Preterm birth and infant mortality in Switzerland: Social inequality trends before, during and after the COVID-19 pandemic

Study protocol for a PhD thesis

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Overarching goal

The overarching goal of this PhD thesis is to examine trends of social inequalities in preterm birth and infant mortality before, during and after the COVID-19 pandemic in Switzerland. The planned research is organized across three aims. First, we will describe annual trends of socioeconomic inequalities in preterm birth and infant mortality between 2012 and 2024 (Aim I). Second, we will describe trends of sociodemographic inequalities in preterm birth and infant mortality between 2012 and 2024 (Aim II). Third, we will quantify the impact of the first wave of the COVID-19 pandemic (March-June 2020) on these socioeconomic and sociodemographic inequalities for both outcomes (Aim III).

Background

General background

Social inequalities refer to differences in health outcomes that are systematic, preventable, and unjust, occurring either between different populations, among social groups within a population, or along a continuum of social position[1]. In this PhD thesis, we will primarily study social inequalities in preterm birth and infant mortality in Switzerland.

Preterm birth is commonly defined as a birth occurring before 37 completed weeks of gestation. Preterm birth constitutes a major public health concern due to its high prevalence[2] and its substantial long-term health consequences[3–6], such as (but not limited to) Attention-Deficit/Hyperactivity disorder, impaired cognitive performance, or asthma. Preterm birth is also known as being one of the leading cause of infant mortality[7].

Infant mortality is commonly defined as a death occurring during the first year of life. Infant mortality can serve as a key indicator of overall population health and a key indicator of the performance of healthcare systems[8]. Given the strong biological and epidemiological link between preterm birth and infant mortality, examining both outcomes jointly provides a more comprehensive understanding of early-life health risks. An international overview of these outcomes is presented next, followed by a more detailed focus on Switzerland.

Globally, preterm birth rates have increased since 1990, reaching a peak around 2010[9], and have largely plateaued over the past decade (2010–2020)[10], although these recent trends are heterogenous across countries. In comparison, neonatal mortality (infant death between birth and 28 completed days of life) rates have shown a consistent decline between 1990 and 2017 across all world regions[11]. Trends observed across Europe closely align with these global patterns. While preterm birth rates have shown diverging trajectories across countries since the mid-1990s[12], infant mortality has exhibited a clear and consistent decline across the region since 1990[13–15]. In Switzerland, however, both rates have declined over the period 2007–2024.

Preterm birth rate declined from 7.4% in 2007 to 6.1% in 2024[16] and infant mortality rate declined from 3.9‰ in 2007 to 3.3‰ in 2024[17]. Figure 1 shows the temporal trends of both outcomes from 2007 to 2024[16,17].

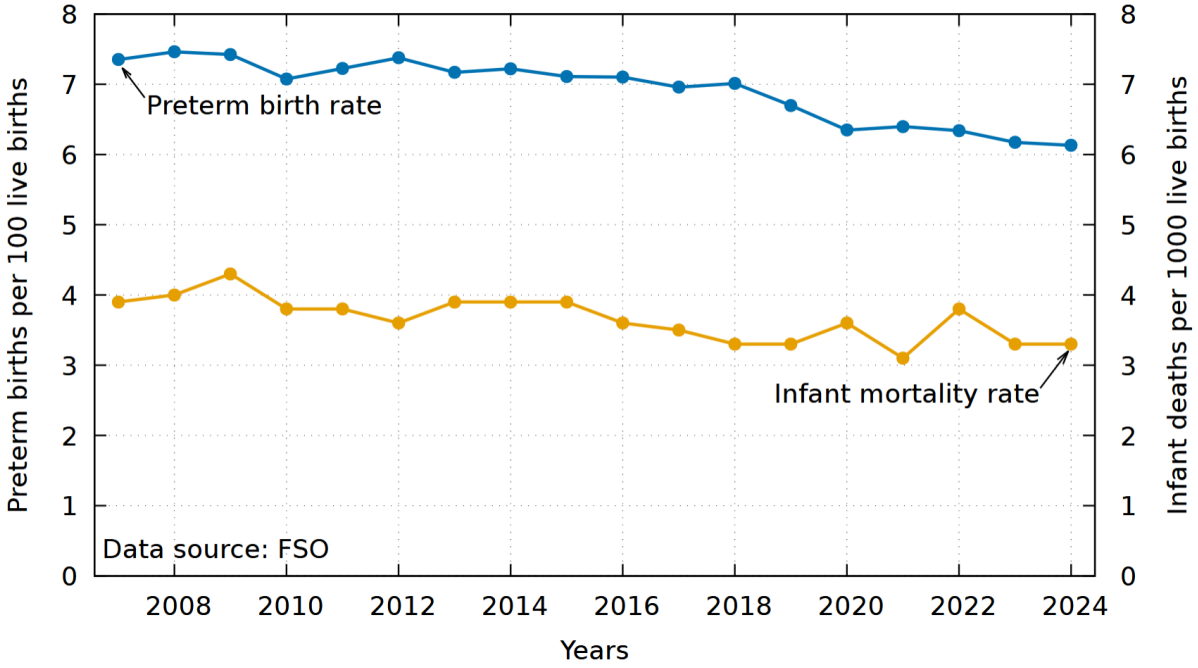

Figure 1: Annual preterm birth and infant mortality rates (per 100 and 1000 live births respectively) from 2007 to 2024 in Switzerland (data source: FSO)

While both outcomes registered an overall decline, their trends (slopes) differ. The preterm birth rate exhibits a gradual overall decline, with some year-to-year fluctuations, decreasing from higher levels in the late 2000s to lower levels in more recent years. Infant mortality rates show a less pronounced downward pattern, remaining relatively stable over time with modest fluctuations, particularly during COVID-19 pandemic. These differing trajectories may also vary across social strata, a dimension explored in this PhD thesis.

State of the field

To understand how health outcomes vary across social strata, this PhD thesis is guided by the Fundamental Causes Theory. This theory states that social factors influence health outcomes through intermediary mechanisms; a process that can be broadly represented as: social factors → (potential) mechanisms → outcomes. In this thesis, the social factors (exposures) of interest include socioeconomic position and selected demographic characteristics, while the outcomes under study are preterm birth and infant mortality. These outcomes may be shaped by social factors through underlying mechanisms—such as health behaviors or access to healthcare—which will not be assessed within the scope of this PhD thesis. Within this conceptual framework, the analyses will specifically focus on distinct dimensions of social inequalities.

In this PhD thesis, we focus on two specific types of inequalities: socioeconomic and sociodemographic inequalities. Socioeconomic inequalities, as defined in this thesis, refer primarily to differences in income and levels of area deprivation. Sociodemographic inequalities, as defined in this thesis, relate mainly to variations in maternal or child nationality, migration status, and country of birth. Inequalities remain poorly characterized in Switzerland though trends in the outcomes are known: the following paragraphs review the available evidence.

Evidence suggests that socioeconomic and sociodemographic inequalities are present in preterm birth in Switzerland, although the available literature remains relatively limited. In a study[18] using data spanning 2011 – 2017, women with household incomes below the fifth decile (reference category) show increased odds ratio of extremely preterm birth. Those in the lowest income decile (first decile) have particularly elevated odds ratio of preterm birth compared to the reference group. Regular migrants (i.e., women with residence permits from countries worldwide) have lower odds ratio of preterm birth than Swiss women in Switzerland[19]. This pattern was also observed among women with annual residence permits and asylum seekers[18]. Compared to mothers born in Switzerland, mothers originating from certain countries not belonging to the Organization for Economic Co-operation and Development (OECD) had higher odds ratio of extremely preterm birth, whereas mothers from countries belonging to the European Union or the European Free Trade Association (EU/EFTA) had reduced odds ratio of extremely preterm birth[18]. While evidence on inequalities in preterm birth is limited, evidence on inequalities in infant mortality is somewhat more extensive.

Socioeconomic and sociodemographic factors may also shape the risk of infant mortality in Switzerland, though trends over the past decade are not fully known. Studies[18,20] using individual-level administrative data from 2011–2018 have shown clear socioeconomic inequalities: women in the lowest income decile had higher odds ratio of infant mortality than those in the fifth (reference) decile[18], and infants from neighborhoods in the first four quintiles of area-level socioeconomic position exhibited higher rate ratio than those in the fifth quintile[20]. Sociodemographic inequalities were also observed. The odds of infant death appears lower among asylum seekers than among Swiss women[18]. Higher rate ratio has been reported among infants born to mothers from European countries outside the European Economic Area compared with those born to mothers of Swiss nationality[20]. Similarly, infants born to mothers born in non-OECD countries outside the EU/EFTA exhibit higher odds ratio of mortality relative to those born to mothers born in Switzerland[18], whereas lower odds ratio is observed among infants born to mothers born in EU/EFTA countries compared with mothers born in Switzerland[18]. Finally, a study[21] has demonstrated that children of foreign nationalities exhibit higher rates of infant mortality compared to Swiss children, with this inequality showing no significant reduction over the period from 1980 to 2010. These socioeconomic and sociodemographic

characteristics are particularly important in the Swiss context, where the sociodemographic landscape has changed substantially over the last decade.

In Switzerland, more than 40% of the population has a migration background, a proportion that has increased steadily since 2010,[22] so temporal changes in sociodemographic inequalities may capture both changes in outcome risk across groups and changes in the size and composition of those groups over time. Other recent changes in Switzerland make it necessary to re-examine social inequalities in these outcomes.

Specifically, recent public health and policy developments may have modified exposure to risk and access to care across social groups. First, a policy implemented in early 2014 aimed at fully covering illness-related costs during pregnancy (and after) may have reduced financial barriers to healthcare and, in turn, influenced inequalities in the outcomes[23]. Second, Switzerland has been one of the European countries most affected by the COVID-19 pandemic, which may have had differential effects across social groups[24].

Context for understanding social inequalities in these outcomes can be provided by examining both the structure of the Swiss healthcare financing system and a major reform implemented in 2014. Health insurance is mandatory for residents of Switzerland and is provided only by private insurers, so patients financially contribute to medical treatments and consultations via deductibles and co-payments[25]. Out-of-pocket spending is high; Switzerland has the highest cost sharing in the Organization for Economic Cooperation and Development[26]. To ensure equal treatment during pregnancy, the Swiss Federal Council implemented a health policy expansion on March 1, 2014, which aimed at full coverage of healthcare costs (including deductibles and copayments) in the event of illness or complications, whether related or not to the pregnancy or congenital infirmity, from 13 weeks' gestation to 8 weeks postpartum[27]. This policy expansion did not change prenatal care specific to the monitoring of a normal pregnancy, which was already fully covered before March 1, 2014.

Evidence suggests that the 2014 policy expansion had only limited effects on outcomes and reinforced socioeconomic inequalities in its benefits. This policy expansion induced a modest population-wide reduction in low-birth-weight births without reducing preterm births or neonatal mortality (death from birth to 28 days of life[23], but it did reveal socioeconomic inequalities in the policy's impact: children of parents not at risk of poverty had lower rates of extremely preterm births (before 27 weeks of gestational age; 0.19%) and neonatal deaths (0.13%) after policy initiation and benefited more from the expansion than children of low-income parents[23]. Implementation barriers may have contributed to these inequalities. Insurers differed on the question of which health-care services were covered by the policy expansion, and the Federal Office did not issue clarification until 4 years after implementation. These barriers may have

contributed to greater benefits among families with higher socioeconomic status. While this policy represents one potential source of social inequalities in preterm birth and infant mortality, the COVID-19 pandemic constitutes another major contextual factor over the past decade.

The COVID-19 pandemic and associated containment measures may have acted as a socially differentiated shock, amplifying pre-existing inequalities in health risks and healthcare access[28]. Individuals did not have equal resources to protect themselves from exposure to the virus or to cope with the multiple economic and social difficulties brought by public health measures[29]. A nationwide study conducted in Switzerland[30] found that people living in deprived areas tested less frequently while facing higher risks of testing positive and requiring hospitalization compared to those in affluent areas. This suggests structural barriers to healthcare access and/or a reduced capacity of deprived populations to benefit from protective interventions—such as access to testing facilities or timely, high-quality care—potentially leading to increased inequalities in preterm birth or infant mortality.

Beyond these structural barriers, the pandemic may also have influenced preterm birth through more direct biological and behavioral mechanisms. First, as infection is the most well-established cause of spontaneous preterm birth[31], lockdown measures may have produced an immediate and substantial reduction in circulating infections through decreased social interaction and increased hygiene measures[32]. Second, prenatal COVID-19 infection increased the likelihood of preterm birth, with a large impact during the first 2 years of the pandemic that waned by 2022 thanks to available vaccination[33].

Research gap

In the context of the 2014 policy expansion, prior research[23] focused on estimating a local average treatment effect—that is, the effect around the time of policy implementation—leaving the longer-term consequences insufficiently understood. In particular, it is unknown whether the reported increase in inequalities was temporary or has persisted in the years following implementation. Similarly, while the COVID-19 pandemic may have had socially stratified impacts, whether these differential effects translated into a worsening of pre-existing inequalities in the outcomes remains to be established[34–36]. Addressing these gaps requires a comprehensive analysis of temporal trends in socioeconomic and sociodemographic inequalities across both outcomes, spanning periods before and after major structural and contextual changes.

Additionally, as the proportion of the population with a migration background has increased steadily since 2010, it is unknown whether temporal changes in sociodemographic inequalities capture true changes in outcome risk and not changes in the size of those groups over time. The methodological approaches used to conduct this comprehensive analysis are presented in the next section.

Methods

General considerations

We will practice Open Science principles to improve the accountability and reproducibility of research. This will include publishing a protocol on the Open Science Framework and online sharing of analytic scripts[37,38].

Data sources

The research will use existing, nationwide individual-level data obtained from linked administrative registers covering the period 2012–2024. Data sources include the Federal Statistical Office (FSO) for the Swiss Vital Statistics (BEVNAT), the Swiss Population and Household Statistics (STATPOP) and the Swiss-SEP index, and the Central Compensation Office (CCO) for income tax records. The BEVNAT, STATPOP and CCO registers will be linked based on the individual social security number (pseudo-anonymized by the FSO). The Swiss-SEP index and the BEVNAT will be linked based on the residential building identifier (pseudo-anonymized by the FSO).

Populations of interest

The target population will comprise all individuals born among the permanent resident population in Switzerland between 2012 and 2024. The permanent resident population is defined in accordance with the FSO definition[39] and includes the following groups:

- Persons holding Swiss nationality whose principal residence is in Switzerland;
- Holders of B and C residence permits;
- Officials, including diplomats and members of their families, who hold a legitimation card issued by the Federal Department of Foreign Affairs (FDFA);
- Holders of L (short-stay) permits with a minimum length of stay of 12 months;
- Holders of N or S permits (individuals in the asylum process) who have resided in Switzerland for at least 12 months.

The study population will include all individuals born among the permanent resident population enumerated in the administrative registers (see Data sources). The analytic sample will include all births without missing information on any of the variables of interest (see next section). Finally, analyses of preterm birth will examine all births while analyses of infant mortality will examine all live births.

Variables

<u>Health outcomes</u>

Preterm birth is defined as delivery before 37 completed weeks of gestation[40] (i.e., up to 36 weeks and 6 days). Preterm births is further classified into moderate/late preterm (32–36 weeks), very preterm (28–31 weeks), and extremely preterm (22–27 weeks), reflecting clinically meaningful differences in survival rates, morbidity risks, and developmental outcomes[41,42]. Preterm birth is defined for both live births and stillbirths, the latter being defined, according to the FSO[43], as the birth of a child with no signs of life at delivery and a birth weight of at least 500 grams or a gestational age of at least 22 completed weeks. Subgroup analyses (stillbirths, moderate/late preterm live births, very preterm, and extremely preterm births) will be conducted as supplementary analyses.

Infant mortality encompasses all deaths occurring before the first birthday[44] (i.e., within the first 365 days of life). Infant mortality can be further stratified by age period: the neonatal period, defined as birth (day 0) through 27 completed days of life, further subdivided into the early neonatal period (day 0–6) and the late neonatal period (days 7–27) and the postneonatal period, defined as days 28–364. Age-specific and cause-specific analyses may be performed as supplementary analyses.

For supplementary analyses, low case numbers in some subcategories may lead to computational issues in inequality estimation; therefore, we will consider combining subgroups (e.g., very and extremely preterm) or aggregating calendar years (e.g., biennial rather than annual intervals); detailed specifications and rationales will be documented in the respective study protocols.

Exposures

Socioeconomic exposures

Socioeconomic position will be examined at both the area and household levels, allowing inequalities to be assessed across complementary spatial and individual dimensions[45,46]. Area-level socioeconomic position (SEP) is typically derived by aggregating individual-level indicators, such as unemployment rates, prevalence of manual occupations, and educational attainment, within a geographic unit[47]. Area-level health inequalities will be assessed using the Swiss-SEP index [48], initially developed using data from the 2000 census, and further complemented using 2012–2015 micro-censuses[49]. The index covers approximately 1.53 million neighborhoods across Switzerland, each defined as the 50 nearest households to a given residential building based on the road network. For each neighborhood, four socioeconomic dimensions are captured:

1. Median rent per square meter — reflecting local housing costs
2. Proportion of crowded households — as an indicator of housing deprivation

3. Proportion of adults with primary education or less — measuring low educational attainment
4. Proportion of adults in manual or unskilled occupations — capturing low occupational position

These four components were estimated from micro-census households and combined into a single composite score using principal component analysis, yielding one Swiss-SEP value per residential building. The typical road distance between a reference building and the boundaries of its neighborhood was around 272 meters (median of neighborhood means).

In addition to this area-level indicator, individual-level socioeconomic position will be assessed to capture household-specific socioeconomic circumstances. At the individual level, socioeconomic position will be operationalized using household income. Household-level socioeconomic position will be assessed using total household income, defined as the combined gross earnings of both parents (where applicable) over the preceding three years. Together, these area- and household-level measures provide a multidimensional assessment of socioeconomic inequalities.

Sociodemographic exposures

Sociodemographic exposures will be captured through measures of nationality and migration status, reflecting key dimensions of social stratification in the Swiss context. Nationality will be assessed using categorical groupings (e.g. Swiss, OECD, non-OECD, …). Migration status will be assessed using standard residence categories, including for example Swiss citizens and holders of permit C, permit B, and other residence permits. Both measures will be categorized to capture meaningful sociodemographic gradients while ensuring adequate numbers of outcome events for robust analysis.

Specific aims

The specific aims of this study are structured using Hernán's taxonomy of data science tasks[50]. Within this framework, the first two aims are descriptive, while the third is explicitly causal.

Aim I: Measure annual trends of socioeconomic inequalities in preterm birth and infant mortality between 2012 and 2024 in Switzerland.

Hypothesis: Socioeconomic inequalities have been stable before (2012–2019), increased during the COVID-19 pandemic (2020–2022), while after the pandemic (2023-2024) they have returned to their pre-pandemic levels.

Study design – Statistical analysis: Descriptive study implementing a repeated cross-sectional design – We will perform repeated cross-sectional analyses to estimate annual absolute and relative socioeconomic inequalities in preterm birth and infant mortality. These inequalities will

be evaluated for two primary socioeconomic indicators (exposures): household income and area-level deprivation (Swiss-SEP index). We will assess inequalities using both simple contrasts – differences and ratios between the most and least advantaged groups – and summary measures across the full socioeconomic spectrum, namely the Slope Index of Inequality (SII) and the Relative Index of Inequality (RII)[51]. We will additionally adjust our inequality estimates for other available covariates, including maternal age, child sex, multiple births, and parity, in accordance with established equity-based value frameworks[52,53].

Aim II: Measure trends of sociodemographic inequalities in preterm birth and infant mortality between 2012 and 2024 in Switzerland.

Hypothesis: Migrants from EU/EFTA countries have smaller rates of the outcomes compared to Swiss residents during 2012–2019. This did not change during the pandemic period.

Study design – Statistical analysis: Repeated cross-sectional analysis – We will apply Oaxaca-Blinder decomposition[54] to assess the extent to which observed changes in preterm birth and infant mortality between 2012 and 2024 are attributable to shifts in population composition (e.g., migrant status distribution and nationality distributions) versus changes in outcome-specific rates within these groups. We will assess inequalities using simple contrasts – differences and ratios between the sociodemographic groups. We will additionally adjust our inequality estimates for other available covariates, including maternal age, child sex, multiple births, and parity, in accordance with established equity-based value frameworks[52,53].

Aim III: Quantify the effect of the first wave of COVID-19 pandemic on socioeconomic and sociodemographic inequalities in preterm birth and infant mortality.

Hypothesis: The first wave of COVID-19 pandemic exacerbated pre-pandemic levels of socioeconomic and sociodemographic inequalities in preterm birth and infant mortality.

Study design – Statistical analysis: Causal study implementing an interrupted time series design – We will apply a spatio-temporal regression model, similar to those used in previous studies examining the effect of COVID-19 on all-cause mortality in Switzerland[55]. We will model 2012–2019 inequalities trends to predict the expected March-June 2020 inequalities had the pandemic not occurred (i.e. a counterfactual outcome). We will quantify the effect of the pandemic as the observed minus predicted monthly inequalities.

Strengths

This PhD thesis has several key strengths related to its scope, data sources, and analytical approach. In particular, our analyses will span an extended period, notably covering the pre-pandemic, pandemic, and post-pandemic phases. The analyses will rely on high-quality nationwide administrative data, ensuring comprehensive population coverage and small degree

of measurement error. Furthermore, we will apply advanced, interdisciplinary demographic and epidemiological analytical techniques to rigorously investigate these inequalities. Despite these strengths, several limitations must be considered.

Limitations

The findings obtained within this PhD thesis are subject to some limitations that should be acknowledged. Statistically, a constraint lies in the relative rarity of the infant mortality outcome which could pose challenges for the precision of the estimated associations with socioeconomic and sociodemographic factors. We will consider finite target population corrections[56] to overcome this potential issue. Beyond this statistical consideration, additional data-related limitations should be acknowledged.

One important data-related limitation concerns the measurement of area-level socioeconomic position. The available Swiss-SEP index is a static measure of area-level deprivation and may pose challenges for interpreting inequalities trends. The initial version of the index is derived from data collected in the 2000 census, while a revised version based on data from 2012–2015 has subsequently been released[49]. Since that time, no substantial revisions or updates to the index have been undertaken. As Switzerland's population has grown and new residential buildings have been constructed, these additions fall outside the neighborhood boundaries defined in the 2012–2015 version of the index — since neighborhoods are geographically anchored to buildings existing at that time — resulting in missing Swiss-SEP values for residents in these new buildings.

A final limitation concerns the availability of key epidemiological information. In particular, the lack of data on maternal COVID-19 infection prevents distinguishing between direct effects of the virus and indirect effects related to lockdown measures (Aim III).

Expected results and public health significance

This PhD thesis aims to generate three peer-reviewed articles, supplemented by contributions to national and international conferences. These outputs, all based on original research, will constitute the principal components of the doctoral thesis. Figure 2 presents the projected timeline for the project. Building on this structured research plan, the thesis is expected to generate findings that address key gaps in understanding health inequalities in Switzerland.

The findings of this PhD thesis will provide robust empirical evidence on the trends and magnitude of socioeconomic and sociodemographic inequalities in preterm birth and infant mortality in Switzerland. By conducting a comprehensive assessment of inequalities associated with both socioeconomic and sociodemographic factors, this thesis will highlight the significance of structural determinants of health and the limitations of attributing health outcomes

solely to individual responsibility. Finally, the results will underscore the importance of ongoing monitoring of health inequalities, offering evidence that may inform public health surveillance and guide policy development aimed at reducing inequalities. These insights will not only contribute to the scientific literature but also provide actionable recommendations for policymakers and public health practitioners.

Estimated timeline

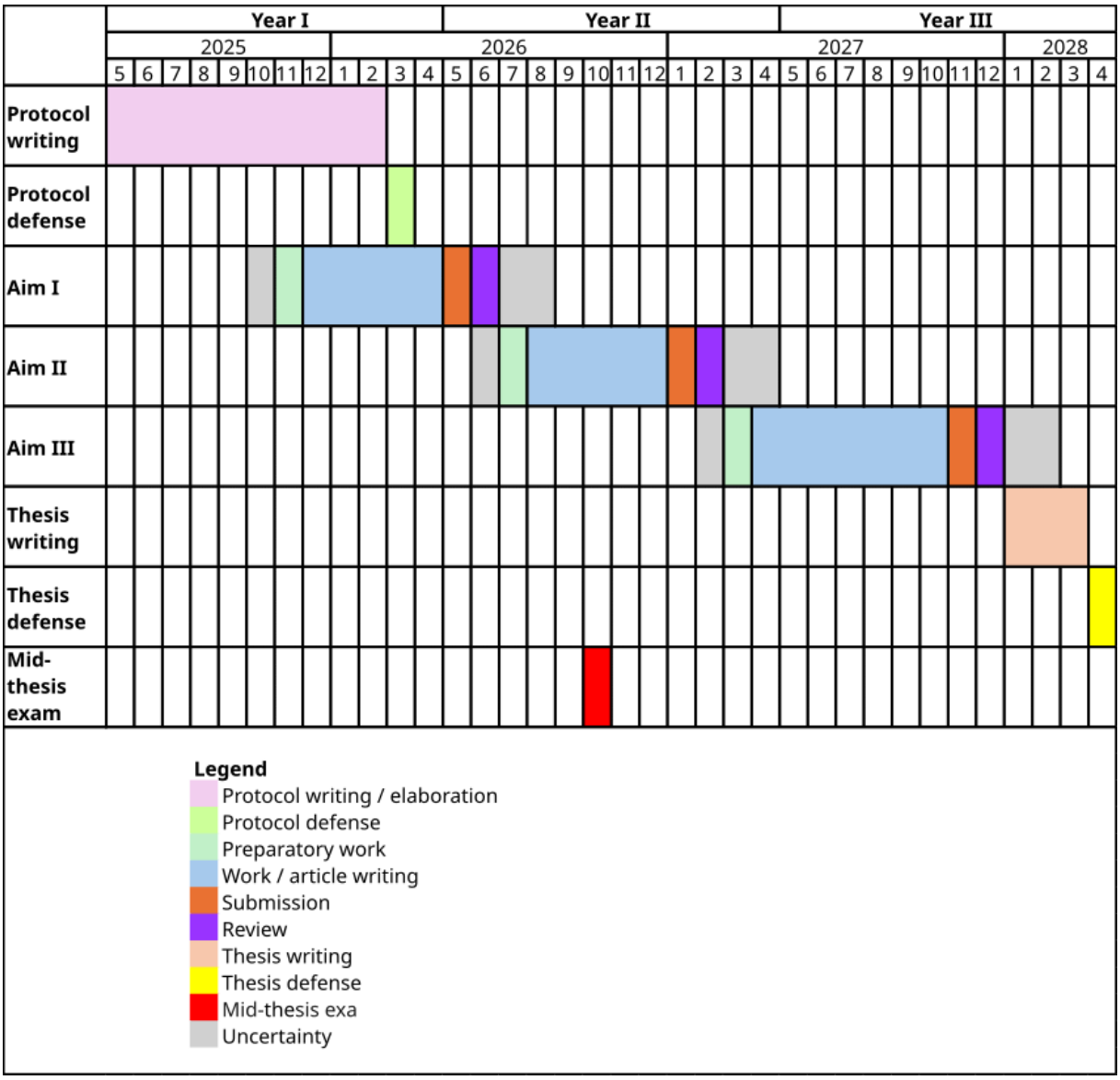

Figure 2: Estimated timeline

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