## 1. Background

I’ve taken a look at the paper: “Assessing the impact of rising child poverty on the unprecedented rise in infant mortality in England, 2000–2017: time trend analysis”:

<https://bmjopen.bmj.com/content/bmjopen/9/10/e029424.full.pdf>

A summary of this paper could read (my paraphrasing):

*There has been an unprecedented rise in infant mortality since 2013/4, could deprivation be a driving force behind this? We conclude that deprivation has led to more infant deaths, specifically 24 infant deaths per 100,000 live births in the most deprived areas. Also, there have been 572 excess infant deaths compared with how many deaths we would have expected, given previous trends in the infant mortality rate.*

I have a few issues with this, hence the blog post. First, I didn’t like that they used “excess mortality” as their outcome (which looks at trends, rather than what’s actually happened), because it is not equivalent to “more mortality”. A trend could get *more* positive without *becoming* positive: if infant deaths went down by 1 per 1,000 live births in 2010-2013 (a good thing), but then only went down by 0.5 per 1,000 births in 2014-2017 (a less good thing, but still good), then that would be an “excess mortality” of 0.5 per 1,000 births per year. Infant mortality hasn’t actually gotten any worse though, it’s just decreasing at a slower pace than before.

Now, that might still be good to know. But it’s also important to remember that there is a lower limit – mortality, sadly even for infants, cannot be zero – even if it could, that means that eventually the trend of mortality would have to stop at zero. I would have liked an assessment of what the cause of death was for the “excess mortality”.

My other main issue was that they said one of their analyses was causal. It wasn’t, and could never have been. This irritated me.

Because the paper used openly accessible data, I could reanalyse it at my leisure, which is always nice. I wanted to see if I could estimate the mortality rates, and see how they compared with the published data. I also wanted to reassess the claim that deprivation (as measured by IMD) was associated with the trend in mortality rates. If possible, I also wanted to see where the extra deaths were coming from – what were the ages of the babies that were dying?

This isn’t my field, and my analyses were conducted quickly, so if I did anything wrong feel free to comment – all my code is available here <https://github.com/sean-harrison-bristol/infant_mortality_reanalysis>, along with all the files I downloaded from the Office of National Statistics (ONS), which are also linked in this post.

Dr Anna Pease @Annaspease asked me to take a look this and looked over my initial results, give her a shout if you’re interested in this kind of thing as this is something she does for a living.

I’m thinking of including a tldr in these posts, as I can see this one is now over 5,000 words long (sorry). So here it is, **tldr**: the increase in infant mortality looks like it’s a shift from stillbirths to deaths in babies under 1 day old, i.e. there is no increase in infant mortality, just the way it is recorded. Also, deprivation isn’t associated with the increase anyway.

## 2. Methods

### Data preparation

I took the ONS data for births and deaths (split by local authority area, for the years 2010-2017 inclusive) from the following URLs:

* Birth data here: <https://www.ons.gov.uk/peoplepopulationandcommunity/birthsdeathsandmarriages/livebirths/datasets/birthsbyareaofusualresidenceofmotheruk>
* Death data here: <https://www.ons.gov.uk/peoplepopulationandcommunity/birthsdeathsandmarriages/deaths/datasets/deathsregisteredbyareaofusualresidenceenglandandwales>

I tied each of the local authority areas to deprivation (as measured using the Index of Multiple Deprivation, IMD) of that area in 2015, with data taken from a data portal:

* IMD data from: <https://opendatacommunities.org/slice?dataset=http%3A%2F%2Fopendatacommunities.org%2Fdata%2Fsocietal-wellbeing%2Fimd%2Findicesbyla&http%3A%2F%2Fopendatacommunities.org%2Fdef%2Fontology%2Fcommunities%2Fsocietal_wellbeing%2Fimd%2Findices=http%3A%2F%2Fopendatacommunities.org%2Fdef%2Fconcept%2Fgeneral-concepts%2Fimd%2Fcombineddeprivation&http%3A%2F%2Fpurl.org%2Flinked-data%2Fcube%23measureType=http%3A%2F%2Fopendatacommunities.org%2Fdef%2Fontology%2Fcommunities%2Fsocietal_wellbeing%2Fimd%2FlaavscoreObs>

From the birth data, I took the total number of live births (column F in table 1 or 1a).

From the death data, I took the number of infant (under 1 year), neonatal (under 4 weeks) and perinatal (stillbirths and deaths under 1 week) deaths, as well as the rates for those deaths (columns H-J and O-Q from table 1a).

I tied everything together, after formatting the local authority areas (ONS coding of place names changes over time and between datasets, unhelpfully).

I then removed areas with only 1 year of data (useless for estimating trends), estimated rates from births and deaths (if missing), estimated number of births from rates and deaths (if missing), then estimated the standard error of the rates.

I ended up with 324 areas in England with at least two mortality rates, same as the original publication, which is a good start.

### Outcomes

I looked at:

* Infant mortality (under 1 year): this outcome excludes stillbirths
* Neonatal mortality (under 4 weeks): this outcome also excludes stillbirths
* Perinatal mortality (stillbirths and deaths under 1 week): this outcome obviously includes stillbirths, but I have no way of estimating the number of stillbirths, see below
* Postnatal mortality (between 4 weeks and 1 year): I created this outcome, it’s just infant mortality minus neonatal mortality, to estimate whether any observed effects on infant mortality are from neonatal mortality or postnatal mortality

Stillbirths were not recorded explicitly in the death or birth data (which includes only live births). I tried to estimate stillbirths based on the number of perinatal deaths and the perinatal rate (births + stillbirths = deaths \* 1000 / perinatal rate), but because the number of perinatal deaths is relatively low, the imprecision of the rate estimates (to 1 decimal place, eurgh) meant I kept getting negative estimates of the number of stillbirths. I know the lower bound is 0 and the upper bound is perinatal deaths minus neonatal deaths, but that doesn’t really help.

The reason it matters is that the standard error (SE) of an incidence rate is sqrt(cases/N2), with N being the number of births, which includes stillbirths for the perinatal mortality rate. I therefore might be overestimating the SE of the perinatal mortality rate by not accounting for stillbirths, but this is preferable to underestimating the SE. As far as I can tell, this can’t be helped.

I only estimated the SE if there were deaths in an area – there’s no SE of an incidence if there are no incidences.

The other reason the SE matters is that I don’t think the paper that did this analysis initially took variance in the mortality rates into account in their analyses. Without their code, I can’t tell for sure though. Actually, without their code, there’s a lot that I’m uncertain of, I wish people would always publish their code (if they can, for instance when it’s publicly available data).

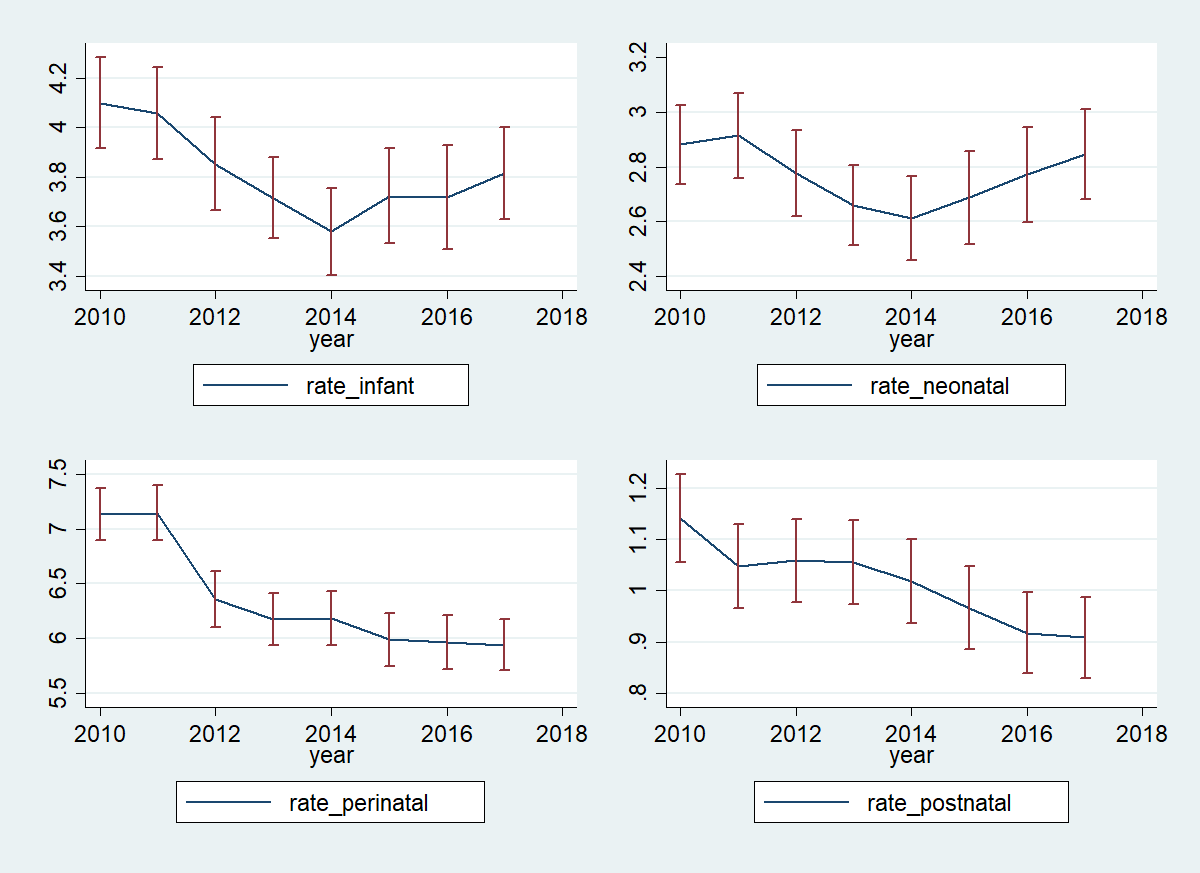
## 3. Analyses

I’m mixing the methods and results for the analyses, as it’s probably a little clearer than presenting methods then results.

### i) Does the average mortality rate change over time?

I meta-analysed all rate estimates in all areas using random-effects separately for each year between 2010 and 2017, giving a weighted estimate of the mortality rates for each year. In plain English, I took a weighted average of the mortality rates across all areas of England, giving more weight to areas where there were more births and/or more deaths (as these have more statistical power).

**Figure 1** shows the mortality rates averaged over all areas.



**Figure 1**: Mortality rates over time, Y-axis = mortality rate (per 1,000 live births/live births & stillbirths)

It is clear 2014 had the lowest infant and neonatal mortality rates (not 2013, strangely, as this was the lowest point in the published study). There’s a clear trend of decreasing mortality up to 2014, then increasing mortality up to 2017. However, perinatal and postnatal death rates have been consistently decreasing since 2010. This implies the rise in infant mortality rate has been in neonates, i.e. those aged less than 4 weeks. There could still be a trade-off in stillbirths, because I don’t know the stillbirth mortality rate, i.e. if stillbirths went down a lot and deaths within 1 week went up a little, we could still see a reduction in perinatal mortality rate and an increase in neonatal mortality rate, even though the increase in death rate is exclusively in the 0-1 week range.

Basically, I don’t know at this stage what age the increase happens, it’s just before in those aged less than 4 weeks, and could include those aged less than 1 week.

I used variance weighted least squares (VWLS – this is equivalent to linear regression, but accounts for the variance on the estimates of mortality rate, which I took so much time to estimate earlier) to estimate the trend of mortality rates overall, and between, 2010-2014 and 2014-2017 (my data shows the lowest infant mortality rate was in 2014, so I’ll use this as the “inflection point” – the point at which the trend goes from downwards to upwards).

The overall trend was a reduction over time in all mortality rates with P values below 0.001 (except neonatal mortality, where P = 0.17). This means that between 2010 and 2017, the evidence says the overall trend in infant, perinatal and postnatal mortality rates were downwards, which is good.

However, there were clear differences in the trend between 2010-2014 and 2014-2017, with very small P values (<0.001), so we can be confident the change in trend from downwards to upwards is real for infant and neonatal mortality rates, but not perinatal and postnatal mortality rates. **Table 1** shows the mortality rates in different years, as well my estimates of the trends in mortality between different years.

**Table 1**: Average mortality rate estimates for each year, mortality rates expressed per 1,000 live births, 95% confidence intervals in brackets

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Year** | **Infant mortality rate** | **Neonatal mortality rate** | **Perinatal mortality rate** | **Postnatal mortality rate** |
| 2010 | 4.09 (3.91 to 4.28) | 2.88 (2.73 to 3.02) | 7.13 (6.89 to 7.37) | 1.14 (1.05 to 1.22) |
| 2011 | 4.05 (3.87 to 4.24) | 2.91 (2.75 to 3.07) | 7.14 (6.89 to 7.40) | 1.04 (0.96 to 1.12) |
| 2012 | 3.85 (3.66 to 4.04) | 2.77 (2.62 to 2.93) | 6.35 (6.09 to 6.61) | 1.05 (0.97 to 1.14) |
| 2013 | 3.71 (3.55 to 3.87) | 2.65 (2.51 to 2.80) | 6.17 (5.93 to 6.40) | 1.05 (0.97 to 1.13) |
| 2014 | 3.57 (3.40 to 3.75) | 2.61 (2.45 to 2.76) | 6.18 (5.93 to 6.43) | 1.01 (0.93 to 1.10) |
| 2015 | 3.72 (3.53 to 3.91) | 2.68 (2.51 to 2.85) | 5.98 (5.74 to 6.22) | 0.96 (0.88 to 1.04) |
| 2016 | 3.71 (3.50 to 3.92) | 2.77 (2.59 to 2.94) | 5.96 (5.71 to 6.21) | 0.91 (0.83 to 0.99) |
| 2017 | 3.81 (3.63 to 4.00) | 2.84 (2.68 to 3.01) | 5.93 (5.70 to 6.17) | 0.90 (0.82 to 0.98) |
| Trend: 2010-2017 | -0.050 (-0.079 to -0.021) | -0.017 (-0.041 to 0.007) | -0.181 (-0.218 to -0.144) | -0.030 (-0.043 to -0.018) |
| Trend: 2010-2014 | -0.138 (-0.194 to -0.081) | -0.078 (-0.125 to -0.031) | -0.287 (-0.364 to -0.210) | -0.023 (-0.049 to 0.003) |
| Trend: 2014-2017 | 0.071 (-0.009 to 0.153) | 0.078 (0.007 to 0.150) | -0.073 (-0.180 to 0.032) | -0.037 (-0.073 to -0.001) |

OK, I’m fairly certain there is an increase in neonatal mortality, which shows up as an increase in infant mortality. Does deprivation make a difference?

### ii) Does IMD make a difference to the mortality rates over time?

I estimated the trend for mortality rate between 2010 and 2017 for all areas separately, then used VWLS to estimate the association between deprivation and the overall trend in mortalities over time.

For infant, neonatal and postnatal mortality rates, increasing deprivation made the trends more negative, i.e. the more deprived the area, the greater the reduction in mortality rates (as presented in the published paper – the decreasing inequality bit). However, nothing had an incredibly low P value, so there isn’t much to say here.

I also estimated the same trends between 2010-2014 and 2014-2017 for all areas separately, then used VWLS again to estimate the association between deprivation and the year-specific trends in mortality rates over time.

Again, most estimates were negative, so higher deprivation was associated with mortality rate trends that decreased more over time compared with lower deprivation. Again, P values were all high.

**Table 2**: Estimated association of deprivation (per 10 unit increase in IMD) and mortality rate trends, for all years, 2010-2014 and 2014-2017, mortality rates expressed per 1,000 live births

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Year** | **Infant mortality rate** | **Neonatal mortality rate** | **Perinatal mortality rate** | **Postnatal mortality rate** |
| Trend: 2010-2017 | -0.025 (-0.055 to 0.004) | -0.024 (-0.051 to 0.002) | 0.019 (-0.016 to 0.056) | -0.006 (-0.022 to 0.009) |
| Trend: 2010-2014 | -0.054 (-0.115 to 0.005) | -0.040 (-0.095 to 0.014) | 0.010 (-0.066 to 0.087) | -0.024 (-0.058 to 0.010) |
| Trend: 2014-2017 | -0.031 (-0.117 to 0.055) | -0.023 (-0.103 to 0.055) | -0.027 (-0.132 to 0.077) | -0.000 (-0.048 to 0.047) |

From this, I concluded that deprivation was not materially associated with the trend of mortality rates, i.e. increasing deprivation did not materially increase or decrease mortality rate trends over time.

However, the published paper looked at quintiles of deprivation, rather than deprivation as a continuous variable. Non-linear effects might show up in categorical analyses, so I looked at those.

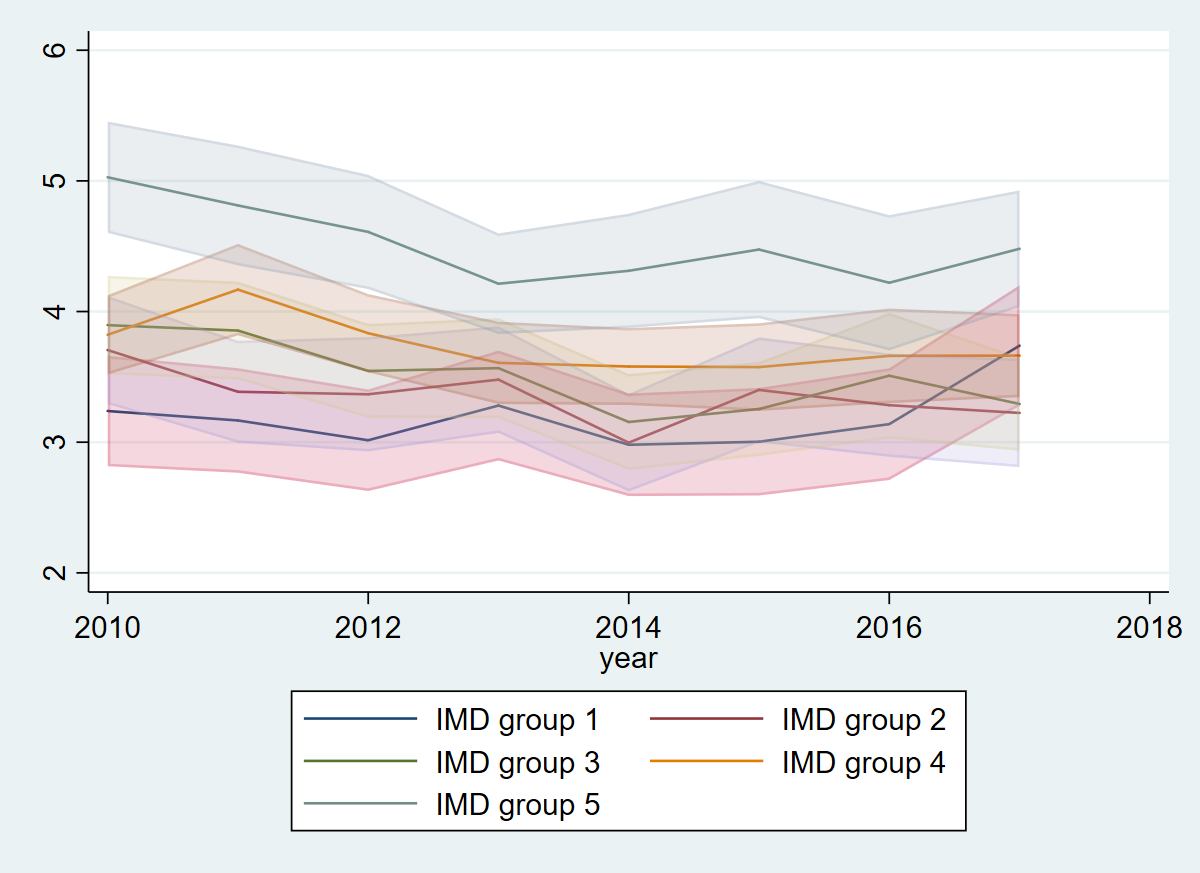
### iii) Does categorical deprivation make a difference to mortality rates over time?

I grouped the areas into 5 fifths of deprivation (as measured using IMD), based on the 324 areas I had in my analysis. These quintiles may be different to the published paper, which could have used other quintile points, but my data should be similar, given it’s representative of vast areas of the country.

For this analysis, I used both random-effects meta-analysis to get the average mortality rates in each year (which means I could reproduce the graph from the published paper), as well as using VWLS to estimate trends for each area separately, then seeing whether deprivation affects the rate trends.

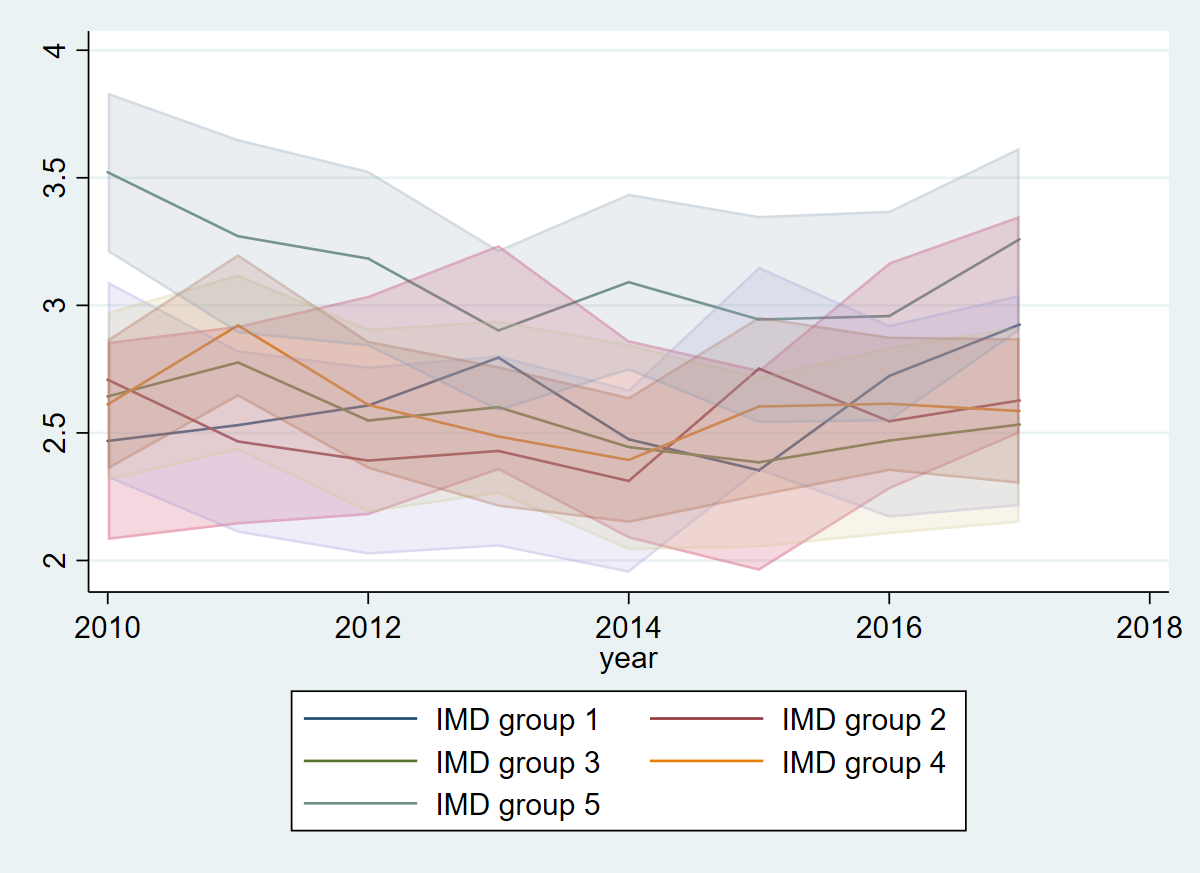
The figures I’ve made have way more variance than the published figure, I think because they aren’t accounting for the variance on the incidence rates (or I’m wrong, which is also a good possibility). Note that for all graphs, being in the most deprived fifth is bad for mortality rates, but this analysis is looking at whether bring in the most deprived fifth is bad for the *trend* in mortality rates over time.

I used Stata to make the graphs. Apparently, it took until Stata 15 to allow transparency in graphs, which seems long overdue. These aren’t as nice as R graphs (the published paper used R to make the graphs), but I didn’t want to spend hours fiddling with ggplot2, so here we are.



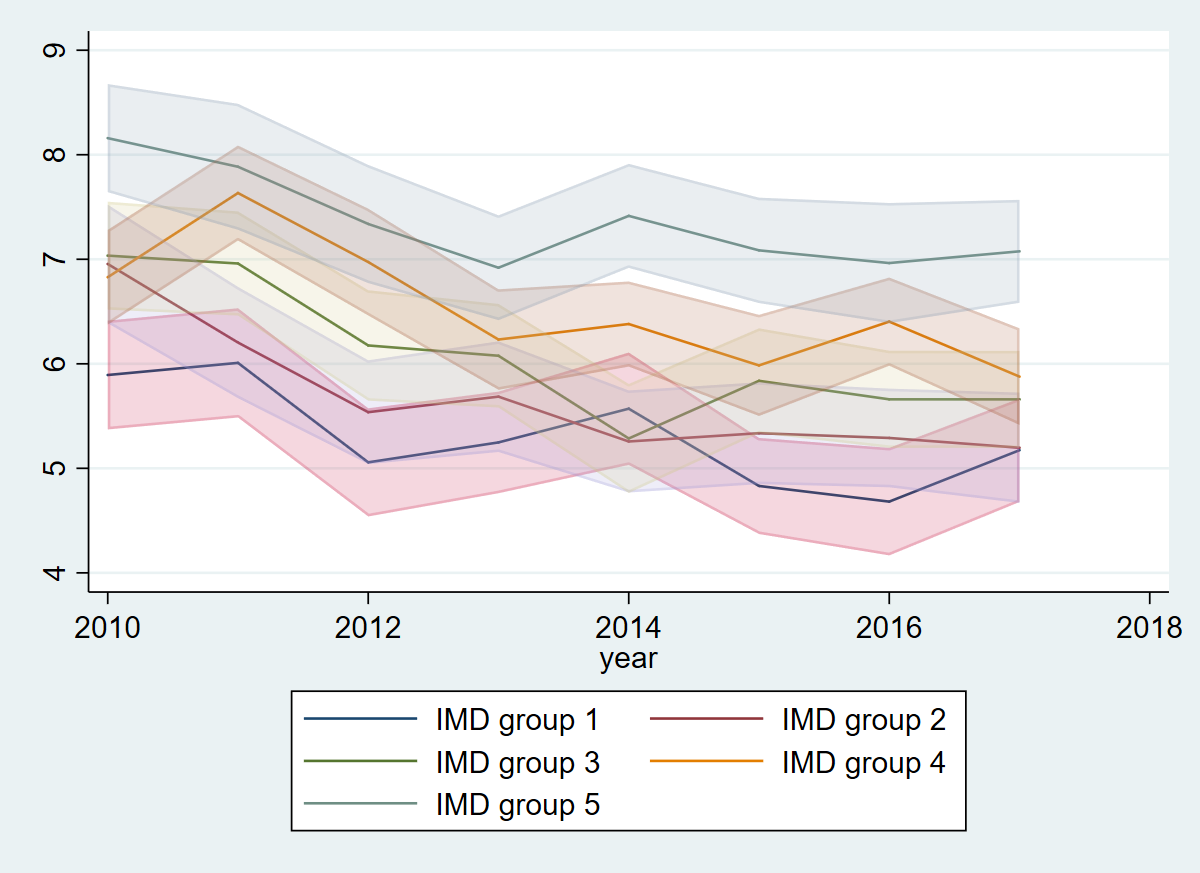
**Figure 2** Deprivation-specific infant mortality rates, Y-axis = mortality rate (per 1,000 live births)

**Figure 2** shows the deprivation-specific infant mortality rates – shaded areas are the 95% confidence interval of each deprivation group. The notable feature is that there is a big increase in infant mortality rates for the least deprived fifth of areas, taking it ahead of all other fifths except the most deprived. This isn’t in the published paper, and really matters for all these analyses. However, it’s clear from the confidence intervals that there isn’t going to be any evidence from statistical analyses for, well, anything – the precision is just too low.



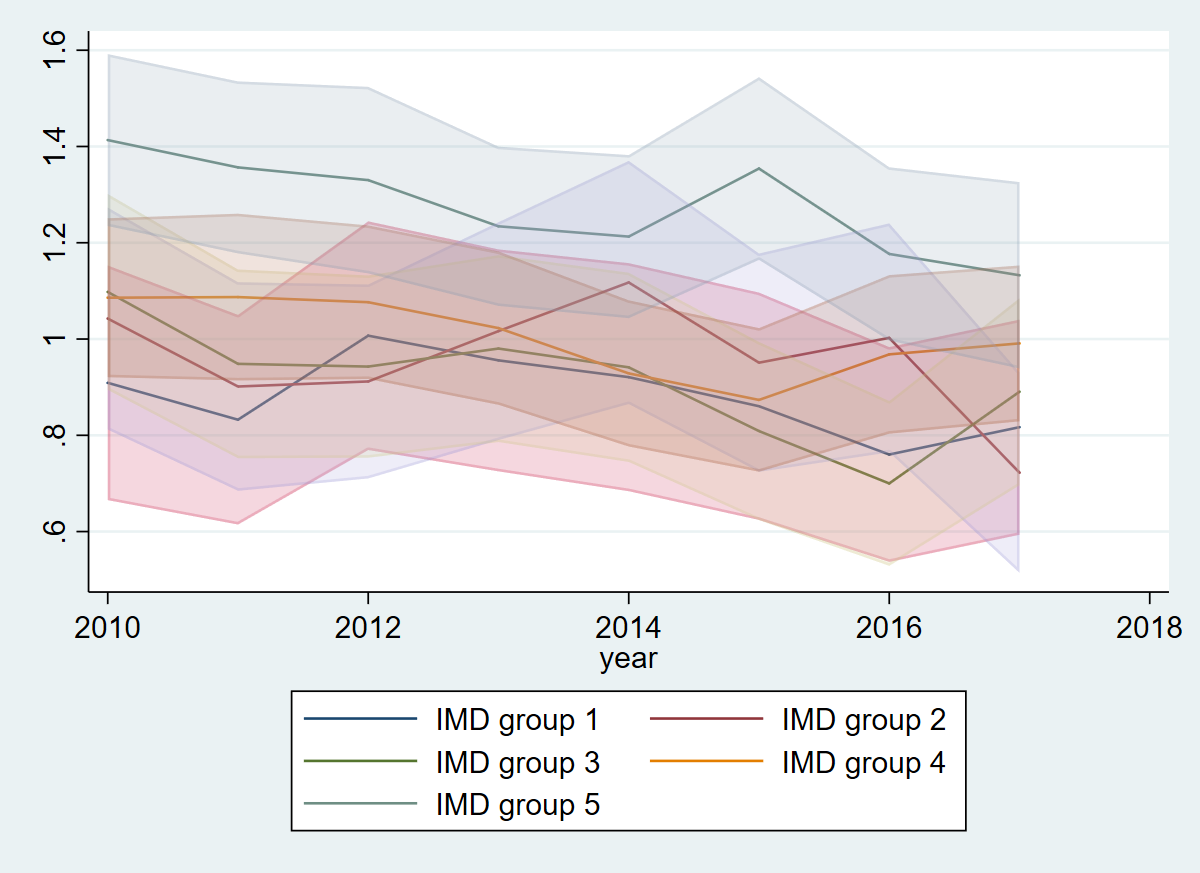
**Figure 3** Deprivation-specific neonatal mortality rates, Y-axis = mortality rate (per 1,000 live births)

**Figure 3** shows the deprivation-specific neonatal mortality rates. There’s even less going on here, but the least deprived fifth is also behaving weirdly – I put this down to the imprecision of the data and natural variation.



**Figure 4** Deprivation-specific perinatal mortality rates, Y-axis = mortality rate (per 1,000 live births and stillbirths)

**Figure 4** shows the deprivation-specific perinatal mortality rates. This shows a similar general reduction in perinatal mortality rates over time, reasonably equally for all IMD fifths.



**Figure 5** Deprivation-specific postnatal mortality rates, Y-axis = mortality rate (per 1,000 live births)

**Figure 5** shows the deprivation-specific postnatal mortality rates. This shows a similar general reduction in postnatal mortality rates over time, reasonably equally for all deprivation fifths.

From the graphs, I don’t conclude that deprivation has an association with mortality rate trends over time, but the statistical tests might show otherwise.

For the overall trend, deprivation fifths do not have trends in mortality rates that are statistically distinct, i.e. there is no evidence to say the trend in each deprivation fifth is different to the least deprived fifth. On average, though, the trends are more negative in more deprived areas. This is also true in 2010-2014.

**Table 3** Average mortality rate estimates for each year by IMD quintile, including trend analysis from 2010-2017, 2010-2014 and 2014-2017, mortality rates expressed per 1,000 live births.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Year** | **Infant mortality rate** | **Neonatal mortality rate** | **Perinatal mortality rate** | **Postnatal mortality rate** |
| IMD quintile = 1 | | | | |
| 2010 | 3.23 (2.81 to 3.66) | 2.46 (2.08 to 2.85) | 5.89 (5.37 to 6.41) | 0.90 (0.66 to 1.15) |
| 2011 | 3.16 (2.76 to 3.56) | 2.53 (2.14 to 2.92) | 6.00 (5.48 to 6.53) | 0.83 (0.61 to 1.05) |
| 2012 | 3.01 (2.62 to 3.40) | 2.60 (2.17 to 3.03) | 5.05 (4.53 to 5.57) | 1.00 (0.76 to 1.24) |
| 2013 | 3.28 (2.86 to 3.70) | 2.79 (2.35 to 3.23) | 5.24 (4.76 to 5.73) | 0.95 (0.72 to 1.18) |
| 2014 | 2.98 (2.58 to 3.37) | 2.47 (2.08 to 2.86) | 5.57 (5.03 to 6.10) | 0.92 (0.68 to 1.15) |
| 2015 | 3.00 (2.59 to 3.41) | 2.35 (1.95 to 2.74) | 4.83 (4.37 to 5.29) | 0.86 (0.62 to 1.09) |
| 2016 | 3.13 (2.71 to 3.56) | 2.72 (2.27 to 3.16) | 4.68 (4.16 to 5.19) | 0.76 (0.53 to 0.98) |
| 2017 | 3.73 (3.27 to 4.20) | 2.92 (2.49 to 3.35) | 5.17 (4.67 to 5.66) | 0.81 (0.59 to 1.04) |
| Trend: 2010-2017 | 0.029 (-0.036 to 0.095) | 0.034 (-0.028 to 0.097) | -0.142 (-0.221 to -0.064) | -0.017 (-0.052 to 0.017) |
| Trend: 2010-2014 | -0.042 (-0.170 to 0.086) | 0.023 (-0.101 to 0.147) | -0.146 (-0.312 to 0.018) | 0.016 (-0.058 to 0.091) |
| Trend: 2014-2017 | 0.227 (0.037 to 0.417) | 0.168 (-0.015 to 0.351) | -0.111 (-0.340 to 0.117) | -0.040 (-0.143 to 0.062) |
| IMD quintile = 2 | | | | |
| 2010 | 3.70 (3.29 to 4.11) | 2.70 (2.32 to 3.09) | 6.95 (6.38 to 7.52) | 1.04 (0.81 to 1.27) |
| 2011 | 3.38 (2.99 to 3.77) | 2.46 (2.10 to 2.82) | 6.20 (5.67 to 6.73) | 0.90 (0.68 to 1.11) |
| 2012 | 3.36 (2.92 to 3.80) | 2.39 (2.02 to 2.76) | 5.53 (5.04 to 6.03) | 0.91 (0.71 to 1.11) |
| 2013 | 3.47 (3.07 to 3.88) | 2.42 (2.05 to 2.80) | 5.68 (5.15 to 6.21) | 1.01 (0.79 to 1.24) |
| 2014 | 2.99 (2.62 to 3.36) | 2.31 (1.95 to 2.67) | 5.25 (4.76 to 5.74) | 1.11 (0.86 to 1.37) |
| 2015 | 3.40 (2.99 to 3.80) | 2.75 (2.35 to 3.15) | 5.33 (4.84 to 5.82) | 0.95 (0.72 to 1.17) |
| 2016 | 3.28 (2.88 to 3.67) | 2.54 (2.16 to 2.92) | 5.29 (4.81 to 5.76) | 1.00 (0.76 to 1.24) |
| 2017 | 3.22 (2.80 to 3.63) | 2.62 (2.21 to 3.04) | 5.19 (4.66 to 5.72) | 0.72 (0.51 to 0.93) |
| Trend: 2010-2017 | -0.050 (-0.113 to 0.012) | 0.008 (-0.051 to 0.068) | -0.203 (-0.284 to -0.122) | -0.020 (-0.054 to 0.013) |
| Trend: 2010-2014 | -0.135 (-0.259 to -0.011) | -0.081 (-0.198 to 0.036) | -0.380 (-0.547 to -0.214) | 0.024 (-0.050 to 0.099) |
| Trend: 2014-2017 | 0.064 (-0.111 to 0.240) | 0.082 (-0.090 to 0.255) | -0.020 (-0.246 to 0.205) | -0.117 (-0.219 to -0.014) |
| IMD quintile = 3 | | | | |
| 2010 | 3.89 (3.51 to 4.27) | 2.64 (2.31 to 2.97) | 7.03 (6.51 to 7.55) | 1.09 (0.89 to 1.30) |
| 2011 | 3.85 (3.48 to 4.22) | 2.77 (2.43 to 3.12) | 6.95 (6.46 to 7.45) | 0.94 (0.75 to 1.14) |
| 2012 | 3.54 (3.18 to 3.90) | 2.54 (2.18 to 2.90) | 6.17 (5.64 to 6.70) | 0.94 (0.75 to 1.13) |
| 2013 | 3.56 (3.18 to 3.94) | 2.60 (2.26 to 2.94) | 6.07 (5.58 to 6.57) | 0.98 (0.78 to 1.17) |
| 2014 | 3.15 (2.78 to 3.52) | 2.44 (2.04 to 2.84) | 5.28 (4.76 to 5.80) | 0.94 (0.74 to 1.13) |
| 2015 | 3.25 (2.89 to 3.61) | 2.38 (2.05 to 2.71) | 5.83 (5.33 to 6.33) | 0.80 (0.62 to 0.99) |
| 2016 | 3.50 (3.02 to 3.98) | 2.47 (2.10 to 2.83) | 5.66 (5.19 to 6.12) | 0.70 (0.52 to 0.87) |
| 2017 | 3.29 (2.93 to 3.65) | 2.53 (2.14 to 2.91) | 5.65 (5.19 to 6.12) | 0.89 (0.69 to 1.08) |
| Trend: 2010-2017 | -0.091 (-0.149 to -0.032) | -0.036 (-0.091 to 0.017) | -0.208 (-0.283 to -0.132) | -0.039 (-0.068 to -0.009) |
| Trend: 2010-2014 | -0.178 (-0.296 to -0.060) | -0.052 (-0.166 to 0.060) | -0.437 (-0.600 to -0.274) | -0.027 (-0.090 to 0.035) |
| Trend: 2014-2017 | 0.057 (-0.106 to 0.221) | 0.038 (-0.135 to 0.211) | 0.086 (-0.133 to 0.306) | -0.028 (-0.115 to 0.058) |
| IMD quintile = 4 | | | | |
| 2010 | 3.82 (3.51 to 4.12) | 2.61 (2.35 to 2.86) | 6.82 (6.37 to 7.28) | 1.08 (0.92 to 1.25) |
| 2011 | 4.16 (3.81 to 4.51) | 2.92 (2.64 to 3.20) | 7.63 (7.17 to 8.08) | 1.08 (0.91 to 1.26) |
| 2012 | 3.83 (3.53 to 4.13) | 2.61 (2.35 to 2.86) | 6.97 (6.46 to 7.48) | 1.07 (0.91 to 1.23) |
| 2013 | 3.60 (3.29 to 3.92) | 2.48 (2.21 to 2.76) | 6.23 (5.75 to 6.71) | 1.02 (0.86 to 1.18) |
| 2014 | 3.57 (3.28 to 3.87) | 2.39 (2.14 to 2.64) | 6.38 (5.97 to 6.78) | 0.92 (0.77 to 1.08) |
| 2015 | 3.57 (3.23 to 3.91) | 2.60 (2.25 to 2.95) | 5.98 (5.50 to 6.46) | 0.87 (0.72 to 1.02) |
| 2016 | 3.66 (3.29 to 4.02) | 2.61 (2.35 to 2.87) | 6.40 (5.98 to 6.82) | 0.96 (0.80 to 1.13) |
| 2017 | 3.66 (3.34 to 3.98) | 2.58 (2.30 to 2.87) | 5.87 (5.41 to 6.33) | 0.99 (0.82 to 1.15) |
| Trend: 2010-2017 | -0.049 (-0.099 to -0.000) | -0.021 (-0.063 to 0.020) | -0.181 (-0.251 to -0.110) | -0.023 (-0.049 to 0.001) |
| Trend: 2010-2014 | -0.097 (-0.193 to -0.000) | -0.083 (-0.164 to -0.002) | -0.224 (-0.362 to -0.086) | -0.038 (-0.089 to 0.011) |
| Trend: 2014-2017 | 0.032 (-0.106 to 0.170) | 0.067 (-0.052 to 0.186) | -0.108 (-0.303 to 0.085) | 0.027 (-0.042 to 0.097) |
| IMD quintile = 5 | | | | |
| 2010 | 5.02 (4.60 to 5.45) | 3.52 (3.20 to 3.83) | 8.15 (7.64 to 8.67) | 1.41 (1.23 to 1.59) |
| 2011 | 4.81 (4.35 to 5.27) | 3.27 (2.88 to 3.65) | 7.88 (7.28 to 8.48) | 1.35 (1.17 to 1.53) |
| 2012 | 4.60 (4.17 to 5.04) | 3.18 (2.83 to 3.52) | 7.33 (6.77 to 7.90) | 1.33 (1.13 to 1.52) |
| 2013 | 4.21 (3.82 to 4.59) | 2.90 (2.58 to 3.21) | 6.91 (6.41 to 7.42) | 1.23 (1.06 to 1.39) |
| 2014 | 4.31 (3.87 to 4.74) | 3.09 (2.74 to 3.43) | 7.41 (6.91 to 7.91) | 1.21 (1.04 to 1.38) |
| 2015 | 4.47 (3.94 to 4.99) | 2.94 (2.53 to 3.35) | 7.08 (6.58 to 7.58) | 1.35 (1.16 to 1.54) |
| 2016 | 4.22 (3.70 to 4.73) | 2.95 (2.54 to 3.37) | 6.96 (6.38 to 7.53) | 1.17 (0.99 to 1.35) |
| 2017 | 4.48 (4.03 to 4.92) | 3.25 (2.89 to 3.61) | 7.07 (6.58 to 7.56) | 1.13 (0.93 to 1.32) |
| Trend: 2010-2017 | -0.084 (-0.154 to -0.014) | -0.049 (-0.104 to 0.005) | -0.144 (-0.225 to -0.062) | -0.033 (-0.062 to -0.005) |
| Trend: 2010-2014 | -0.207 (-0.343 to -0.072) | -0.130 (-0.235 to -0.025) | -0.239 (-0.402 to -0.076) | -0.052 (-0.107 to 0.002) |
| Trend: 2014-2017 | 0.032 (-0.167 to 0.233) | 0.051 (-0.109 to 0.211) | -0.110 (-0.333 to 0.112) | -0.037 (-0.118 to 0.043) |

For 2014-2017, there is again no evidence that deprivation is associated with a change in trend. The trend estimates are either very close to 0 (perinatal and postnatal mortality rates) or negative (i.e. more deprivation = more reduction in mortality rates, infant and neonatal mortality rates).

**Table 4** Estimated association of deprivation (for each fifth of deprivation compared to the least deprived fifth) and mortality rate trends, for 2010-2017, 2010-2014 and 2014-2017, mortality rates expressed per 1,000 live births

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **IMD quintile** | **Infant mortality rate** | **Neonatal mortality rate** | **Perinatal mortality rate** | **Postnatal mortality rate** |
| Trend: 2010-2017 | | | | |
| 1 | Reference | Reference | Reference | Reference |
| 2 | -0.080 (-0.171 to 0.010) | -0.026 (-0.113 to 0.060) | -0.060 (-0.173 to 0.051) | -0.002 (-0.051 to 0.046) |
| 3 | -0.120 (-0.208 to -0.032) | -0.071 (-0.154 to 0.012) | -0.065 (-0.174 to 0.043) | -0.021 (-0.067 to 0.024) |
| 4 | -0.079 (-0.162 to 0.003) | -0.055 (-0.131 to 0.020) | -0.038 (-0.143 to 0.066) | -0.006 (-0.050 to 0.036) |
| 5 | -0.114 (-0.210 to -0.017) | -0.083 (-0.167 to -0.000) | -0.001 (-0.114 to 0.111) | -0.016 (-0.061 to 0.029) |
| Trend: 2010-2014 | | | | |
| 1 | Reference | Reference | Reference | Reference |
| 2 | -0.093 (-0.272 to 0.085) | -0.104 (-0.275 to 0.066) | -0.234 (-0.468 to 0.000) | 0.008 (-0.097 to 0.114) |
| 3 | -0.136 (-0.311 to 0.038) | -0.075 (-0.244 to 0.092) | -0.290 (-0.522 to -0.058) | -0.043 (-0.141 to 0.054) |
| 4 | -0.055 (-0.216 to 0.105) | -0.106 (-0.254 to 0.042) | -0.077 (-0.293 to 0.137) | -0.055 (-0.145 to 0.035) |
| 5 | -0.165 (-0.352 to 0.021) | -0.153 (-0.316 to 0.009) | -0.093 (-0.325 to 0.139) | -0.068 (-0.161 to 0.024) |
| Trend: 2014-2017 | | | | |
| 1 | Reference | Reference | Reference | Reference |
| 2 | -0.162 (-0.422 to 0.096) | -0.085 (-0.336 to 0.166) | 0.090 (-0.230 to 0.412) | -0.076 (-0.221 to 0.068) |
| 3 | -0.170 (-0.421 to 0.080) | -0.129 (-0.382 to 0.122) | 0.197 (-0.119 to 0.514) | 0.012 (-0.122 to 0.146) |
| 4 | -0.195 (-0.430 to 0.039) | -0.100 (-0.319 to 0.117) | 0.002 (-0.297 to 0.302) | 0.068 (-0.056 to 0.192) |
| 5 | -0.194 (-0.471 to 0.081) | -0.116 (-0.360 to 0.126) | 0.000 (-0.318 to 0.320) | 0.003 (-0.127 to 0.134) |

Conclusion from this: deprivation is not associated with mortality rate trends over time, either overall or between 2010-2014 or 2014-2017.

### iv) When did the deaths occur?

Anna asked me to look at when the deaths occurred, specifically. To do this, I used different data that Anna sent, which is a summary of deaths at different ages for England and Wales (cms2017 <https://www.ons.gov.uk/file?uri=/peoplepopulationandcommunity/birthsdeathsandmarriages/deaths/datasets/childmortalitystatisticschildhoodinfantandperinatalchildhoodinfantandperinatalmortalityinenglandandwales/2017/previous/v1/cms2017.xls> , Table 16). I had the number of live births, the number of stillbirths, and the number of deaths for babies aged:

* 0-1 days
* 1-7 days
* 7-28 days
* 28 days – 3 months
* 3 months – 6 months
* 6 months – 1 year

Although I couldn’t do anything about the association with deprivation with this data, I could produce some graphs and analyses detailing how mortality rates have changed over time for all those categories of mortality (and combinations of those categories).

Firstly, I made graphs of mortality rate for live births up to 1 year, which showed the same as in the previous analyses – a decrease in mortality rate until 2014 (again, not 2013), then an increase, see **Figure 6**.



**Figure 6** Average mortality rate for live births up to 1 year, Y-axis = mortality rate per 1,000 live births

However, when I include stillbirths in the mortality rate, I get **Figure 7**.

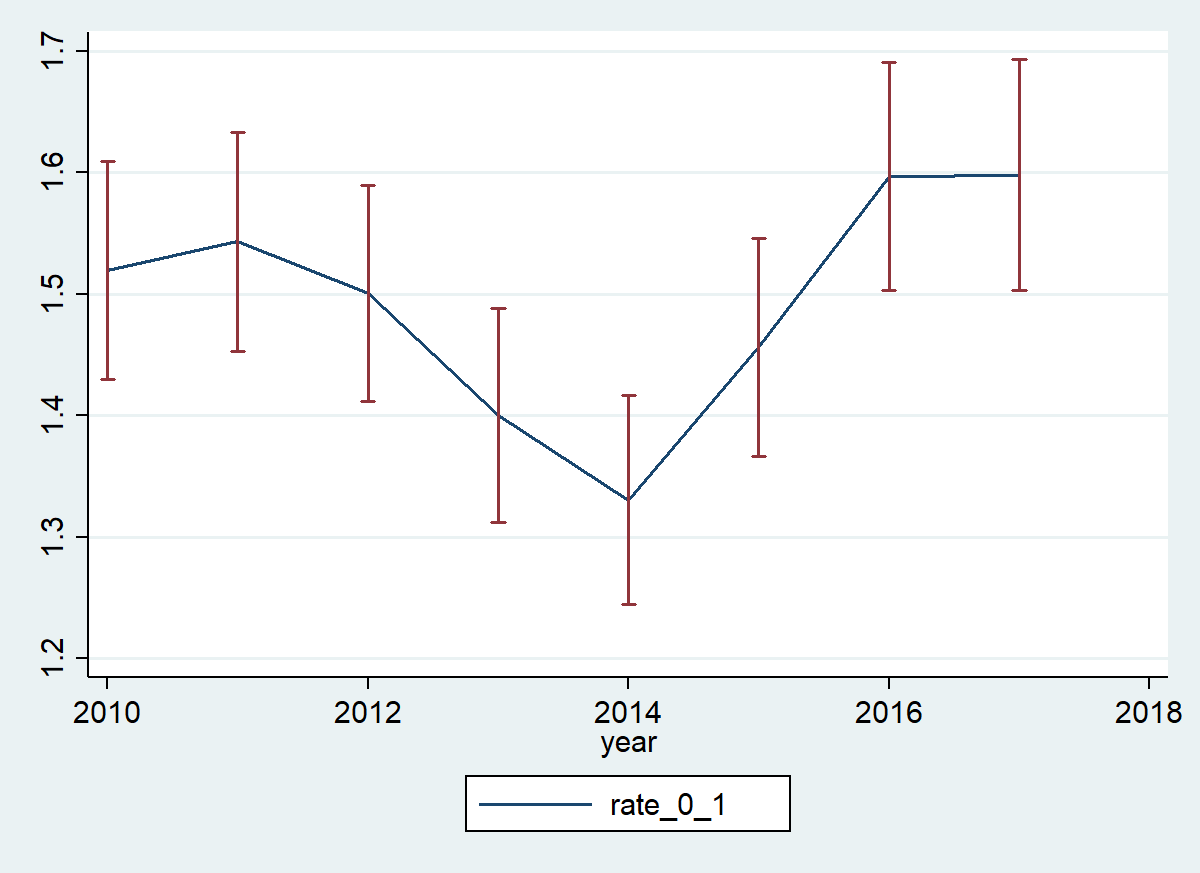


**Figure 7** Average mortality rate for all births up to 1 year (includes stillbirths), Y-axis = mortality rate per 1,000 births

Here, there is no change in trend in 2014 – the mortality rate slows down but doesn’t go back up in 2014.

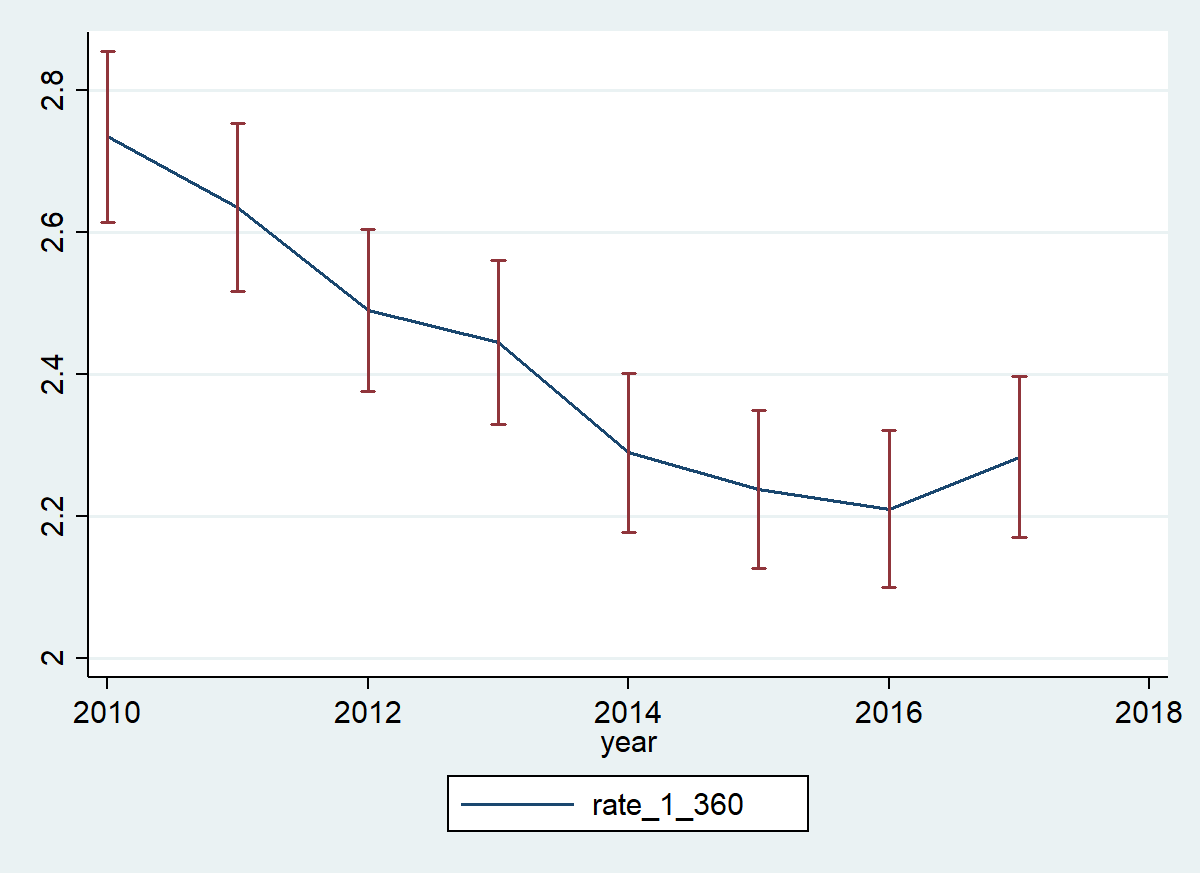
So where is the extra mortality in figure 6 coming from?

It turns out, mostly from mortality at aged less than 1 day, **Figure 8**.



**Figure 8** Average mortality rate for all live births up to 1 day, Y-axis = mortality rate per 1,000 live births

When I remove deaths aged less than 1 day from the rest of the live births, I get **Figure 9**.



**Figure 9** Average mortality rate for all live births from 1 day to 1 year, Y-axis = mortality rate per 1,000 live births

Again, there is no sign of the 2014 change in trend. There *is* a slight increase in 2017, which may or may not be relevant, but it’s nothing like **Figure 6**.

I made graphs for the other age groups, but it doesn’t show anything particularly interesting (to me, anyway). Essentially, mortality rates decrease in each age group, and tend to slow or reverse a tiny amount around 2014, but it’s not consistent in either time or magnitude:

* Aged 1-7 days, the slope is consistently downwards
* Aged 7-28 days, the slope is down to 2014, hovers, then increases just for 2017 (the likely cause of the upward inflection between 2016 and 2017 in figure 8)
* Aged 28 days – 3 months, the slope is downward to 2015, when it jumps in 2016 and decreases again in 2017
* Aged 3 months – 6 months, the slope is down to 2012, up to 2014, then down again
* Aged 6 months – 1 year, the slope is down to 2014, up to 2015, then down again
* Stillbirth, decreases from 2011-2017

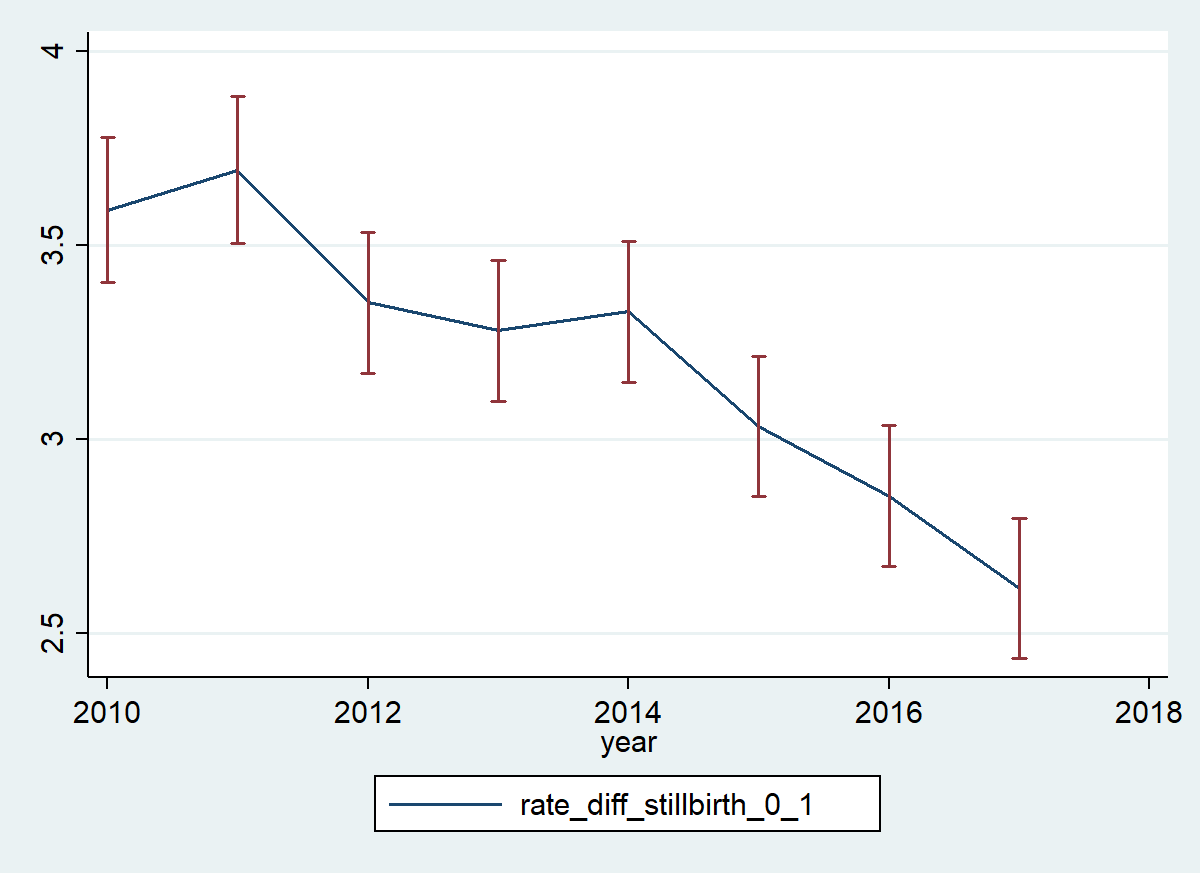
The SEs for each year are quite large in all analyses – I really don’t think the published paper took this into account, potentially leading to their conclusions (but then, why does everything I have show a 2014 inflection point, not 2013?).

Extra bit of information: the rates of stillbirth and rates of mortality in <1 day olds are congruous from 2010-2014, i.e. as stillbirth rates go down, so do mortality rates for <1 day olds: VWLS estimate of 0.32 change in mortality rate in <1 day olds for a unit increase in stillbirth rate (95% CI: 0.14 to 0.49).

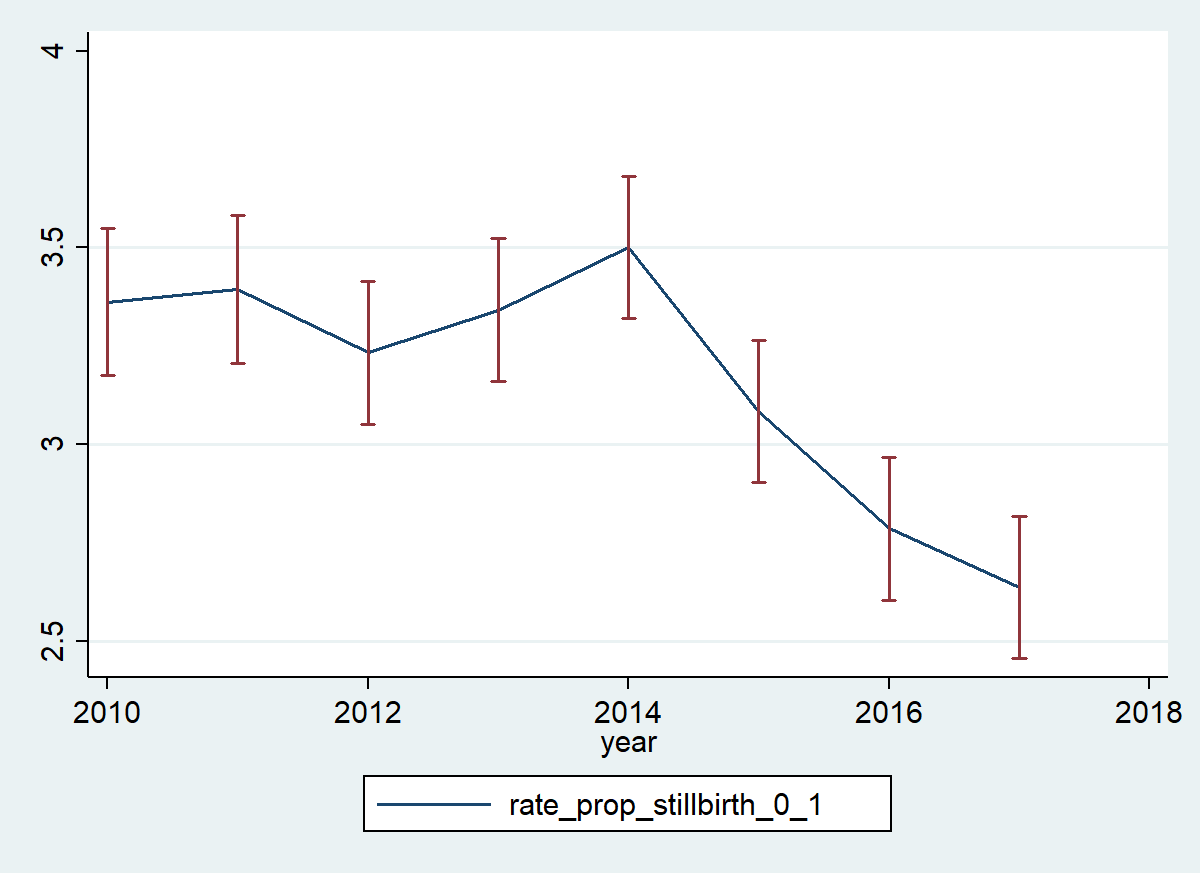
In comparison, in 2014-2017 the two rates are divergent, i.e. as stillbirth rates go down, mortality rates for <1 day olds go up: VWLS estimate of -0.61 change in mortality rate in <1 day olds for a unit increase in stillbirth rate (95% CI: -0.90 to -0.33). It’s not a one-to-one association, so this is only suggestive of something going on, it’s not definitive.

Also, the correlation coefficients (r) between the stillbirth and mortality rates for <1 day olds are 0.89 in 2010-2014, and -0.85 in 2014-2017. **Figures 9** and **10** show the dependence between the two rates: **Figure 9** is the stillbirth rate minus the rate of mortality for <1 day olds over time, **Figure 10** is the stillbirth rate divided by the rate of mortality for <1 day olds over time. They both show a reasonably stable ratio until 2014, when it suddenly drops.

*Note: the Y-axis values are similar (as are the estimates), but this is just random chance, it just happens the difference between the rates is roughly equal to the ratio of the rates.*



**Figure 10** The stillbirth rate minus the rate of mortality for <1 day olds, Y-axis = difference in mortality rate per 1,000 live births



**Figure 11** The stillbirth rate divided by the rate of mortality for <1 day olds, Y-axis = ratio of stillbirth rate and rate of mortality for <1 day olds

My conclusion from all of this is that the perceived increase in infant mortality comes from the increase in mortality for babies under 1 day old, which to my mind are very similar to the stillbirths – given stillbirths have continued to go down, it is plausible the perceived increase in infant mortality is down to keeping babies, who would have otherwise been stillborn, alive for a few hours. Or there could have been a change in recording procedure. Or the demographics of mothers could have changed. Or anything, really.

## 4. Conclusion

The infant mortality rate has increased between 2014 and 2017, which is bad since it decreased between 2010 and 2013. This seems to be driven almost entirely from the neonatal mortality rate, specifically in babies who die within a day – when looking at perinatal and postnatal mortality rates, everything appears to be decreasing over time (which is good).

Although deprivation is associated with mortality rates in all instances, I can’t find any association between deprivation and mortality rate *trends*, i.e. there is no evidence for an association between increasing deprivation and increasing or decreasing mortality rate trends over time, looking at all years, 2010-2014 and 2014-2017.

### Why are my results different to the published paper?

Not sure, it would help if people published their code. I’d guess that they haven’t accounted for the variance in the estimates of the mortality rates, which means their estimates are too precise. It also means that estimates from small areas with few people got more weight than they should have had. Given the model in web appendix 3 <https://bmjopen.bmj.com/content/bmjopen/9/10/e029424/DC1/embed/inline-supplementary-material-1.pdf?download=true> , I don’t think they accounted for the variance in the outcome (mixed effects regression I \*think\* should be equivalent to a random effects meta-analysis model though [maybe without the variance in the outcome?], so who knows…). In any case, that’s my best theory for why our graphs of infant mortality rate over time split by deprivation quintiles are different.

I didn’t repeat their analysis looking at child poverty. They’re wrong to say that accounting for time-invariant confounders means their estimate is “likely to reflect a causal association” though. It’s only causal if there are literally no time-variant confounders or the child poverty and infant mortality rate association, which seems far-fetched. Government policy seems like a confounder, as do the regional, national and global economies (although it depends on whether they are using child poverty as a proxy for deprivation?). Also, it assumes the case-mix of mothers is stable or time-invariant, which is nonsense.

Anyway, it would take some time to redo this analysis, and given I’m reasonably certain that the increase in infant mortality is actually a shift from stillbirths to mortality under 1 day old, I don’t necessarily think there would be much to be gained from doing another analysis. Without knowing *why* the shift seems to have occurred, any new analyses run the risk of being biased in any case.