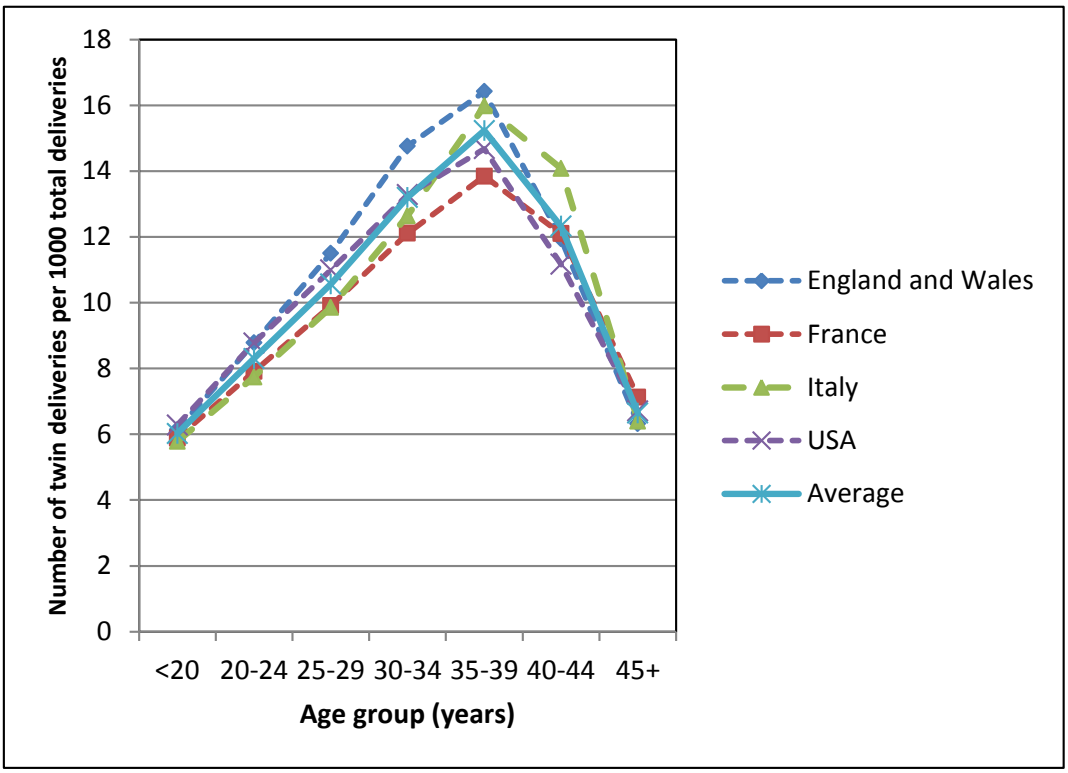


Figure 2. Twinning rate by age group in 1965-1969 in four countries: England and Wales, France, Italy, USA



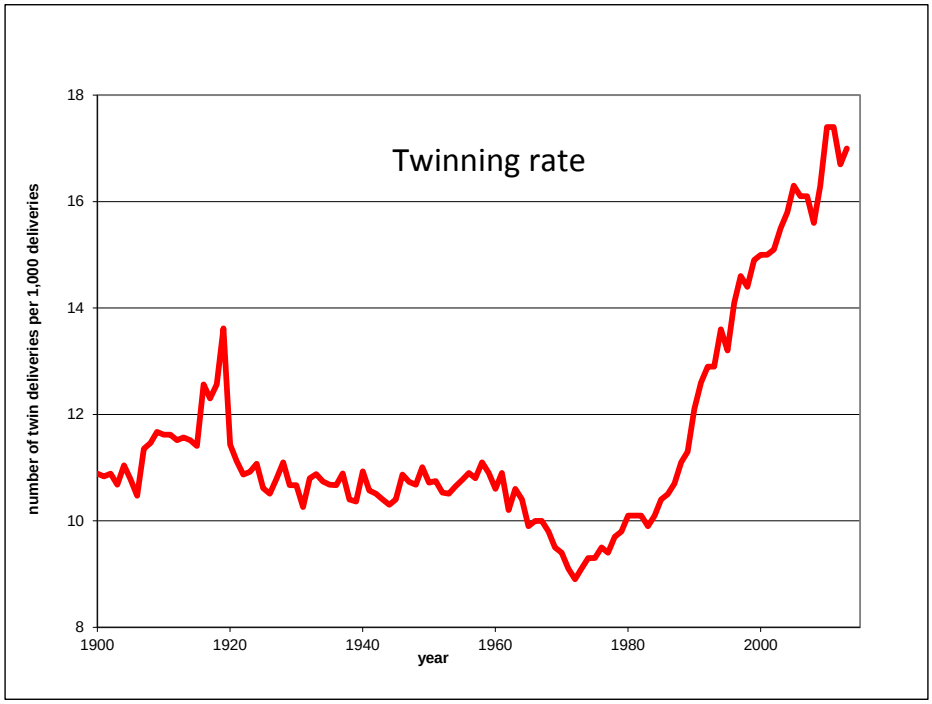
Source: Statistical office of each country

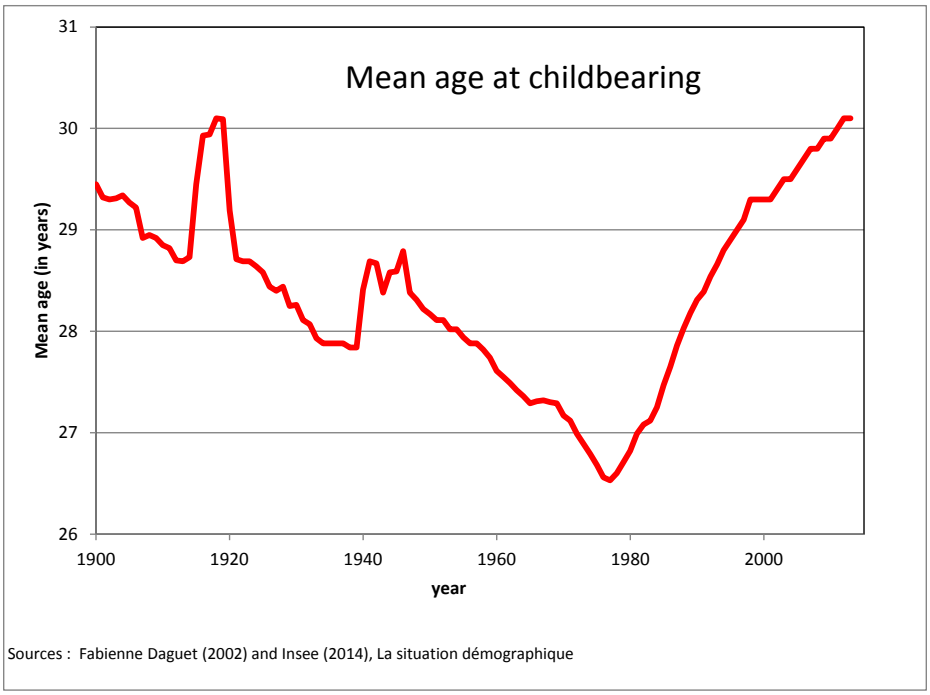
Notes:

1 – The period 1965-1969 has been chosen here because it is just before the start and expansion of medically assisted reproduction,

2 - France and USA: twin deliveries only; England and Wales, and Italy: multiple deliveries (including triplet or more deliveries).

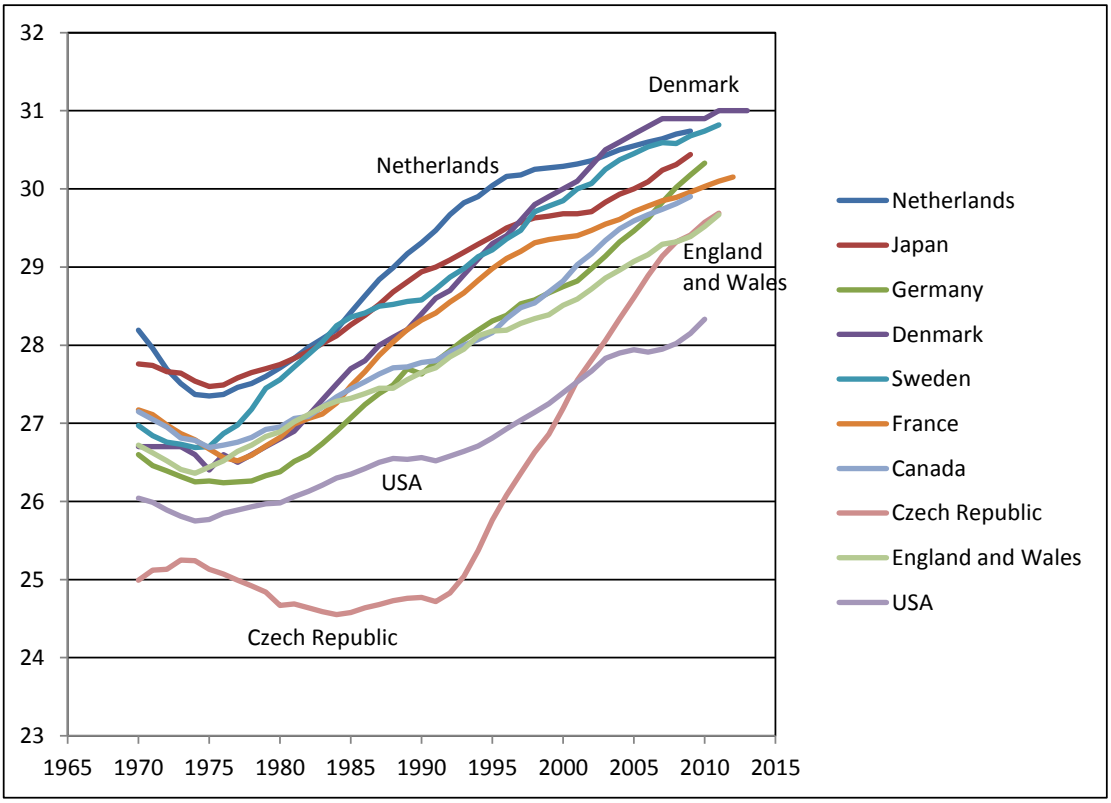
Figure 3. Evolution of mean age at childbearing and twinning rate in France since 1900





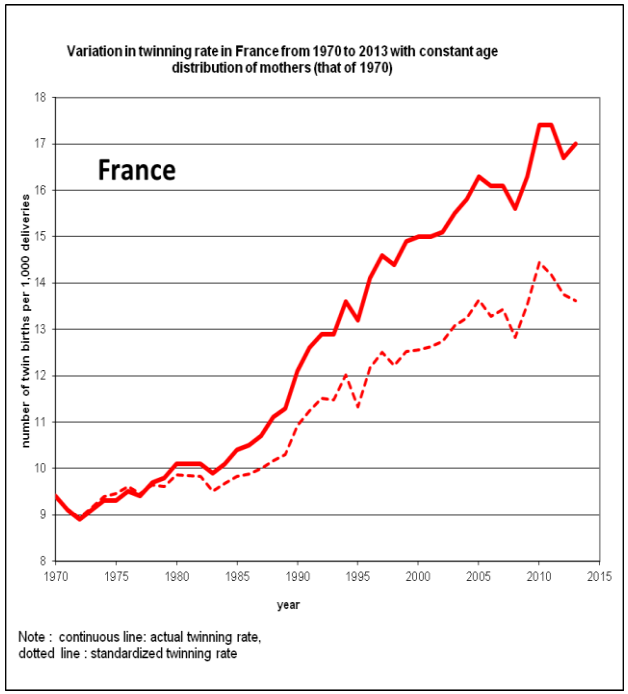
Sources : Fabienne Daguet (2002) and Insee (2014), La situation démographique

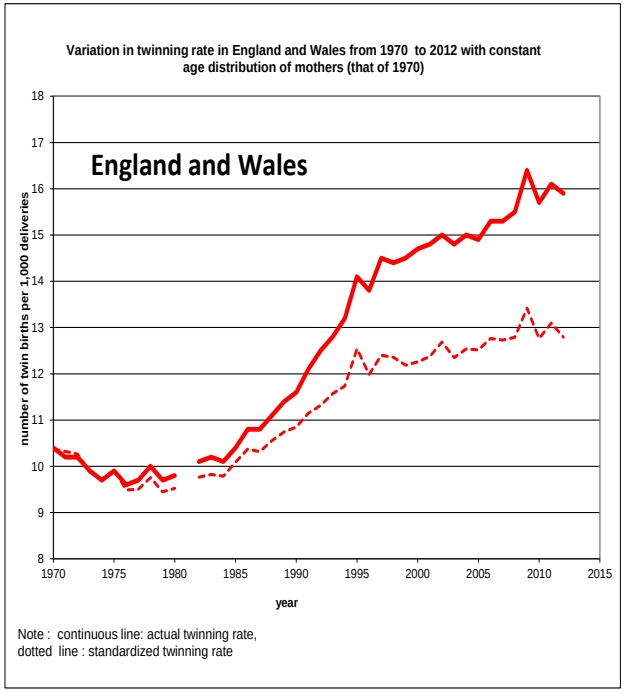
Figure 4. Evolution of mean age of childbearing since the 1970s in a selection of developed countries



Source: Human Fertility Database

Figure 5. Evolution of the twinning rates in France, England and Wales, and the USA, 1970 to 2013. Comparison between observed and age standardized rates.





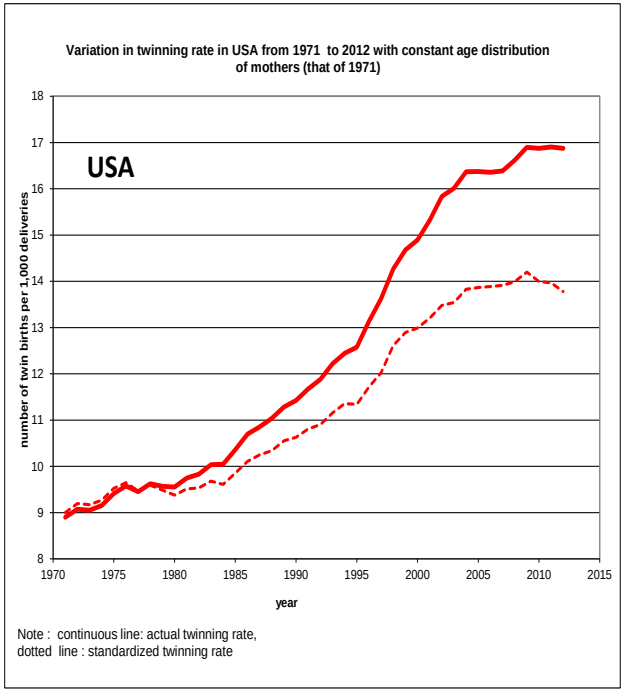


Figure 6. Evolution of twinning rates in France, England and Wales, the Netherlands, and the USA, 1970 to 2013. Comparison between observed and predicted twinning rates if only age distribution of mothers had changed.

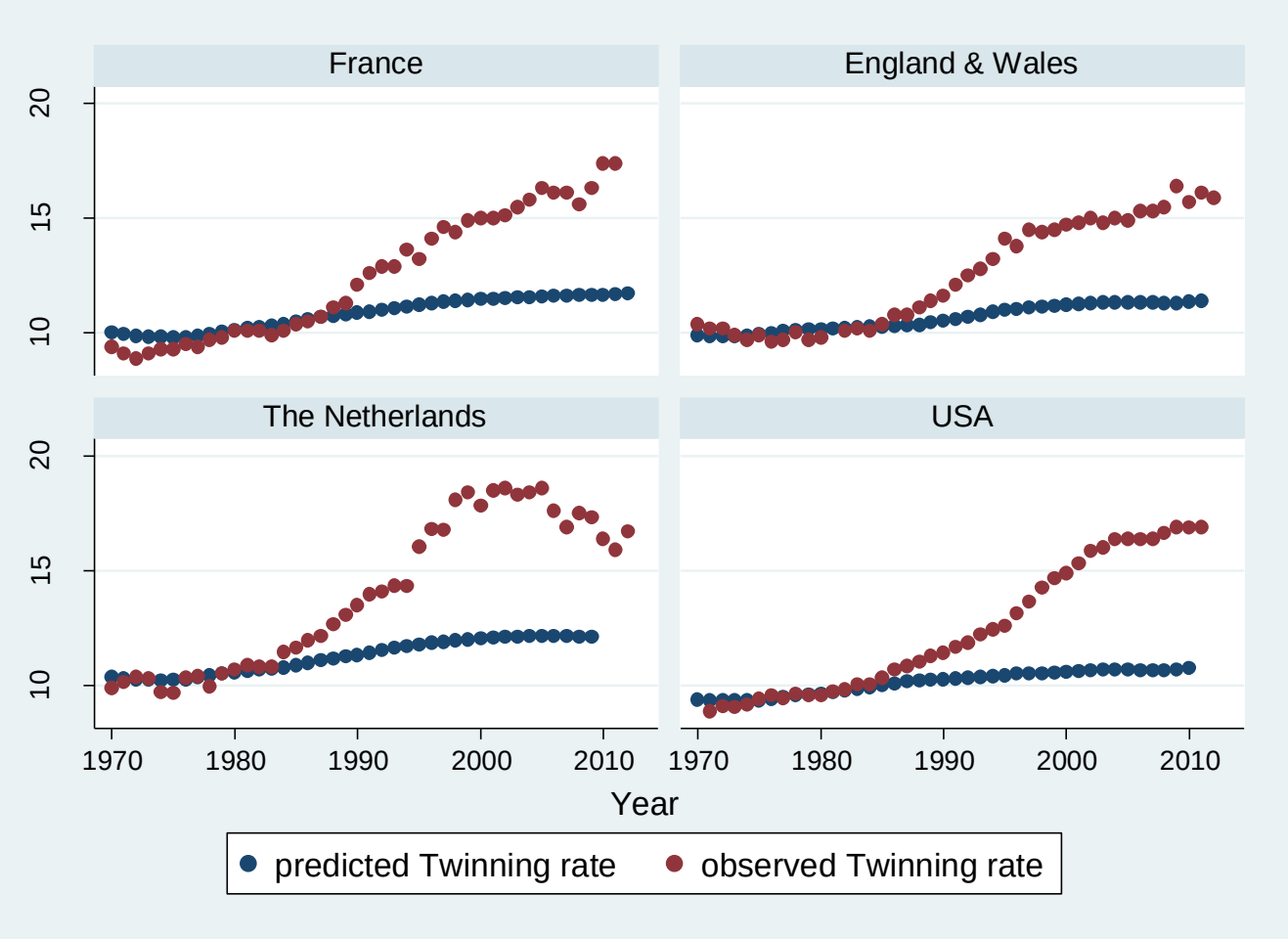


Figure 7. Estimated increases of the twinning rate due to delayed childbearing and to other factors (mainly medically assisted reproduction – MAR) from 1970 to 2005.

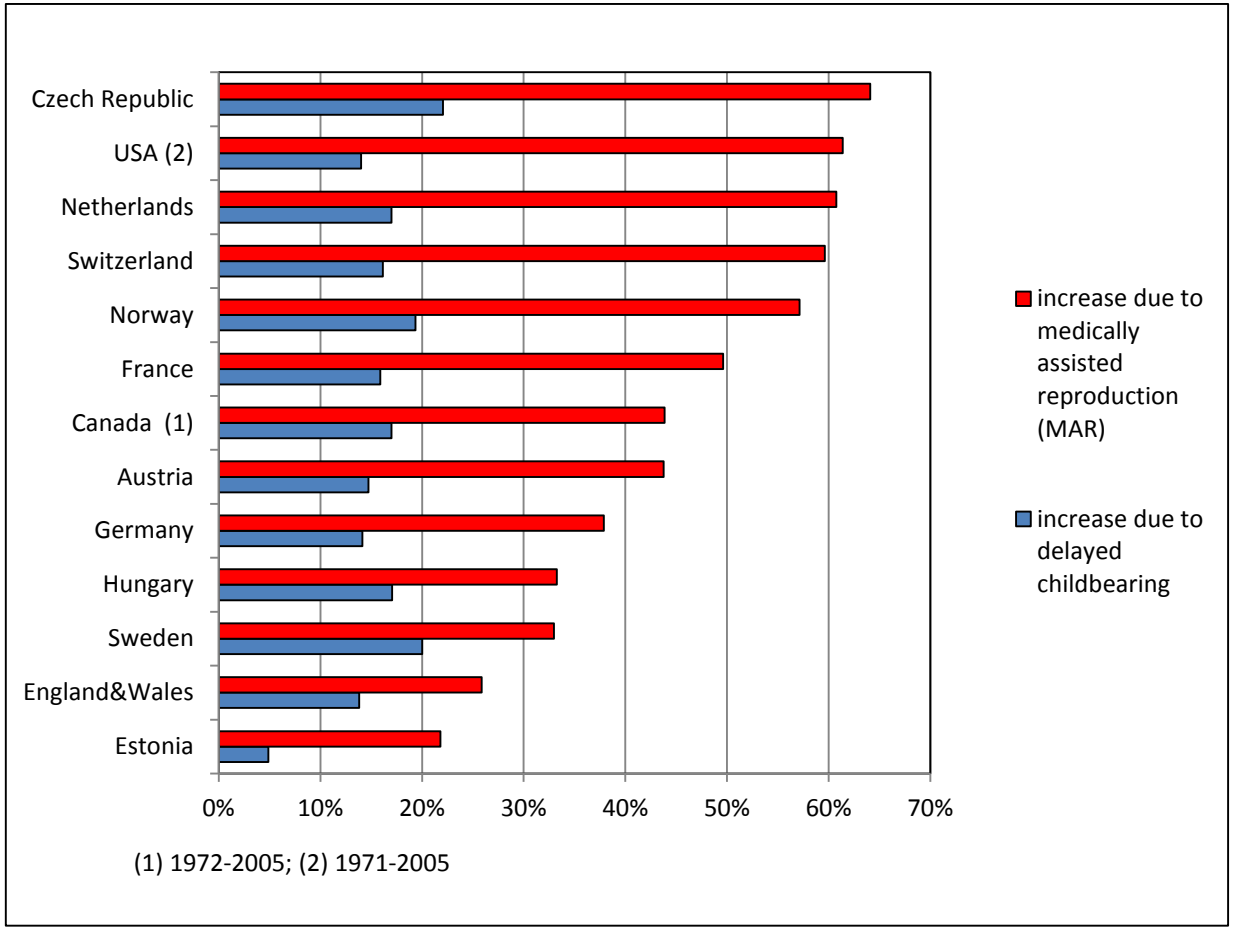
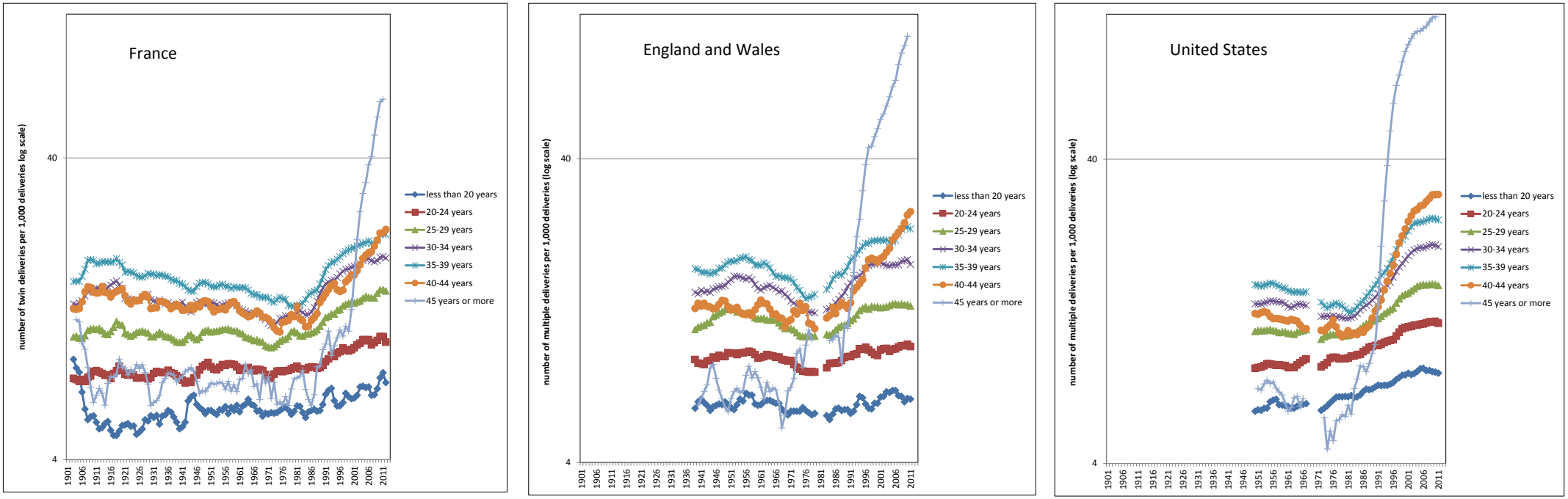
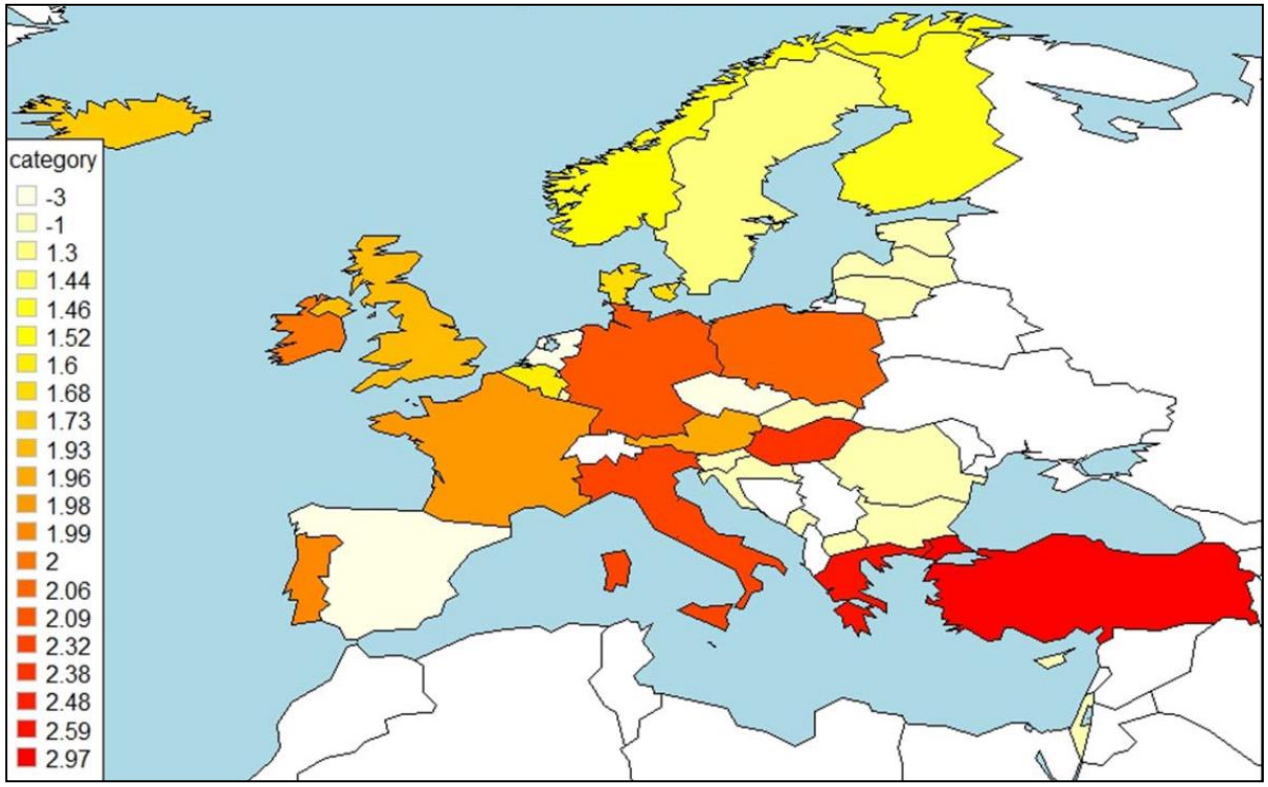


Figure 8. Evolution of twinning rates by age-group. France (1901-2011), England and Wales (1939-2011), United States (1949-2011)



Source: Data from Statistical Office of each country, author's calculations.
Notes:
1 – Vertical axis: log scale
2 – France and United States: twin deliveries only; England and Wales: all multiple deliveries (including, triplets, quadruplets, etc.)
3 - Age-groups "less than 20 years" to "40-44", three-year moving averages, age-group "45 years and above", five-year moving averages

Figure 9. Average number of fresh nondonor embryos per fresh embryo transfer cycle in Europe, 2006-2007.



Source: (Mills et al. 2014) (figure 4, page 19).

Notes : -3 and -1 represent missing data.

Table 1. Increase of the twinning rate from 1970 to 2005 in developed countries and fractions of the increase due to the delay of childbearing and to other factors (mainly medically assisted reproduction - MAR)

Country	Twinning rate (number of twin deliveries per thousand total deliveries)		Increase of the twinning rate during the period 1970-2005 (multiplication factor)			Ratio between the increase due to delayed childbearing and that due to other factors	Fraction of the increase due to other factors than delayed childbearing (%)
	1970	2005	observed	estimated if only childbearing had been delayed	estimated if childbearing had not been delayed and only other factors had changed		
	A	B	C= A/B	D	E=C/D	(D-1)/E-1)	(E-1)/C-1)
Austria	9.0	14.9	1.65	1.15	1.44	0.34	67%
Canada (1)	9.2	15.4	1.68	1.17	1.44	0.39	64%
Czech Republic	9.6	19.2	2.00	1.22	1.64	0.34	64%
England&Wales	10.4	14.9	1.43	1.14	1.26	0.53	60%
Estonia	10.2	13.1	1.28	1.05	1.22	0.22	79%
France	9.4	16.3	1.73	1.16	1.50	0.32	68%
Germany	9.8	15.4	1.57	1.14	1.38	0.37	66%
Hungary	10.4	16.2	1.56	1.17	1.33	0.51	59%
Netherlands	9.9	18.6	1.88	1.17	1.61	0.28	69%
Norway	9.8	18.3	1.88	1.19	1.57	0.34	65%
Sweden	8.6	13.7	1.60	1.20	1.33	0.61	55%
Switzerland	8.8	16.4	1.85	1.16	1.60	0.27	70%
USA (2)	8.9	16.4	1.84	1.14	1.61	0.23	73%
To be added by December 2014: Australia, China, Finland, Hong Kong, Japan, Russia, South Korea, Taiwan							

(1) 1972-2005; (2) 1971-2005

Table 2. Reversal in twinning rate trends in developed countries

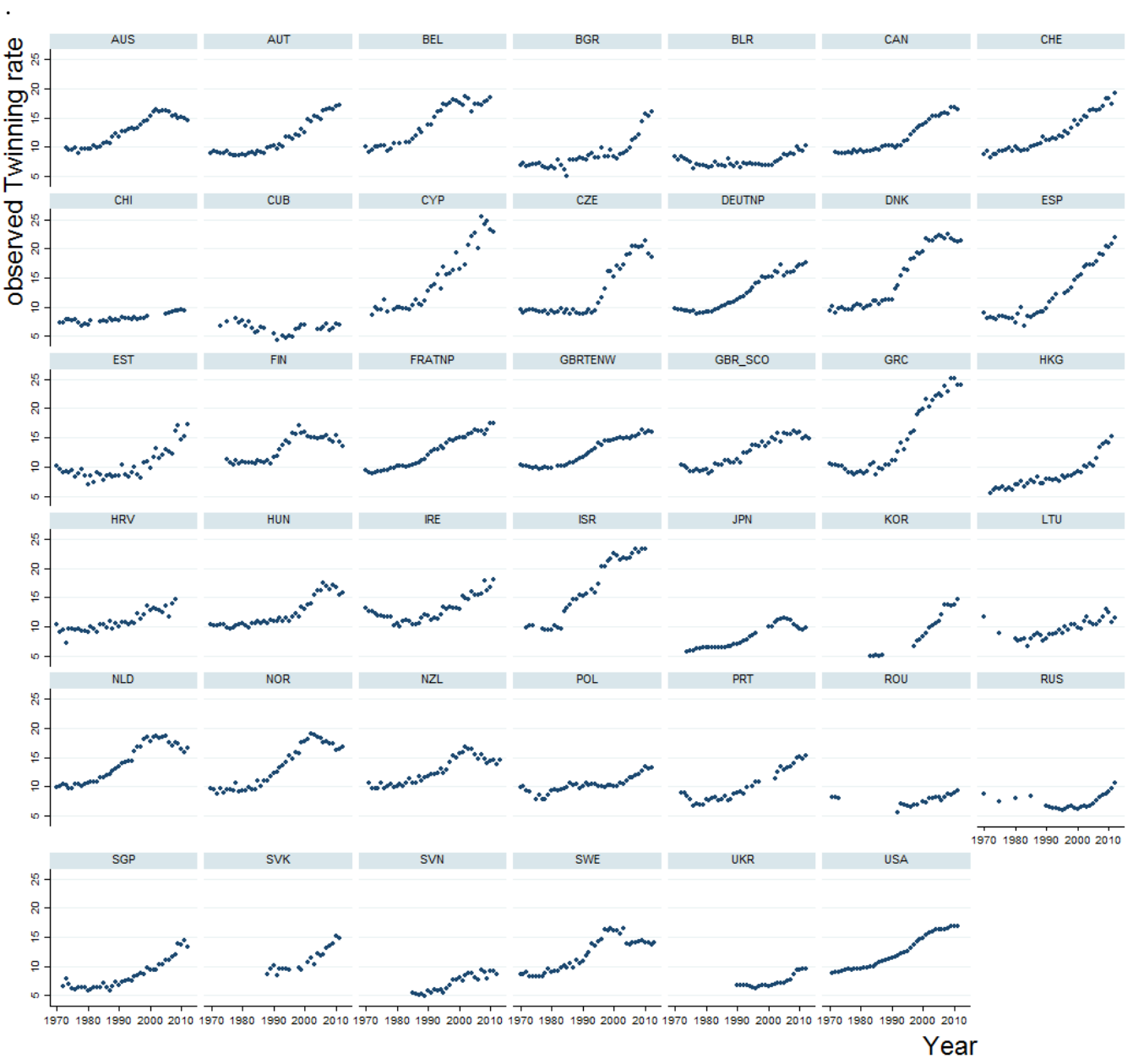
Country	Did the twinning rate peaked or reached a plateau and declined afterwards in the recent period?	Year or period of peak/plateau
European countries		
Austria	no	
Belarus	no	
Belgium	no	
Bulgaria	no	
Croatia	no	
Cyprus	no	
Czech Republic	yes	2010
Denmark	yes	2005-2008
England&Wales	no	
Estonia	no	
Finland	yes	1998
France	no	
Germany	no	
Greece	no	
Hungary	yes	2006
Iceland	yes	1997-2006
Ireland	no	
Italy	no	
Latvia	no	
Lithuania	no	
Moldova	no	
Netherlands	yes	2001-2005
Norway	yes	2002
Poland	no	
Portugal	no	
Romania	no	
Russia	no	
Scotland	yes	2008
Serbia	no	
Slovakia	no	
Slovenia	no	
Spain	no	
Sweden	yes	1999-2003
Switzerland	no	
Ukraine	no	
Other developed countries		
Australia	yes	2002-2004
Canada	no	
Israel	no	
Japan	yes	2005
New Zealand	yes	2002
United States	no	
Other countries		

Chile	no
Cuba	no
Honk Kong	no
Korea (South)	no
Singapore	no

Note:

1 – The list includes all countries for which twinning rate by year for the recent decades could be estimated with enough certainty

Appendix 1 Figure A1. Twinning rate trends since 1970 in countries for which we have data (observed twinning rate – number of twin deliveries per 1,000 total deliveries)



Appendix 2 - Monozygotic (MZ) and dizygotic (DZ) twinning rates

There are two types of twins, monozygotic (MZ) twins (also called identical twins) and dizygotic (DZ) twins (fraternal). The frequencies of both types follow different patterns reflecting their different biological origins and determinants. MZ twins are the results of a single fertilized ovum splitting in two during the very early stages of development. In the case of DZ twins, the ovaries release two ova during a single cycle and both ova are fertilized. While the outcome in both cases is a multiple birth, the two phenomena are independent and are ruled by separate laws. The proportion of MZ twin births remains rather constant regardless of the mother's age, birth order, or geographic origin. For decades before 1970, MZ twin rates varied between 3.5 and 4.5 per thousand (Bortolus et al. 1999; Bulmer 1970). Over the past 40 years, however, the frequency of MZ twin births has increased in developed countries, rising for example by about 50% in France (Couvert 2011).

In contrast to MZ twin rates, the frequency of DZ twin births is highly variable according to maternal age, birth rank and region or country. Mother's age is the main factor: beginning with a level close to zero at puberty, the DZ twinning rate steadily increases, peaks at age 37, then rapidly decreases, returning to the zero level at menopause (Bulmer 1970). As a consequence the variations of the overall twinning rate by age of the mother (both types of twins being included) closely reflects the variations of the dizygotic twinning rate over a nearly constant monozygotic rate.

The twin pregnancies resulting from several embryos transfer are DZ ones, so ART influence the DZ twinning rate. ART may however have slightly pushed up also MZ twinning rate since women undergoing ART have approximately double the chance of having a MZ twin pregnancy than women conceiving naturally (Vitthala et al. 2009) (cf also (Aston, Peterson and Carrell 2008).

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