Antibiotic dispensing for children in Belgium before, during and after the COVID-19 pandemic.

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List of abbreviations

AMR	antimicrobial resistance
AMS	antimicrobial stewardship
ATC	Anatomical Therapeutic Chemical classification system
COVID-19	coronavirus disease 2019
CRP	C-reactive protein
DDD	Defined Daily Dose
DOTID	days of therapy per 1.000 inhabitants per day
GP	general practitioner
MIS-C	multisystem inflammatory syndrome in children
NAP	National action plan
NIHDI	National Institute for Health and Disability Insurance
OOH	out-of-hours
ORL	Otolaryngologist
POCT	Point-of-care testing
Statbel	The Belgian statistical office

Abstract

Objective: The aim of this study is to analyse the ambulatory antibiotic dispensing for children in Belgium before, during and after the COVID-19 pandemic.

Methods: We analysed an anonymous dataset retrieved from Farmanet, containing data on the dispensing of antibiotics for systemic use for children aged 0-12 years, during the period from 2014 until 2023. The dispensing data included the number of packages, DDDs and expenditures. These measures were analysed for all antibiotics collectively, by ATC-3 class and by chemical substances. Further subgroups were divided based on patient characteristics, specialty of prescriber and geographic region.

Results: During the COVID-19 pandemic the use of antibiotics among children substantially decreased in Belgian ambulatory care (–42.7%). A partial recovery occurred (+66.9%) following the pandemic. The most pronounced decreases during the pandemic, followed by the sharpest subsequent increases, occurred in prescriptions issued by general practitioners, in rural areas of Flanders and the Walloon region, in children aged 7–12 years and in those receiving standard reimbursement.

Conclusion: Antibiotic utilisation in the paediatric population was markedly altered by the COVID-19 pandemic, characterised predominantly by a substantial decline in prescribing followed by a post pandemic resurgence. This pattern underscores the persistent vulnerability of antimicrobial stewardship efforts and reinforces the imperative for sustained, systematic strategies to mitigate the progression of antimicrobial resistance.

Abstract

Onderzoeksvraag: Het doel van deze studie is het analyseren van de ambulante distributie van antibiotica aan kinderen in België vóór, tijdens en na de COVID-19-pandemie.

Methoden: We hebben een anonieme dataset uit Farmanet geanalyseerd, die gegevens bevat over de uitgifte van antibiotica voor systemisch gebruik aan kinderen van 0 tem 12 jaar in de periode van 2014 tot en met 2023. De data omvatten het aantal verpakkingen, DDD's en uitgaven. Deze gegevens werden geanalyseerd voor alle antibiotica gezamenlijk, per ATC-3-klasse en per chemische stof. Verdere subgroepen werden ingedeeld op basis van patiëntkenmerken, specialisme van de voorschrijver en geografische regio.

Resultaten: Tijdens de COVID-19-pandemie is het gebruik van antibiotica bij kinderen in de Belgische eerstelijnszorg aanzienlijk gedaald (–42.7 %). Na de pandemie vond een gedeeltelijk herstel plaats (+66.9 %). De sterkste dalingen tijdens de pandemie, gevolgd door de sterkste stijgingen daarna, deden zich voor bij voorschriften van huisartsen, in landelijke gebieden van Vlaanderen en Wallonië, bij kinderen van 7 tem 12 jaar die een standaardvergoeding ontvangen.

Conclusie: Het antibioticagebruik bij kinderen is door de COVID-19-pandemie ingrijpend veranderd, wat vooral tot uiting kwam in een aanzienlijke daling van het aantal voorschriften, gevolgd door een stijging na de pandemie. Dit patroon benadrukt de aanhoudende kwetsbaarheid van de inspanningen op het gebied van antimicrobieel beheer en het belang van duurzame, systematische strategieën om de toename van antimicrobiële resistentie tegen te gaan.

Introduction

Antibiotics are an essential component of modern medicine and play a crucial role in the treatment of bacterial infections, including those affecting young children (1). Despite their therapeutic undeniable value, excessive and inappropriate use of antibiotics has become a major driver of antimicrobial resistance (AMR), a growing global health threat that undermines the effectiveness of existing treatments and contributes to increased morbidity and mortality (2).The rising prevalence of resistant pathogens complicates the management of common infections and poses serious challenges to healthcare systems worldwide, leading to prolonged hospital stays, higher healthcare costs and poorer clinical outcomes worldwide (2).

According to recent data from the Global Burden of disease 2021 study, approximately 4.71 million deaths worldwide in 2021 were associated with bacterial AMR, of which 1.14 million deaths were directly attributable to resistant infections (2). The experts forecast that, without effective interventions, AMR could account for up to as many as 1.91 million deaths annually, with an 8.22 million deaths associated with AMR annually by 2050 (2). These alarming projections highlight the urgent need for rational antibiotic use and prudent prescribing practices, particularly in vulnerable populations such as young children.

Children represent a particularly vulnerable group when it comes to antibiotic prescribing. This vulnerability can be attributed to multiple factors. One of the primary reasons is that their immune systems are still in the process of developing, making them more susceptible to serious and potentially life-threatening complications from bacterial infections, such as pneumonia, sepsis, or meningitis (3). Because of this heightened risk, healthcare providers often adopt a more cautious approach, by reducing the threshold for prescribing antibiotic therapy, particularly when there is uncertainty about the underlying cause of the illness (4). In other words, the fear of missing a serious bacterial infection can outweigh concerns about unnecessary antibiotic use, especially in younger children who may deteriorate rapidly if not treated promptly.

This vulnerability is further amplified by the high prevalence of viral respiratory infections in paediatric populations. Viral pathogens such as respiratory syncytial virus, influenza, and adenovirus are extremely common in young children and often present with clinical features that closely resemble those of bacterial infections (5). This clinical overlap creates a substantial diagnostic ambiguity, especially in primary care settings, where rapid diagnostic testing is not routinely available, forcing physicians to rely primarily on their clinical judgment within a limited consultation time, often averaging around 15 minutes (6). The limited use or the absence of point-of-care testing (POCT) diagnostic tools, such as C-reactive protein (CRP) tests, can hinder clinicians' ability to distinguish between bacterial and viral infections and to accurately assess the severity of illness. It has been shown that wider implementation of these tools reduces diagnostic uncertainty and thereby prevents potentially avoidable antibiotic prescriptions and hospital referrals (7). Consequently, uncertainty regarding diagnosis and prognosis remains a major driver of antibiotic overprescription, particularly for self-limiting viral infections.

In addition to clinical uncertainty, variations in antibiotic prescribing among primary care physicians are also influenced by a combination of contextual and behavioural factors, including time constraints during consultations, individual prescribing habits, and perceived expectations of parents (4-8). This can lead to a lower threshold for prescribing antibiotics. For example, general practitioners (GPs) may feel inclined to prescribe antibiotics when they are faced with perceived expectations or pressure from parents (9-10). Feelings of time pressure during consultations and a desire to maintain a relationship of trust with families also play a role. In such cases, strategies like delayed

prescribing are sometimes employed as a compromise, aiming to reassure parents while limiting immediate use of antibiotic (9-10). These dynamics underscore the complexity of antibiotic prescribing in primary care, where medical, social and behavioural drivers interact and may lower the threshold for initiating antibiotic treatment in children.

The COVID-19 pandemic, which emerged in early 2020, has profoundly disrupted healthcare systems worldwide. Public health and social measures, such as lockdowns, social distancing, school closures, mandatory facemasks, and stricter hygiene practices, have significantly reduced the transmission of common respiratory pathogens (11). While these interventions were primarily aimed at reducing the spread of the coronavirus, they have also slowed the circulation of other common respiratory pathogens (12). As a result, paediatric consultations for respiratory infections, one of the main predictors of antibiotic prescribing in children, declined markedly during this period (13). Although children are typically at higher risk of bacterial complications, emerging evidence indicated that they generally experienced milder courses of COVID-19 compared to adults, likely due to distinct immunological mechanisms (14).

These shifts in healthcare utilization and infection epidemiology were reflected in prescribing behaviours. The fast expansion of telemedicine may also have influenced prescribing behaviours in several ways, either by reducing unnecessary prescriptions or, conversely, encouraging precautionary prescribing due to limited possibilities for physical examination (15). Several studies conducted in European countries, including the Netherlands, Denmark, and Italy, reported a substantial decline in antibiotic use during the pandemic, including among children, largely driven by reduced disease incidence and changes in healthcare-seeking behaviour (13, 16, 17). However, there is little evidence on how these trends have developed in Belgium, highlighting the need for country-specific analyses.

Understanding how antibiotic use evolved after the COVID-19 pandemic is particularly important in Belgium, a country where antibiotic use in primary care has been historically higher compared with several of its neighbouring countries (18). Despite long-standing efforts to promote the prudent antimicrobial use, inappropriate prescribing remains a persistent challenge (19). In Belgium, most antibiotics are prescribed in primary care, where GPs represent the primary point of contact for paediatric patients. Children therefore constitute a key population for antimicrobial stewardship (AMS) initiatives (5).

Analysing post-pandemic antibiotic use in children helps determine whether the changes observed during COVID-19 represent a sustained trend in prescribing practices or only temporary effects driven by changes in healthcare utilization. Given these considerations, examining how paediatric antibiotic use shifted before, during, and after the pandemic is essential for evaluating current prescribing practices and identifying opportunities for strengthened AMS within the first line of care.

Therefore, this thesis aims to analyse trends in antibiotic use among children in Belgium between 2014 and 2023, with a specific focus on the impact of the COVID-19 pandemic. Using data on dispensed antibiotic packages, National Institute for Health and Disability Insurance (NIHDI) expenditures, prescriber types, patient types and geographical characteristics, this study seeks to identify temporal patterns and potential shifts in prescribing behaviours. By doing so, it contributes to a better understanding of paediatric antibiotic use and provides insights to support more rational prescribing in future public health contexts.

Methods

For this study, data on the dispensing of antibiotics for systemic use (classified according to the Anatomical Therapeutic Chemical (ATC) classification system, J01) were retrieved from Farmanet (20). This Belgian database contains information on pharmaceutical dispensations, delivered in community pharmacies and reimbursed by the compulsory health insurance (21). The dataset, covering weekly data from 1 January 2014 to 31 December 2023, included dispenses for children aged zero up to and including 12 years, with age calculated as the delivery year of the antibiotic minus the birth year of the child. Antibiotics for topical (ATC D06A) and ophthalmic (ATC S01) use were excluded. Population data for normalization were sourced from Statbel, the Belgian statistical office (22). It should be noted that the way in which age is defined slightly differs between the Statbel population data and the Farmanet database. In Statbel, age is determined by the number of people of a certain age on 1 January of each year. The group 'Other antibacterials' include agents with mechanisms of action not covered by the other mentioned groups (23).

The dispensing data included the number of packages sold, the expenditures covered by the NIHDI and the Defined Daily Dose (DDD) (24). We analysed the data for all antibiotics collectively, by ATC-3 class and by chemical substances. Furthermore, we divided the retrieved antibiotic compounds into broad and small spectrum groups. Since we did not request all antibiotic compounds in our data, this may distort the figures used in this master paper.
Subgroups were stratified based on patient characteristics (i.e., age, gender and reimbursement type), specialty of the prescriber and area (i.e., region and rurality category). Belgium consists of three regions, namely Flanders (Northern part), Walloon region (Southern part) and Brussels Capital Region (25). The classification of municipalities into the rurality categories "city," "town/suburb" or "rural" was based on the European Commission's DEGURBA classification (26).

The study period was further divided into a pre-COVID period (01/01/2014-15/03/2020; 324 weeks), COVID (16/03/2020-13/03/2022; 104 weeks) and a post-COVID (14-03-2022-31-12-2023; 94 weeks). We defined these periods according to the dates found on the website of the Belgian National Crisis Centre (27). The data analysis in Excel utilized pivot tables to create structured overviews. These tables are included in Appendix II.

For all antibiotics collectively and for each subgroup, the number of packages sold, the expenditures covered by the NIHDI and the DDD were calculated by year and time period related to COVID-19. For the tables comparing the above defined time periods, data were normalized by dividing values for the pre-COVID, COVID, and post-COVID periods by their respective durations in weeks: 324, 104 and 94 weeks. This ensured a proportionally comparable dataset, given the significantly longer duration of the pre-COVID period. Descriptive statistics included numbers per 1000 Belgian inhabitants aged zero up to and including 12 years, proportions, absolute changes and relative changes. In addition, subgroup-specific rates were calculated by normalizing the number of packages, expenditures and DDDs to the corresponding population size within each category (e.g., age group, gender, or region) for each year. This allowed for more accurate comparisons between subgroups by accounting for differences in population size. Further analyses assessed relative changes by antibiotic spectrum (broad/narrow), by region and rurality and by age and gender combinations.

Descriptive statistics were performed in Microsoft Excel version 2411, while graphs were created using R version 4.4.1 with the ggplot2 package. During the analysis of the data, we produced more figures in R than those included in the article. Based on relevance, we decided to fully develop three figures. The remaining figures display accurate data are provided the appendix (see Appendix III). The R code corresponding to the three main figures is included in the appendix, whereas code for the additional figures is not reported (see Appendix I).

This master thesis is part of a publication by our co-promotor (28).
As our research is a purely retrospective study involving data that contains only non-identifiable personal data, it does not require approval by an authorised medical ethics committee.

Results

Antibiotic use in children showed clear trends between 2014 and 2023, with the COVID-19 pandemic having a marked impact. These developments are reflected in the number of dispensed packages, NIHDI expenditures, and the distribution by prescriber specialty, patient sex, age, reimbursement status and geographical characteristics.

General trends from 2014 until 2023

In 2014, a total of 1,470,957 antibiotic packages were dispensed (887.58 per 1,000 children). By 2023, this number had decreased to 1,217,145 packages (744.07 per 1,000 inhabitants), representing a 17.3% reduction. In parallel, NIHDI expenditures declined by 30.2% over the same ten-year period. During the COVID-19 period, a substantial decrease was observed in both the number of dispensed packages (–42.7%) and NIHDI expenditures (–49.1%) compared to before the pandemic. Following the pandemic, a partial recovery occurred, with increases of 66.9% and 68.8%, respectively (figure 1).

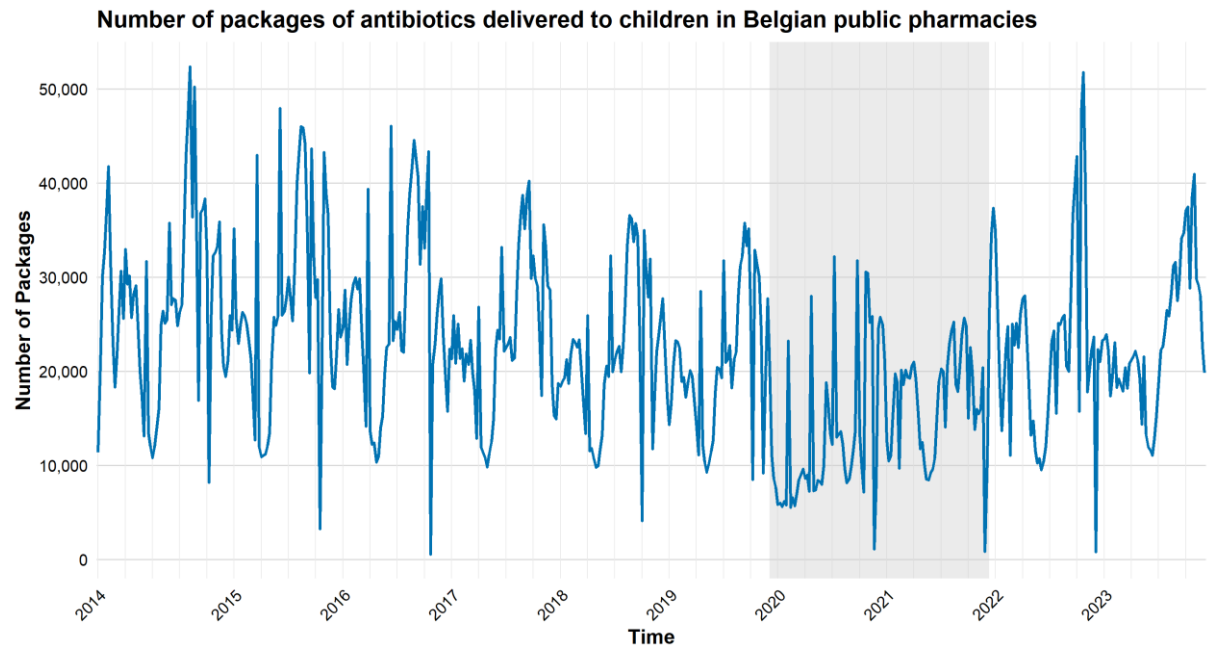


Figure 1. Number of packages of antibiotics delivered to children in Belgian public pharmacies between 2014-2023.
The grey area marks the COVID-19 pandemic, running from the week of 16 March 2020 to the week of 14 March 2022.

Antibiotic classes

Throughout the entire study period, penicillin consistently remained the most prescribed class of antibiotics, accounting for 77.6% of all dispensations in 2023. Macrolides represented the second most common class, with a share of 19.3%. During the COVID-19 period, a decline in the number of dispensed packages was observed across all antibiotic classes compared to the pre-COVID period,

except for tetracyclines, which showed a slight increase of 0.65%. The most pronounced relative decrease was seen in sulphonamides and trimethoprim (–77.3%). NIHDI expenditures decreased across all classes during the pandemic.
Following the COVID-19 period, a renewed increase in the number of dispensations was noted for several classes, including penicillin, tetracyclines, amphenicols, sulphonamides/trimethoprim, and macrolides. For the remaining classes, like other B-lactam antibacterials, aminoglycoside antibacterials, quinolone antibacterials and other antibacterials, the downward trend continued (See Appendix II; table 2). A similar pattern was observed in NIHDI expenditures, except for macrolides, for which a further decline in costs was noted.

Antibiotic compounds

Amoxicillin is the most prescribed antibiotic in children (57.9% of total antibiotic use in 2023). Over the course of 10 years there is a decrease in the number of packages of all compounds except for doxycycline (±129.9%), flucloxacillin (±321.7%) and azithromycin (±68.5%).
During the pandemic, we observe a decline in packages for all compounds except for doxycycline (±7.76%) and flucloxacillin (±6.79%). Remarkable is the decline of 100% of the packages for phenoxymethylpenicillin because of withdrawal from the market on May1, 2019. After the pandemic we mostly observe an increase in use of antibiotic compounds in children except for cefuroxime (-21.0%), ciprofloxacin (-8.78%), nitrofurantoin (-15.7%) and fosfomycin (-4.56%) (figure 2). During the pandemic we report a decrease in use of broad-spectrum antibiotics (-42.3%). There is a small increase in the use of small-spectrum compounds (±1.09%). An increase in use is seen for all types of compounds after the pandemic.

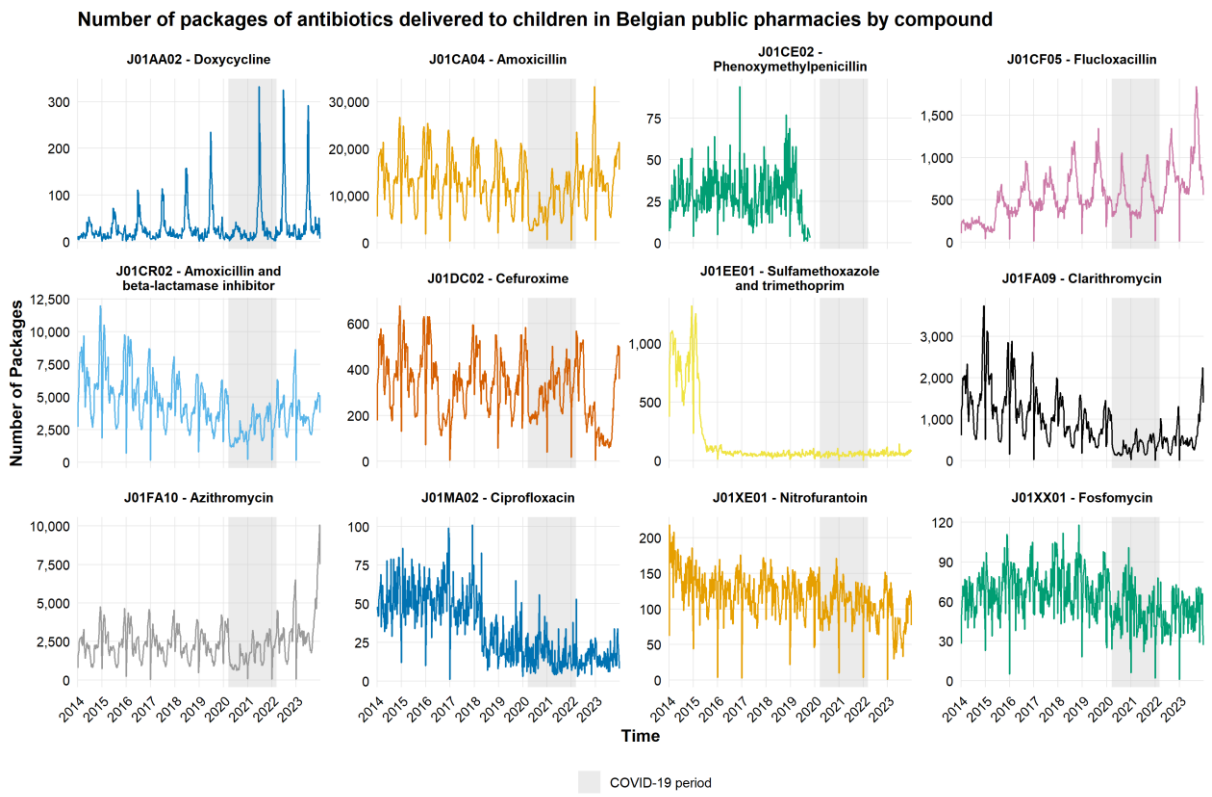


Figure 2. Number of packages antibiotics delivered to children in Belgian public pharmacies by compound between 2014 -2023.
The grey area marks the COVID-19 pandemic, running from the week of 16 March 2020 to the week of 14 March 2022. The y-axis are on different scales.

Specialty of prescriber

Throughout the study period, GPs remained the primary prescribers of antibiotics for children. Before the COVID-19 pandemic, they accounted for 69.1% of all antibiotic dispensations and represented the largest share of associated costs. Paediatricians were the second-largest group, responsible for 23.5% of dispensations. During the pandemic, prescription rates declined across all specialties, followed by a partial recovery in the post-COVID period (figure 3). However, this recovery was smallest among dermatologists, while dentists even showed a continued decrease in antibiotic dispensations after the pandemic (See Appendix II; table 9, table 10).

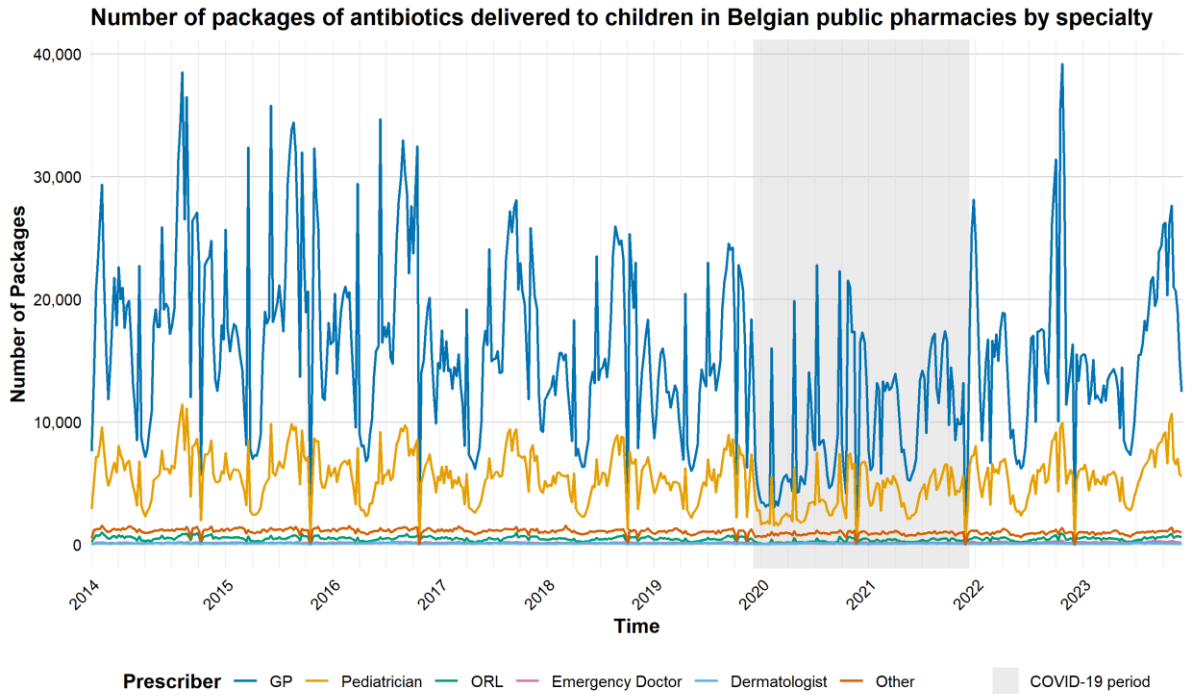


Figure 3. Number of packages of antibiotics delivered to children in Belgian public pharmacies by specialty between 2014-2023.
The grey area marks the COVID-19 pandemic, running from the week of 16 March 2020 to the week of 14 March 2022. Abbreviations: GP = general practitioner, ORL = otolaryngologist

Geographic regions

In all regions, the number of dispensed antibiotic packages decreased during the COVID-19 pandemic, followed by an increase in the period thereafter. A similar trend was observed across the different DEGURBA categories (i.e., urban, suburban, and rural areas). The largest decreases, during the pandemic, in delivered packages were observed in the rural regions (DEGURBA 3) and in the Walloon region. The highest increases after the pandemic were also seen in the Flemish rural regions and the Walloon region (See Appendix II; table 13, table 15).

Patient characteristics

There is an overall decrease in use of antibiotics during the pandemic across both sexes and across all age groups in children followed by a rebound in the post-pandemic period. During the pandemic the highest decrease was seen in girls and among 7-12 years olds (See Appendix II; table 5, table 7). During the following period the largest increase is in delivered packages antibiotics is observed

among boys and 7-12 years old. In children aged 0-1 years old we observed the smallest change in use of antibiotics before, during and after the pandemic.

When examining the reimbursement types of children, a similar pattern was observed, with a decrease in antibiotic use during the pandemic, followed by an increase after. The highest changes in delivered antibiotic packages were observed among the standard reimbursement tariff (See Appendix II; table 17).

Discussion

Main Findings

This study provides a comprehensive overview of antibiotic use in children aged 0–12 years in Belgium between 2014 and 2023. Over this ten-year period, a general downward trend in antibiotic consumption was observed, with a 17.3% reduction in the number of dispensed packages and a 30.2% decrease in NIHDI expenditures. The COVID-19 pandemic had a pronounced impact, leading to a sharp decline in both antibiotic use (–42.7%) and associated costs (–49.1%). Although a partial recovery was noted in the post-pandemic period, pre-pandemic levels were not fully reached.

Penicillin remained the most frequently prescribed antibiotic class throughout the study period, accounting for over three-quarters of all prescriptions in 2023. Macrolides followed as the second most common class. While most antibiotic classes showed a decline during the pandemic, tetracyclines slightly increased. After the pandemic, several classes, including penicillin and macrolides, showed renewed increased use, although others continued to decline (e.g. aminoglycoside antibacterials, quinolone antibacterials).

At the compound level, amoxicillin was by far the most prescribed antibiotic, representing nearly 58% of all paediatric antibiotic use in 2023. Notably, doxycycline, flucloxacillin and azithromycin showed increases over the ten-year period, while phenoxymethylpenicillin disappeared entirely from the market in 2019 (29). The pandemic period was marked by a general decline in compound use, with a few exceptions (e.g. doxycycline and flucloxacillin) and a subsequent increase in the post-pandemic years.

A notable finding is the shift in spectrum preference: during the pandemic, the use of broad-spectrum antibiotics decreased by 42.3%, while the use of narrow-spectrum antibiotics slightly increased (+1.09%). This trend is encouraging from an antibiotic stewardship perspective, as narrow-spectrum antibiotics are preferred when clinically appropriate to reduce the risk of resistance. However, it is important to note that a reduction in antibiotic use is not inherently beneficial if it leads to under-treatment of bacterial infections. The goal remains appropriate prescribing, with a preference for narrow-spectrum agents when possible.

GPs consistently remained the main prescribers of antibiotics for children, followed by paediatricians. Although all specialties decreased prescribing during the pandemic, the extent of recovery varied, with dermatologists and dentists showing the weakest rebound. Geographically, similar trends were observed across all regions and rurality categories, with a pandemic-related dip followed by partial recovery.

Finally, antibiotic use varied by age group, with the highest rates in children aged 2–6 years. The pandemic led to a decrease in use across all age groups, with the most pronounced changes seen in children aged 7–12 years. Reimbursement status remained relatively stable, with the majority of prescriptions falling under the standard tariff.

Comparison with existing literature

The trends observed in this study are in line with findings from several European countries, where the COVID-19 pandemic was associated with substantial changes in paediatric antibiotic prescribing (30). Several studies have reported a decline in antibiotic use during the pandemic, primarily driven by reduced circulation of respiratory pathogens and decreased healthcare utilization. This effect was clearly demonstrated in a cohort study in primary care in the Netherlands, which showed a significant reduction in antibiotic prescribing for common infections during the pandemic period (13).

Also, a nationwide study from Denmark found a sharp reduction in antibiotic use among children in 2020, followed by a fast rebound in the following years, in some cases, even exceeding pre-pandemic levels (16). Similar patterns were observed in Italy, where antibiotic prescribing in paediatric primary care dropped strongly during lockdown periods before gradually increasing as public health restrictions were lifted (17).

In addition, cross-national analyses across European countries have shown that there are considerable variabilities in the magnitude and recovery of antibiotic prescribing after the pandemic (30). While Belgium, the United Kingdom, Germany and Poland experienced a fast return to pre-pandemic prescribing levels, other countries like France and Italy showed more sustained reductions or shifts in prescribing patterns, suggesting that the long-term impact of COVID-19 on antibiotic use may differ between healthcare systems (30). These differences are likely influenced by variations in national prescribing practices, AMS policies and organization of healthcare.

Taken together, these findings indicate that the patterns seen in Belgium are not isolated but rather reflect a broader European phenomenon. However, it remains unclear whether post-pandemic prescribing patterns suggest a return to previous practices or a shift toward a more appropriate antibiotic use, as this appears to vary across settings. This highlights the importance of country-specific analyses to better understand how structural, behavioural, and healthcare-related factors influence antibiotic prescribing in children.

Strengths and Limitations

A major strength of this study is its unique timeframe, covering a full decade and including the pre-pandemic, pandemic and post-pandemic periods. Few international studies have captured such a comprehensive timeline, particularly in paediatric populations. This is due to the large sample size and the use of national-level dispensing data from Farmanet (31). Additionally, the completeness of the dataset, covering various antibiotic classes, prescriber types and patient demographics, allows for a nuanced analysis of prescribing trends. The study provides valuable insights into evolving antibiotic use in children and highlights areas for further investigation.

However, several limitations must be acknowledged. First, while a reduction in antibiotic use was observed during the pandemic, it remains unclear whether this led to under-treatment of bacterial infections and a potential rise in complications. Although children generally experienced milder COVID-19 symptoms, there were reports of delayed care and missed diagnoses, as well as the emergence of multisystem inflammatory syndrome in children (MIS-C), a rare but serious condition temporally associated with COVID-19 infection (32-33).
These findings underscore the importance of balancing reduced antibiotic use with timely and appropriate treatment when needed.

Second, because DDDs are derived from adult dosing standards and therefore may not reliably quantify antibiotic use in paediatric populations, particularly among younger children, we primarily

report the number of dispensed packages. Therefore, the data reported here is harder to compare to data from adults, where DDD is the most used metric. A suggestion for further research is to use the metric days of therapy per 1.000 inhabitants per day (DOTID). It provides a more accurate estimate of antimicrobial exposure in children and is comparable to DOTID in adults. However, this approach requires detailed population-level data, including information on therapy duration such as prescribed days of treatment or days supplied (34).
Furthermore, the study relies on dispensing data, which may not fully reflect actual consumption (i.e. compliance) or clinical appropriateness of prescriptions.

Implications for clinical practice and further research

The findings of this study have various implications for clinical practice, health policy, and AMS in Belgium. Despite the well-known problem of AMR, antibiotic use in Belgium is situated above the European target (35).

Overall, we observed a decline in antibiotic prescriptions during the COVID-19 pandemic. This decline was likely linked to public health measures, but also to changes in health-seeking behaviour (e.g., telemedicine consultations, managing non-severe infections at home). After the pandemic, the usage of antibiotics in children has increased again. These results underline the importance of AMS in Belgium. The Federal Public Service for Public Health has published a new national action plan (NAP) to combat AMR for 2026–2030 (36).

To fight AMR, a change in behaviours is needed among prescribers, healthcare institutions and patients alike. During the COVID-19 pandemic, telemedicine played a key role in maintaining access to care and may have contributed to more cautious antibiotic prescribing (37). The discontinuation of reimbursement for teleconsultations in 2025 may influence future prescribing behaviour (38). Its removal could lead to delayed consultations or increased pressure during in-person visits, potentially affecting prescribing decisions. Previous Belgian research has shown that antibiotic prescribing is higher during out-of-hours (OOH) care compared to regular hours, partly due to increased workload and time constraints (39). This raises the question of whether similar prescribing pressures exist during regular hours, especially given the growing workload in general practice.
Reducing GPs workload may support more deliberate and guideline-concordant prescribing, as time pressure and diagnostic uncertainty are known drivers of inappropriate antibiotic use (40). As for patients, there is a need for more education about antibiotics use and self-management of colds. Merely 59% of Belgians understand that antibiotics are ineffective against viruses (41). 92% indicated that they wanted more information about antibiotics (41). Further improvement of public awareness is essential for AMR.

Our results show that most antibiotics for children are prescribed by GPs and to a secondary extent, by paediatricians. GPs currently receive annual feedback on their antibiotic prescribing behaviour, benchmarked against national indicators developed by the National Council for Quality Promotion (42). However, such feedback systems are not yet systematically implemented in secondary care. The NAP suggests performance-based funding for hospitals based on AMS indicators (36). The plan proposes restrictions on the prescribing of broad-spectrum antibiotics. During the pandemic, fewer broad-spectrum antibiotics were prescribed, in contrast to small-spectrum antibiotics. Subsequently, we saw an increase in both groups. The rise in the use of small-spectrum antibiotics is a positive development considering AMR.

Another implication of the NAP is the use of more POCT by GPs. The use of CRP POCT in children has shown promise in improving AMS. A Belgian randomised control trial found that CRP values were associated with antibiotic prescribing decisions in children with acute infections, and that low CRP

values were linked to lower prescription rates (43). A 2023 international expert consensus concluded that CRP POCT, when combined with clinical assessment and communication strategies, can safely reduce unnecessary antibiotic use in children with acute respiratory tract infections (44). These findings support the potential cost-effectiveness of reimbursing CRP devices in primary care, particularly if they reduce inappropriate prescribing and help combat AMR.

While Belgium does not yet formally integrate the WHO AWaRe classification into its reimbursement or monitoring systems, the national prescribing guidelines are largely aligned with AWaRe principles, promoting the use of small-spectrum 'Access' antibiotics as first-line treatments (45). Further integration of AWaRe into national policy, such as through prescribing audits or reimbursement incentives, could strengthen Belgium's stewardship efforts.

Futhermore, the WHO emphasises that successful stewardship requires structural support, including access to diagnostics, clinical guidelines and feedback systems (46). Belgium is well positioned to build on its existing infrastructure by expanding feedback tools to secondary care, supporting diagnostic innovation and aligning national policy more closely with international frameworks.

Finally, further analysis of this dataset could examine different aspects of antibiotic prescribing among children in Belgium. Additional research fell outside the scope of this study but could provide valuable insights for future research.

Conclusion

Antibiotic utilisation in the paediatric population was markedly affected by the COVID-19 pandemic, with prescribing patterns showing a pronounced overall decline followed by a clear post pandemic rebound. The most substantial reductions and the sharpest subsequent increases, were observed among children aged 7–12 years, in those receiving standard reimbursement, in prescriptions issued by general practitioners, and in rural areas of Flanders and the Walloon region. This epidemiological pattern underscores the ongoing fragility of antimicrobial stewardship efforts and reinforces the necessity for sustained, coordinated strategies to curb the progression of antimicrobial resistance.

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Appendices

Appendix I: R-codes

Code for figure 1. Number of packages of antibiotics delivered to children in Belgian public pharmacies

```
library(ggplot2)
library(dplyr)
# Summarize data
df_summary <- df_Vraag_1_2 %>%
  group_by(`Jaar/week`) %>%
  summarise(`Aantal afgeleverde verpakkingen` =
            sum(`Aantal afgeleverde verpakkingen`), .groups = 'drop')
# Ensure correct order
df_summary$`Jaar/week` <- factor(df_summary$`Jaar/week`,
                                 levels = unique(df_summary$`Jaar/week`))
# Create 3-month positions
week_positions <- seq(1, length(levels(df_summary$`Jaar/week`)), by = 13)
break_values <- levels(df_summary$`Jaar/week`)[week_positions]
# Label only first occurrence of each year
label_values <- ifelse(
  !duplicated(substr(break_values, 1, 4)),
  substr(break_values, 1, 4),
  ""
)
# Define COVID period
covid_start <- "2020 / 11"
covid_end   <- "2022 / 10"
#  Create 1-row dataset for rectangle
covid_df <- data.frame(
  xmin = covid_start,
  xmax = covid_end,
  ymin = -Inf,
  ymax = Inf,
```

```
  fill = "COVID-19 period"
)
# Plot
p <- ggplot(df_summary, aes(x = `Jaar/week`,
                            y = `Aantal afgeleverde verpakkingen`,
                            group = 1)) +
  # Correct rectangle (no warning)
  geom_rect(
    data = covid_df,
    aes(xmin = xmin, xmax = xmax, ymin = ymin, ymax = ymax, fill = fill),
    inherit.aes = FALSE,
    alpha = 0.4
  ) +
  # Main line
  geom_line(color = "#0072B2", linewidth = 0.8) +
  labs(
    title = "Number of packages of antibiotics delivered to children in Belgian public pharmacies",
    x = "Time",
    y = "Number of Packages",
    fill = ""
  ) +
  scale_x_discrete(
    breaks = break_values,
    labels = label_values
  ) +
  scale_y_continuous(labels = scales::comma) +
  # Legend mapping
  scale_fill_manual(
    values = c("COVID-19 period" = "grey80")
  ) +
  theme_minimal(base_size = 12) +
  theme(
    plot.background = element_rect(fill = "white", color = NA),
    panel.background = element_rect(fill = "white", color = NA),
    panel.grid.major.y = element_line(color = "gray85", linewidth = 0.4),
    panel.grid.major.x = element_line(color = "gray92", linewidth = 0.3),
    panel.grid.minor = element_blank(),
    axis.text = element_text(color = "black"),
    axis.title = element_text(color = "black", face = "bold"),
    plot.title = element_text(color = "black", face = "bold", size = 14),
    axis.text.x = element_text(angle = 45, hjust = 1),
    legend.position = "bottom"
  )
# Show plot
P
# Save
ggsave("basisgrafiek_verpakkingen_totaal.png", width = 10, height = 6)
```

Code for figure2. Number of packages of antibiotics delivered to children in Belgian public pharmacies by compound

```
library(ggplot2)
library(dplyr)
# Recode ATC-5 labels
df_Vraag_3$ATC5_Description <- recode(df_Vraag_3$`ATC-5`,
                              "J01AA02" = "J01AA02 - Doxycycline",
                              "J01CA04" = "J01CA04 - Amoxicillin",
                              "J01CE02" = "J01CE02 - Phenoxymethylpenicillin",
                              "J01CF05" = "J01CF05 - Flucloxacillin",
                              "J01CR02" = "J01CR02 - Amoxicillin and beta-lactamase inhibitor",
                              "J01DC02" = "J01DC02 - Cefuroxime",
                              "J01EE01" = "J01EE01 - Sulfamethoxazole and trimethoprim",
                              "J01FA09" = "J01FA09 - Clarithromycin",
                              "J01FA10" = "J01FA10 - Azithromycin",
                              "J01MA02" = "J01MA02 - Ciprofloxacin",
                              "J01XE01" = "J01XE01 - Nitrofurantoin",
                              "J01XX01" = "J01XX01 - Fosfomycin"
)
# Ensure correct time order
df_Vraag_3$`Jaar/week` <- factor(
  df_Vraag_3$`Jaar/week`,
  levels = unique(df_Vraag_3$`Jaar/week`)
)
# X-axis yearly labels
week_positions <- seq(1, length(levels(df_Vraag_3$`Jaar/week`)), by = 53)
# COVID period
covid_start <- "2020 / 11"
covid_end   <- "2022 / 10"

# Colorblind-friendly palette
cb_palette <- c(
  "#0072B2", "#E69F00", "#009E73", "#CC79A7",
  "#56B4E9", "#D55E00", "#F0E442", "#000000",
  "#999999", "#0072B2", "#E69F00", "#009E73"
)

p <- ggplot(
  df_Vraag_3,
  aes(
    x = `Jaar/week`,
    y = `Aantal afgeleverde verpakkingen`,
    group = `ATC-5`,
    color = ATC5_Description
  )
) +

  annotate(
    "rect",
    xmin = covid_start,
    xmax = covid_end,
```

```
  ymin = -Inf,
  ymax = Inf,
  fill = "grey80",
  alpha = 0.4
 ) +

 geom_rect(
  data = data.frame(
   xmin = covid_start,
   xmax = covid_end,
   ymin = -Inf,
   ymax = Inf,
   fill = "COVID-19 period"
  ),
  aes(xmin = xmin, xmax = xmax, ymin = ymin, ymax = ymax, fill = fill),
  inherit.aes = FALSE,
  alpha = 0
 ) +

 geom_line(linewidth = 0.5) +

 facet_wrap(
  ~ ATC5_Description,
  scales = "free_y",
  labeller = labeller(
   ATC5_Description = function(x) {
    vapply(x, function(z) paste(strwrap(z, width = 28), collapse = "\n"), "")
   }
  )
 ) +

 labs(
  title = "Number of packages of antibiotics delivered to children in Belgian public pharmacies by
compound",
  x = "Time",
  y = "Number of Packages",
  fill = ""
 ) +

 scale_x_discrete(
  breaks = levels(df_Vraag_3$`Jaar/week`)[week_positions],
  labels = function(x) substr(x, 1, 4)
 ) +

 scale_y_continuous(labels = scales::comma) +

 scale_color_manual(values = cb_palette) +

 scale_fill_manual(
  values = c("COVID-19 period" = "grey80")
 ) +
```

```
  guides(
    fill = guide_legend(
      override.aes = list(alpha = 0.4),
      order = 1
    ),
    color = "none"
  ) +

  theme_minimal(base_size = 12) +
  theme(
    plot.background = element_rect(fill = "white", color = NA),
    panel.background = element_rect(fill = "white", color = NA),

    panel.grid.major = element_line(color = "gray90", linewidth = 0.3),
    panel.grid.minor = element_blank(),

    axis.text = element_text(color = "black"),
    axis.title = element_text(color = "black", face = "bold"),
    plot.title = element_text(color = "black", face = "bold", size = 14),

    strip.text = element_text(color = "black", face = "bold"),

    axis.text.x = element_text(angle = 45, hjust = 1),

    legend.position = "bottom",
    legend.title = element_text(face = "bold")
  )

# Show
p
# Save
ggsave("facetwrap_ATC5_publication.png", plot = p, width = 12, height = 8, dpi = 300)
```

Code for figure 3. Number of packages of antibiotics delivered to children in Belgian public pharmacies by specialty

```
library(ggplot2)
library(dplyr)
# Summarize data
df_summary <- df_Vraag_6 %>%
  group_by(`Jaar/week`, `Subcategorie voorschrijver`) %>%
  summarise(`Aantal afgeleverde verpakkingen` =
              sum(`Aantal afgeleverde verpakkingen`), .groups = 'drop')
# Order prescribers
total_packages <- df_summary %>%
  group_by(`Subcategorie voorschrijver`) %>%
  summarise(Total = sum(`Aantal afgeleverde verpakkingen`)) %>%
  arrange(desc(Total))
df_summary$`Subcategorie voorschrijver` <- factor(
  df_summary$`Subcategorie voorschrijver`,
  levels = c(
```

```
    total_packages$`Subcategorie voorschrijver`[
      total_packages$`Subcategorie voorschrijver` != "Andere"
    ],
    "Andere"
  )
)
# Recode labels
df_summary$`Subcategorie voorschrijver` <- recode(
  df_summary$`Subcategorie voorschrijver`,
  "Andere" = "Other",
  "Huisarts" = "GP",
  "NKO" = "ORL",
  "Pediater" = "Pediatrician",
  "Dermatoloog" = "Dermatologist",
  "Urgentiearts" = "Emergency Doctor"
)
# Ensure correct time order
df_summary$`Jaar/week` <- factor(
  df_summary$`Jaar/week`,
  levels = unique(df_summary$`Jaar/week`)
)
# X-axis (every 3 months)
week_positions <- seq(1, length(levels(df_summary$`Jaar/week`)), by = 13)
break_values <- levels(df_summary$`Jaar/week`)[week_positions]
label_values <- ifelse(
  !duplicated(substr(break_values, 1, 4)),
  substr(break_values, 1, 4),
  ""
)
# COVID period
covid_start <- "2020 / 11"
covid_end   <- "2022 / 10"
# Colorblind-friendly palette
cb_palette <- c(
  "#0072B2", "#E69F00", "#009E73",
  "#CC79A7", "#56B4E9", "#D55E00",
  "#F0E442", "#000000", "#999999"
)
# Separate dataset for COVID legend (fixes square issue)
covid_legend <- data.frame(
  xmin = covid_start,
  xmax = covid_end,
  ymin = -Inf,
  ymax = Inf,
  fill = "COVID-19 period"
)
# Plot
p <- ggplot(df_summary,
            aes(x = `Jaar/week`,
                y = `Aantal afgeleverde verpakkingen`,
                color = `Subcategorie voorschrijver`,
                group = `Subcategorie voorschrijver`)) +
```

```
  # COVID shading with legend
  geom_rect(
    data = covid_legend,
    aes(xmin = xmin, xmax = xmax, ymin = ymin, ymax = ymax, fill = fill),
    inherit.aes = FALSE,
    alpha = 0.4
  ) +
  # Lines
  geom_line(linewidth = 0.75) +
  labs(
    title = "Number of packages antibiotics delivered to children in Belgian public pharmacies by
specialty",
    x = "Time",
    y = "Number of Packages",
    color = "Prescriber",
    fill = ""
  ) +
  scale_x_discrete(
    breaks = break_values,
    labels = label_values
  ) +
  scale_y_continuous(labels = scales::comma) +
  scale_color_manual(values = cb_palette) +
  scale_fill_manual(
    values = c("COVID-19 period" = "grey80")
  ) +
  # Legends next to each other
  guides(
    color = guide_legend(order = 1, nrow = 1),
    fill  = guide_legend(order = 2, nrow = 1)
  ) +
  theme_minimal(base_size = 12) +
  theme(
    plot.background = element_rect(fill = "white", color = NA),
    panel.background = element_rect(fill = "white", color = NA),
    panel.grid.major.y = element_line(color = "gray85", linewidth = 0.4),
    panel.grid.major.x = element_line(color = "gray92", linewidth = 0.3),
    panel.grid.minor = element_blank(),
    axis.text = element_text(color = "black"),
    axis.title = element_text(color = "black", face = "bold"),
    plot.title = element_text(color = "black", face = "bold", size = 14),
    axis.text.x = element_text(angle = 45, hjust = 1),
    #  Legends horizontal
    legend.position = "bottom",
    legend.box = "horizontal",
    legend.title = element_text(face = "bold"),
    legend.spacing.x = unit(1, "cm")
  )
# Show plot
p
# Save
ggsave("basisgrafiek_verpakkingen_nieuw_V6.png", width = 10, height = 6)
```

Appendix II: Excel tables

1. Relative Change in Antibiotic Classes Before, During, and After the COVID-19 Pandemic

Relative change ATC-3

Time period	J01A	J01B	J01C	J01D	J01E	J01F	J01G	J01M	J01X	Grand Total
pre-covid	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
covid	0.65%	-53.63%	-41.60%	-54.81%	-77.31%	-43.97%	-59.64%	-64.29%	-15.09%	-42.66%
post-covid	20.88%	53.05%	67.98%	-15.55%	15.49%	90.71%	-17.66%	-7.78%	-19.97%	66.90%

Legend: J01A = , Tetracyclines, J01B = Amphenicols, J01C = Beta-Lactam antibacterials, penicillins, J01D = ,other beta-lactam antibacterials, J01E = ,Sulfonamides and Trimethoprim, J01F = Macrolides, Incosamides and Streptogramis, J01G = Aminoglycoside antibacterials, J01M = Quinolone antibacterials, J01X = Other antibacterials

2. Year-to-Year Relative Changes in Antibiotic Classes per 1,000 Inhabitants

Relative change ATC-3

Delivery year	J01A	J01B	J01C	J01D	J01E	J01F	J01G	J01M	J01X	Grand Total
2014	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
2015	1.10%	-8.93%	-2.42%	-4.46%	-59.82%	1.26%	2.13%	-0.07%	-8.73%	-3.79%
2016	2.03%	-23.76%	2.34%	-35.86%	-79.21%	0.81%	11.83%	5.70%	2.07%	-0.97%
2017	0.33%	-5.22%	-12.60%	-42.59%	-29.36%	-15.65%	24.95%	-15.80%	-1.68%	-13.71%
2018	6.94%	-12.86%	-3.36%	41.17%	1.21%	-7.50%	11.37%	-36.97%	2.62%	-3.02%
2019	6.85%	-0.37%	-5.00%	-6.35%	11.16%	-5.33%	-14.17%	-31.58%	-6.02%	-5.12%
2020	-28.18%	-42.15%	-38.85%	-45.12%	-7.46%	-34.22%	-63.07%	-16.69%	-8.69%	-38.11%
2021	50.83%	23.03%	35.11%	31.74%	2.16%	24.66%	1.33%	-18.63%	0.69%	32.45%
2022	-5.37%	20.79%	36.38%	2.09%	8.76%	33.55%	-11.47%	2.62%	-13.56%	33.90%
2023	-0.80%	11.43%	-3.24%	-46.96%	5.64%	30.97%	-15.27%	-2.77%	-14.33%	0.96%

Legend: J01A = , Tetracyclines, J01B = Amphenicols, J01C = Beta-Lactam antibacterials, penicillins, J01D = ,other beta-lactam antibacterials, J01E = ,Sulfonamides and Trimethoprim, J01F = Macrolides, Incosamides and Streptogramis, J01G = Aminoglycoside antibacterials, J01M = Quinolone antibacterials, J01X = Other antibacterials

3. Relative Change in Antibiotic Compounds Before, During, and After the COVID-19 Pandemic

Relative Change ATC-5

Time period	J01AA02	J01CA04	J01CE02	J01CF05	J01CR02	J01DC02	J01EE01	J01FA09	J01FA10	J01MA02	J01XE01	J01XX01	Other	Grand Total
pre-covid	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
covid	7.76%	-40.07%	-100.00%	6.79%	-49.89%	-16.63%	-77.31%	-71.96%	-26.36%	-62.15%	-15.62%	-24.79%	-67.36%	-42.66%
post-covid	67.75%	72.92%		62.91%	52.88%	-21.01%	15.49%	82.10%	96.18%	-8.78%	-15.74%	-4.56%	6.74%	66.90%

Legend: J01AA02 = Doxycycline, J01CA04 = Amoxicillin, J01CE02 = Phenoxymethylpenicillin, J01CF05 = Flucloxacillin, J01CR02 = Amixcillin and beta-lactamase inhibitor, J01DC02 = Cefuroxime, J01EE01 = Sulfamethoxazole and Trimethoprim, J01FA09 = Clarithromycin, J01FA10 = Azithromycin, J01MA02 = Ciprofloxacin, J01XE01 = Nitrofurantoin, J01XX01 = Fosfomycin

4. Year-to-Year Relative Changes in Antibiotic Compounds per 1,000 Inhabitants

Relative Change ATC-5

Delivery year	J01AA02	J01CA04	J01CE02	J01CF05	J01CR02	J01DC02	J01EE01	J01FA09	J01FA10	J01MA02	J01XE01	J01XX01	Other	Grand Total
2014	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
2015	12.94%	-0.97%	1.29%	58.28%	-7.70%	-2.02%	-59.82%	-3.91%	6.16%	0.00%	-17.62%	8.62%	-5.33%	-3.79%
2016	15.82%	3.57%	4.11%	50.48%	-3.39%	-20.81%	-79.21%	-3.88%	7.96%	5.28%	-0.21%	4.62%	-30.23%	-0.97%
2017	-2.94%	-11.18%	-14.78%	6.34%	-17.96%	3.03%	-29.36%	-28.65%	-10.12%	-13.09%	-5.30%	-2.37%	-27.62%	-13.71%
2018	35.42%	-2.63%	29.23%	13.61%	-7.55%	12.57%	1.21%	-13.85%	-1.44%	-34.75%	0.82%	2.44%	6.73%	-3.02%
2019	11.57%	-3.54%	-50.22%	6.45%	-10.54%	-9.74%	11.16%	-18.33%	0.52%	-29.57%	-1.10%	-7.74%	-7.52%	-5.12%
2020	-56.99%	-40.34%	-100.00%	-21.45%	-36.82%	-14.15%	-7.46%	-44.98%	-29.29%	-14.20%	-8.45%	-14.55%	-58.00%	-38.11%
2021	161.84%	39.90%		6.04%	26.96%	22.40%	2.16%	2.52%	30.87%	-26.56%	3.13%	-9.67%	22.80%	32.45%
2022	5.22%	38.45%		25.65%	31.39%	-7.71%	8.76%	21.45%	36.25%	8.04%	-8.21%	-6.73%	11.89%	33.90%
2023	2.49%	-3.32%		33.26%	-9.63%	-42.99%	5.64%	38.07%	32.66%	-1.55%	-19.43%	8.91%	-24.61%	0.96%

Legend: J01AA02 = Doxycycline, J01CA04 = Amoxicillin, J01CE02 = Phenoxymethylpenicillin, J01CF05 = Flucloxacillin, J01CR02 = Amixcillin and beta-lactamase inhibitor, J01DC02 = Cefuroxime, J01EE01 = Sulfamethoxazole and Trimethoprim, J01FA09 = Clarithromycin, J01FA10 = Azithromycin, J01MA02 = Ciprofloxacin, J01XE01 = Nitrofurantoin, J01XX01 = Fosfomycin

5. Relative Change in Antibiotic use by Sex Before, During, and After the COVID-19 Pandemic

Relative Change	Sex		
Time period	F	M	Grand Total
pre-covid	n.a.	n.a.	n.a.
covid	-43.10%	-42.26%	-42.66%
post-covid	66.72%	67.07%	66.90%

6. Year-to-Year Relative Changes in Antibiotic use by Sex per 1,000 Inhabitants

Relative Change	Sex		
Delivery year	F	M	
2014	n.a.	n.a.	
2015	-4.29%	-3.33%	
2016	-1.15%	-0.80%	
2017	-13.96%	-13.49%	
2018	-2.93%	-3.09%	
2019	-5.24%	-5.00%	
2020	-37.89%	-38.31%	
2021	31.20%	33.61%	
2022	33.56%	34.20%	
2023	1.39%	0.58%	

7. Relative Change in Antibiotic use by age category Before, During, and After the COVID-19 Pandemic

Relative Change	Age Category			
Time period	0-1j	2-6j	7-12j	Grand Total
pre-covid	n.a.	n.a.	n.a.	n.a.
covid	-34.02%	-42.71%	-47.51%	-43%
post-covid	46.56%	62.72%	89.23%	67%

8. Year-to-Year Relative Changes in Antibiotic use by Age Category per 1,000 Inhabitants

Relative Change	Age Category		
Delivery year	0-1j	2-6j	7-12j
2014	n.a.	n.a.	n.a.
2015	-3%	-5%	-2%
2016	-6%	0%	2%
2017	-5%	-15%	-14%
2018	-1%	-3%	-4%
2019	-3%	-4%	-7%
2020	-41%	-40%	-33%
2021	57%	48%	-2%
2022	15%	32%	53%
2023	-3%	-8%	19%

9. Relative Change in Antibiotic use by specialiy of Prescriber Before, During, and After the COVID-19 Pandemic

Relative change	Specialty of prescriber				
Time period	GP	Specialist	Dentist	Midwife	Grand Total
pre-covid	n.a.	n.a.	n.a.	n.a.	n.a.
covid	-82.85%	-79.22%	-73.78%		-81.60%
post-covid	60.12%	39.36%	-10.99%	200.00%	50.85%

10. Relative Change in Antibiotic use by specialty of Prescriber Before, During, and After the COVID-19 Pandemic

Relative change	Subcategory specialty of prescriber					
Time period	Dermatologist	GP	ORL	Pediatrics	Emergency Doctor	Others
pre-covid	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
covid	-20.32%	-46.57%	-45.25%	-35.69%	-25.04%	-22.09%
post-covid	6.75%	77.15%	77.55%	55.20%	80.60%	10.08%

11. Year-to-Year Relative Changes in Antibiotic us by Specialty of Prescriber per 1,000 Inhabitants

Relative change	Category prescriber					
Delivery year	GP	Specialist	Dentist	Midwife	(blank)	Grand Total
2014	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
2015	-3.38%	-4.49%	-1.80%		-85.94%	-3.79%
2016	-1.04%	-0.61%	-2.98%		0.85%	-0.97%
2017	-17.05%	-6.22%	-4.34%		288.58%	-13.71%
2018	-2.44%	-3.82%	-4.68%		-93.32%	-3.02%
2019	-6.61%	-1.94%	-1.97%		20.67%	-5.12%
2020	-40.43%	-35.75%	-8.06%		-40.24%	-38.11%
2021	34.79%	32.37%	-3.33%		42.16%	32.45%
2022	40.78%	22.85%	-0.79%	-0.03%	29.25%	33.90%
2023	-1.70%	7.32%	1.38%	102.19%	-22.60%	0.96%

12. Year-to-Year Relative Changes in Antibiotic us by Specialty of prescriber per 1,000 Inhabitants

Relative change	Subcategory specialty of prescriber					
Delivery year	Dermatologist	GP	ORL	Pediatrics	Emergency Doctor	Others
2014	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
2015	0.81%	-3.38%	-11.16%	-4.93%	1.26%	-1.68%
2016	5.17%	-1.04%	-5.02%	-0.91%	12.92%	-0.40%
2017	-10.13%	-17.05%	-3.06%	-6.48%	-2.93%	-3.45%
2018	-7.41%	-2.44%	-6.53%	-3.46%	-12.92%	-5.70%
2019	-1.53%	-6.61%	-1.25%	-2.12%	7.04%	-2.41%
2020	-10.26%	-40.43%	-45.20%	-36.44%	-32.49%	-14.83%
2021	-2.33%	34.79%	38.15%	34.37%	35.82%	3.76%
2022	1.10%	40.78%	34.22%	23.01%	36.25%	4.26%
2023	8.43%	-1.70%	11.75%	6.88%	16.22%	2.87%

13. Relative Changes in Antibiotic use by Region Before, During, and After the COVID-19 Pandemic

Relative change	Region			
Time period	Brussels-Capital Region	Unknown	Flemish Region	Walloon Region
pre-covid	n.a.	n.a.	n.a.	n.a.
covid	-40.16%	-44.94%	-40.92%	-45.96%
post-covid	58.74%	66.69%	61.69%	78.02%

14. Year-to-Year Relative Changes in Antibiotic use by Region per 1,000 Inhabitants

Relative change	Region			
Delivery year	Brussels-Capital Region	Unknown	Flemish Region	Walloon Region
2014	n.a.		n.a.	n.a.
2015	-3.82%		-5.47%	-1.15%
2016	4.51%		-0.15%	-3.55%
2017	-11.03%		-13.99%	-14.02%
2018	-3.91%		4.89%	1.94%
2019	3.75%		-10.46%	-12.67%
2020	-42.09%		-37.17%	-39.74%
2021	34.38%		29.78%	36.23%
2022	32.67%		30.42%	39.74%
2023	-3.72%		-0.16%	11.70%

15. Relative Changes in Antibiotic use by DEGURBA-classification Before, During, and After the COVID-19 Pandemic

Relative change	DEGURBA-Classification				
Time period	1	2	3	Unknown	Grand Total
pre-covid	n.a.	n.a.	n.a.	n.a.	n.a.
covid	-43.98%	-44.24%	-46.87%	-46.68%	-44.57%
post-covid	69.12%	75.01%	81.61%	73.65%	74.20%

16. Year-to-Year Relative Changes in Antibiotic use by DEGURBA-classification per 1,000 Inhabitants

Relative change	DEGURBA-Classification				
Delivery year	1	2	3	Unknown	Grand Total
2014	n.a.	n.a.	n.a.	n.a.	n.a.
2015	-2.84%	-4.65%	-2.66%	1.24%	-3.79%
2016	0.81%	-1.04%	-4.26%	10.11%	-0.97%
2017	-13.58%	-13.74%	-13.97%	-9.54%	-13.71%
2018	-4.45%	-2.60%	-2.62%	39.51%	-3.02%
2019	-4.65%	-4.15%	-8.55%	-33.89%	-5.12%
2020	-38.20%	-37.89%	-38.56%	-45.80%	-38.11%
2021	33.98%	31.12%	34.12%	42.03%	32.45%
2022	31.69%	34.47%	35.76%	56.39%	33.90%
2023	-1.51%	1.42%	4.73%	-20.28%	0.96%

17. Relative Changes in Antibiotic use by Reimbursement type Before, During, and After the COVID-19 Pandemic

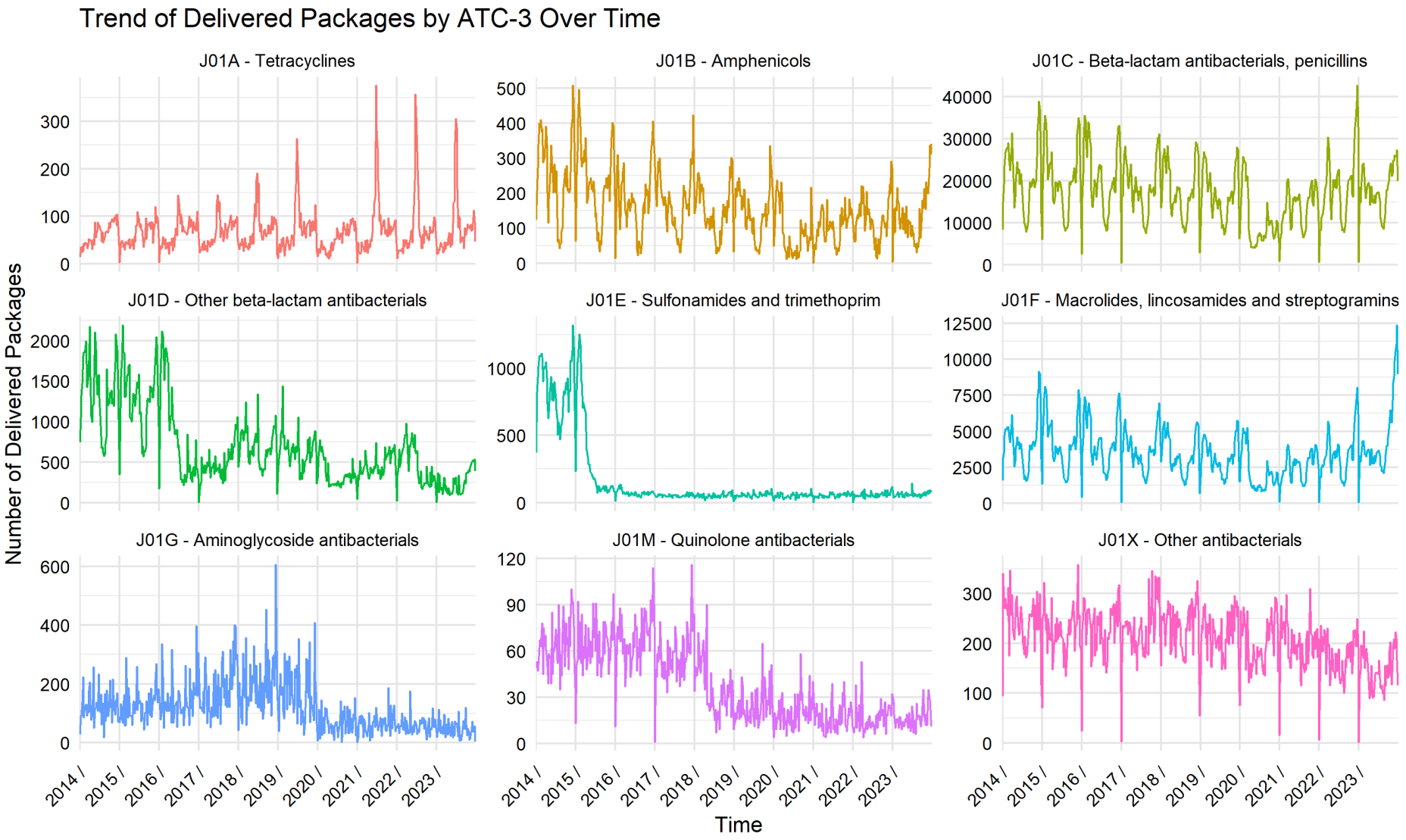
Relative Change	Reimbursement			
Time period	Standard tariff	Preferential tariff	Unknown	Grand Total
pre-covid	n.a.	n.a.	n.a.	n.a.
covid	-43.45%	-39.77%	-92.32%	-43%
post-covid	68.46%	61.52%	789.92%	55%

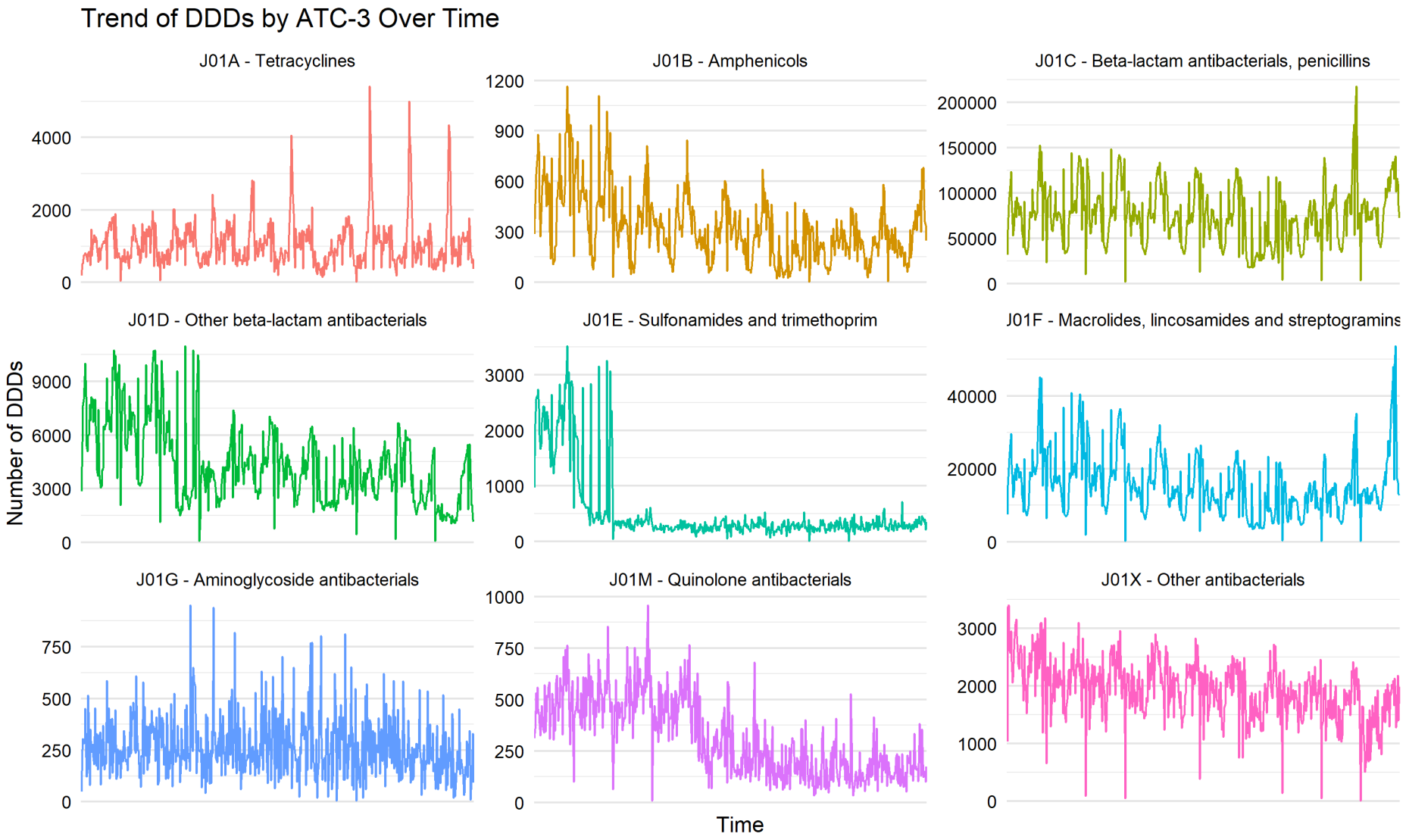
18. Year-to-Year Relative Changes in Antibiotic use by Reimbursement type per 1,000 Inhabitants

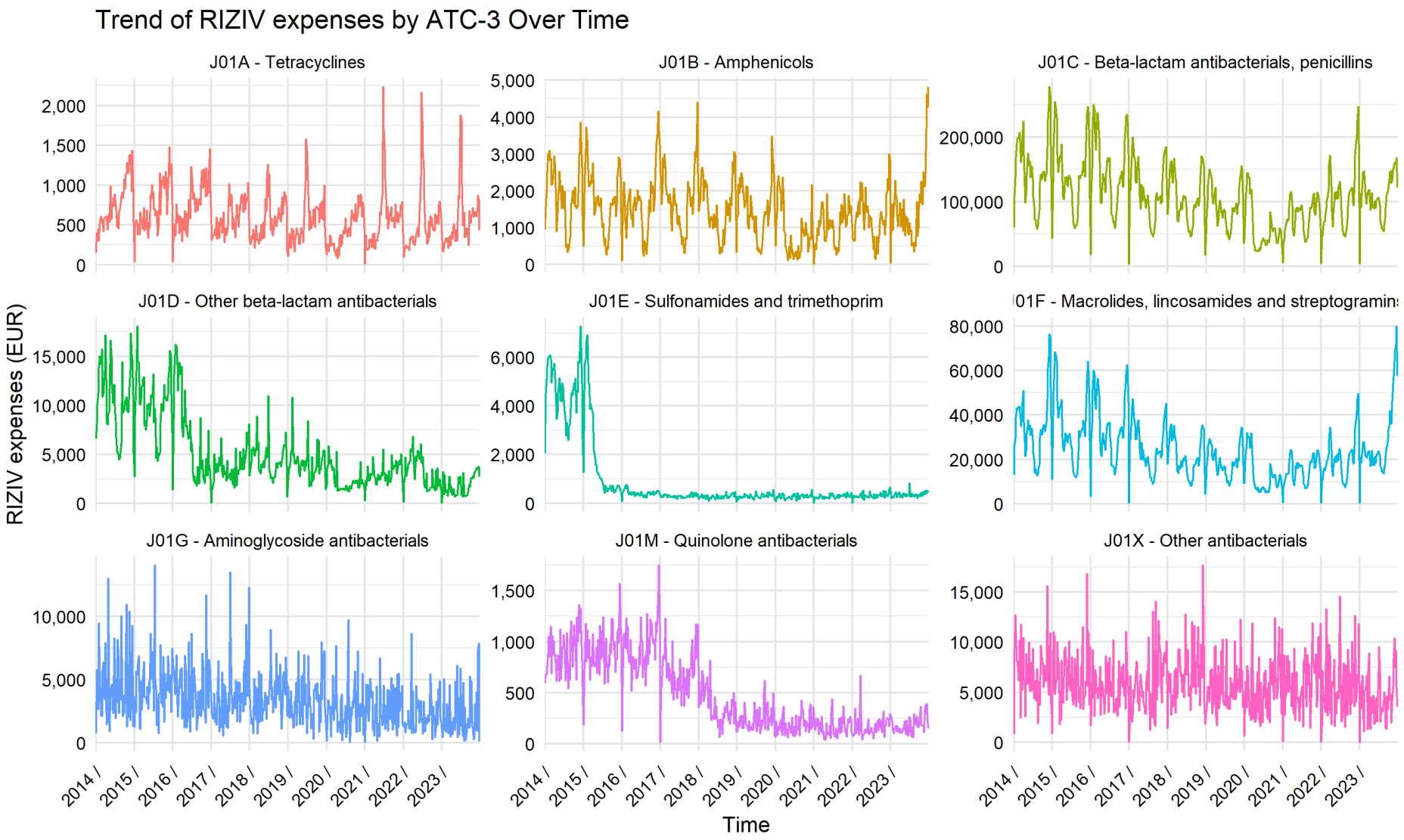
Relative Change	Reimubursement			
Delivery year	Standard tariff	Preferential tariff	Unknown	Grand Total
2014	n.a.	n.a.	n.a.	n.a.
2015	-5%	-1%	-7%	-4%
2016	-2%	4%	-3%	-1%
2017	-15%	-10%	-39%	-14%
2018	-3%	-3%	-6%	-3%
2019	-5%	-5%	23%	-5%
2020	-39%	-36%	-95%	-38%
2021	35%	25%	39%	32%
2022	34%	33%	678%	34%
2023	1%	1%	82%	1%

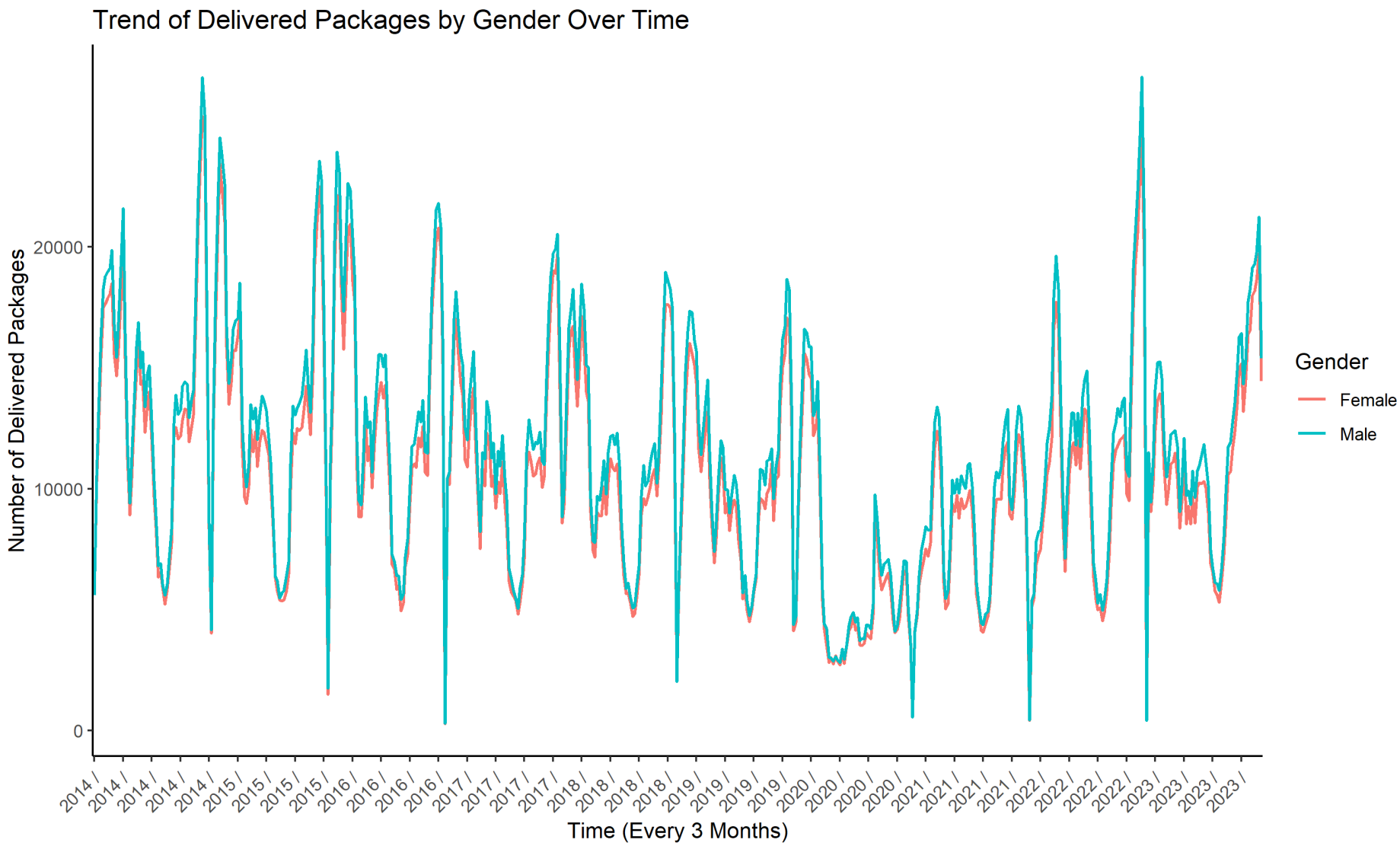
Appendix III: R graphs

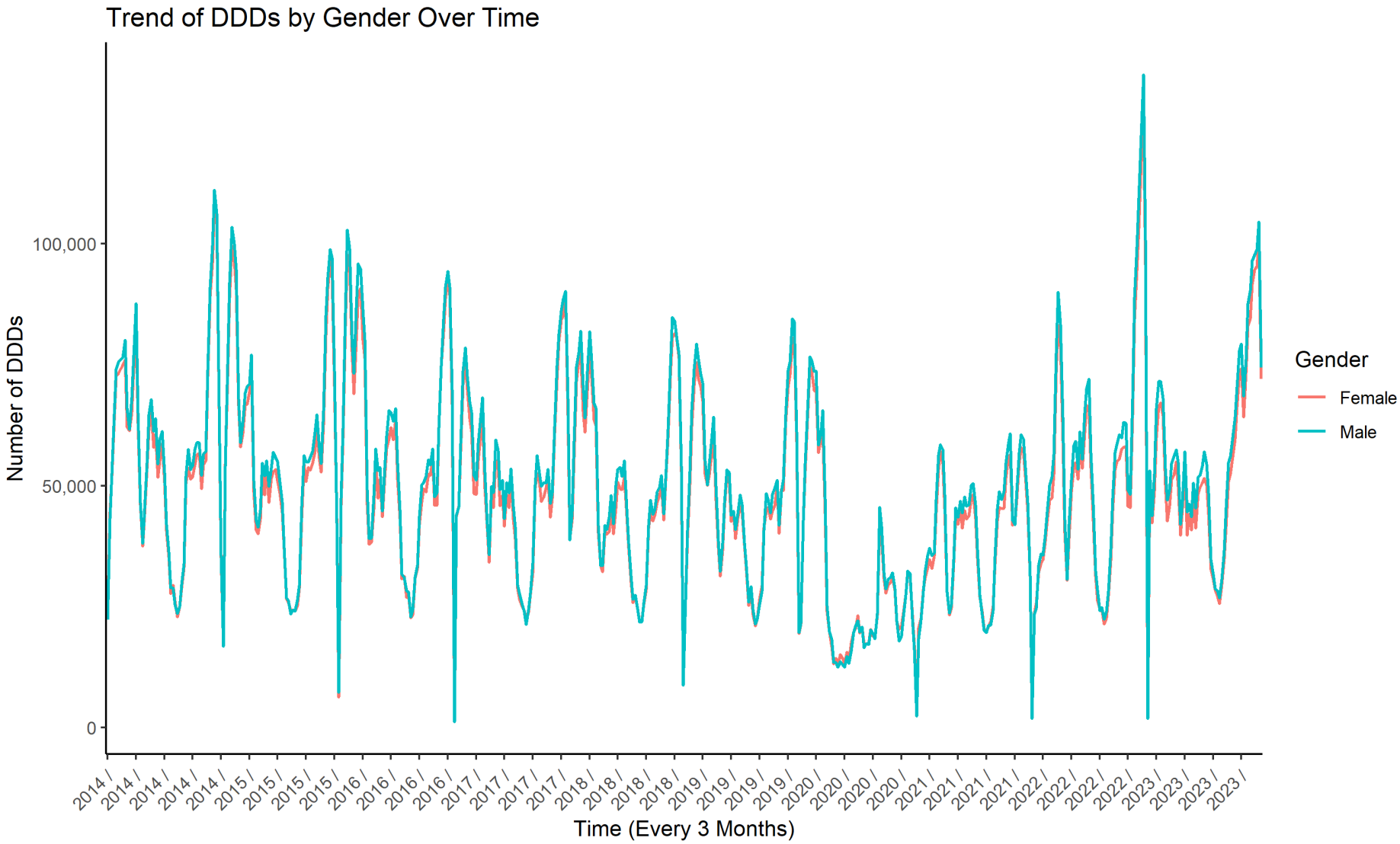
During the analysis of the data, we produced more figures than those included in the article. Based on relevance, we decided to fully develop three figures. The remaining figures display accurate data but have not been further refined in terms of layout.

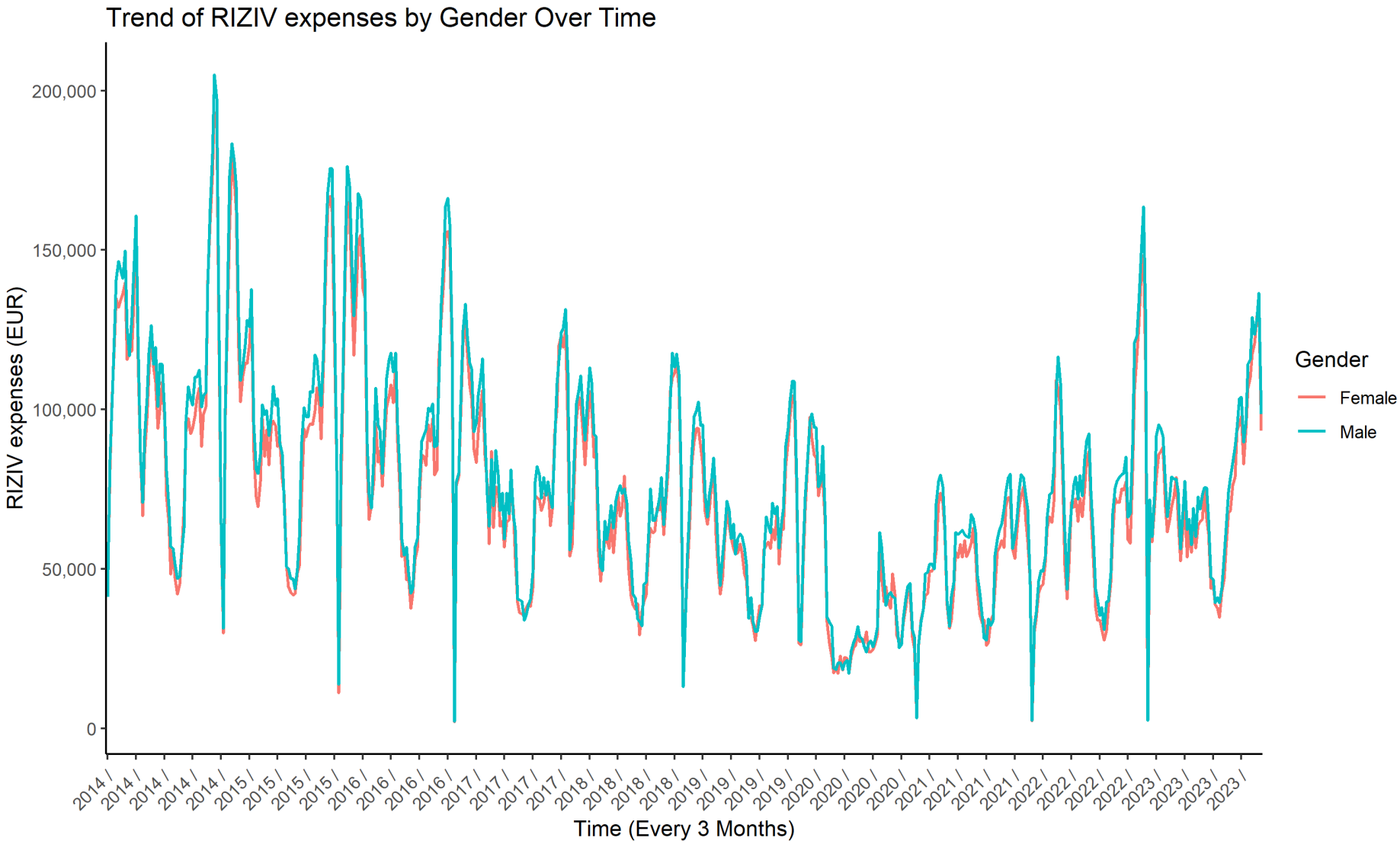

Trend of Delivered Packages by ATC-3 Over Time
J01A - Tetracyclines
J01B - Amphenicols
J01C - Beta-lactam antibacterials, penicillins
J01D - Other beta-lactam antibacterials
J01E - Sulfonamides and trimethoprim
J01F - Macrolides, lincosamides and streptogramins
J01G - Aminoglycoside antibacterials
J01M - Quinolone antibacterials
J01X - Other antibacterials
Number of Delivered Packages
Time
2014
2015
2016
2017
2018
2019
2020
2021
2022
2023

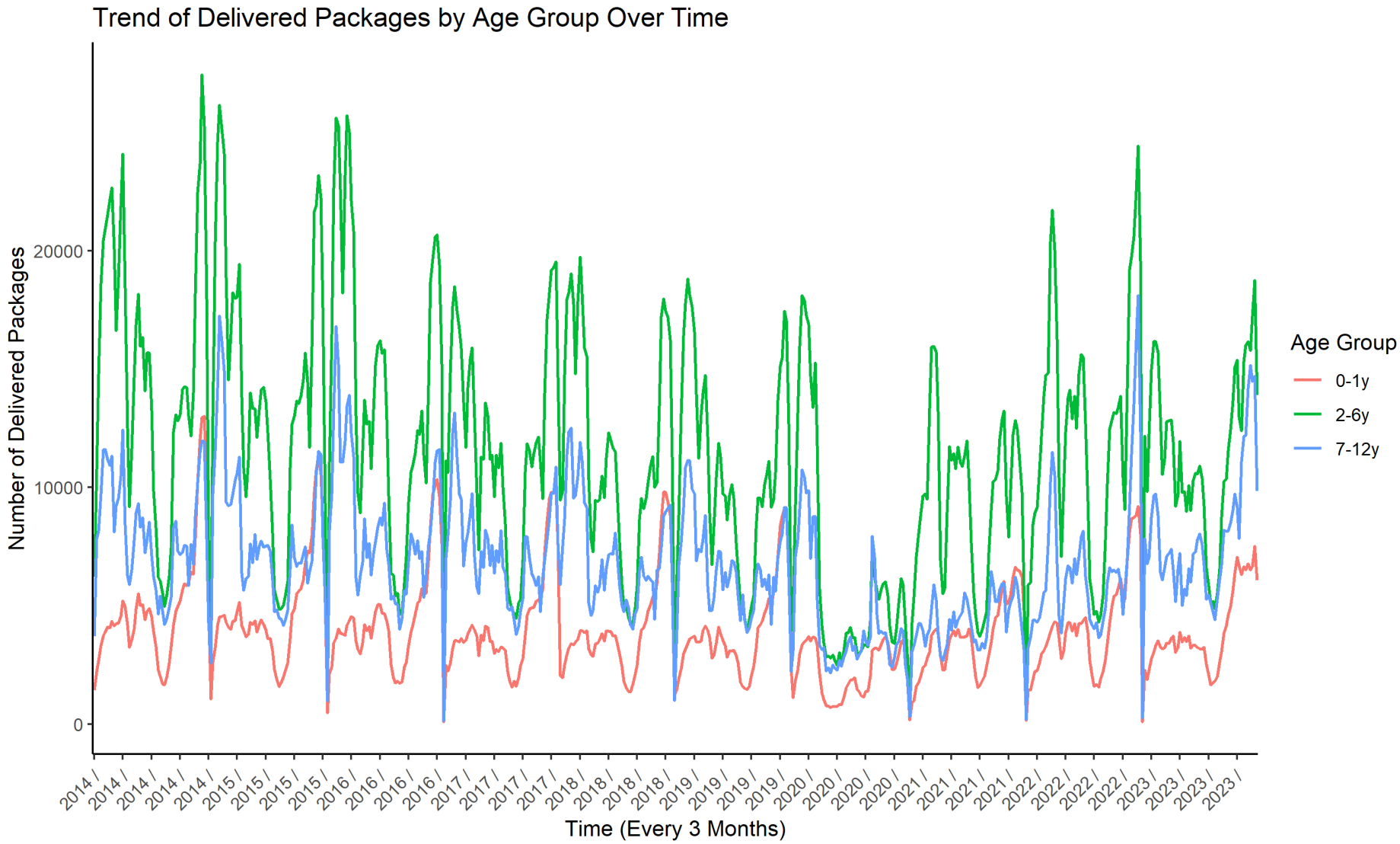

Trend of DDDs by ATC-3 Over Time
J01A - Tetracyclines
J01B - Amphenicols
J01C - Beta-lactam antibacterials, penicillins
J01D - Other beta-lactam antibacterials
J01E - Sulfonamides and trimethoprim
J01F - Macrolides, lincosamides and streptogramins
J01G - Aminoglycoside antibacterials
J01M - Quinolone antibacterials
J01X - Other antibacterials
Number of DDDs
Time

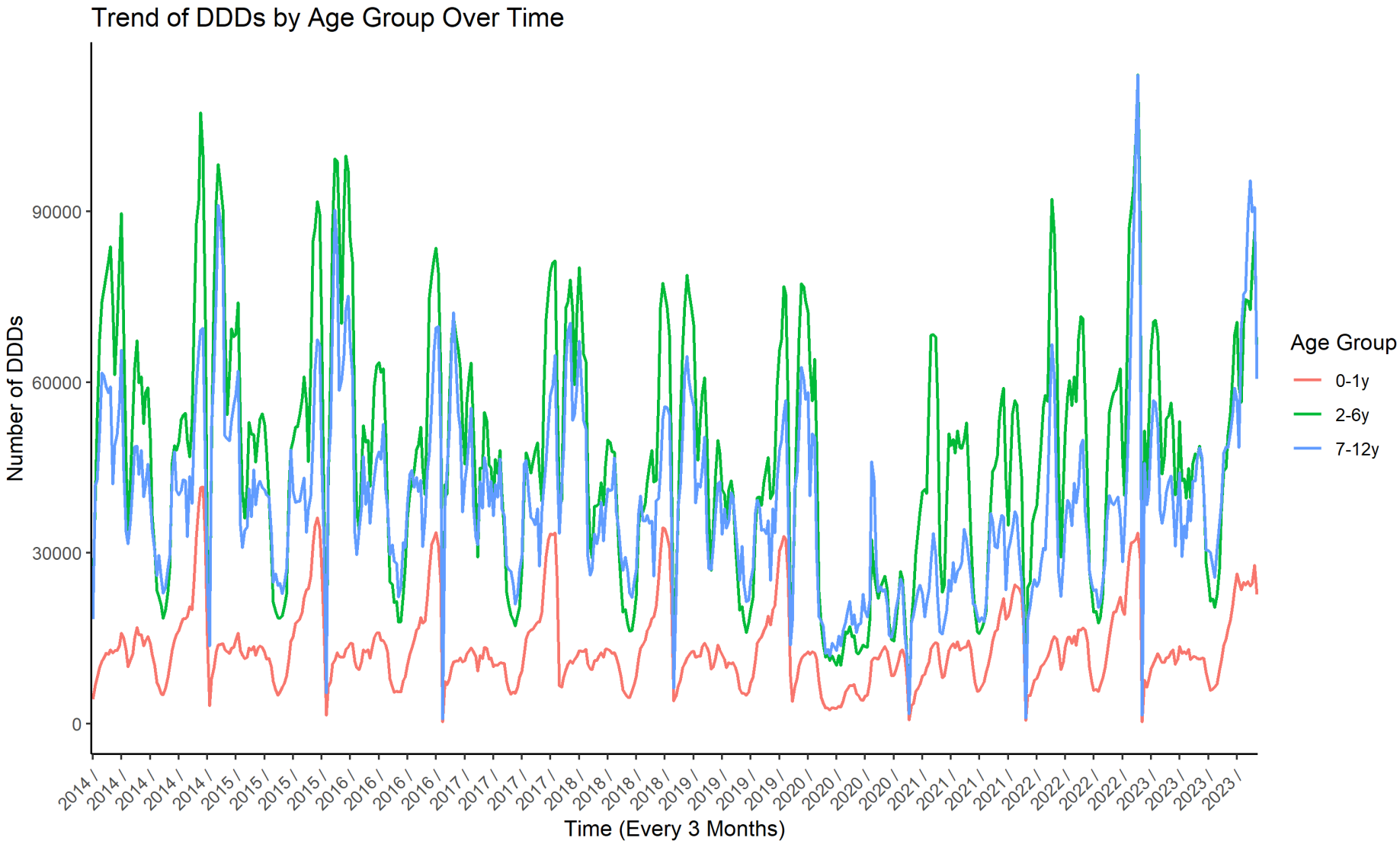

Trend of RIZIV expenses by ATC-3 Over Time
J01A - Tetracyclines
J01B - Amphenicols
J01C - Beta-lactam antibacterials, penicillins
J01D - Other beta-lactam antibacterials
J01E - Sulfonamides and trimethoprim
01F - Macrolides, lincosamides and streptogramins
J01G - Aminoglycoside antibacterials
J01M - Quinolone antibacterials
J01X - Other antibacterials
RIZIV expenses (EUR)
Time
2014
2015
2016
2017
2018
2019
2020
2021
2022
2023

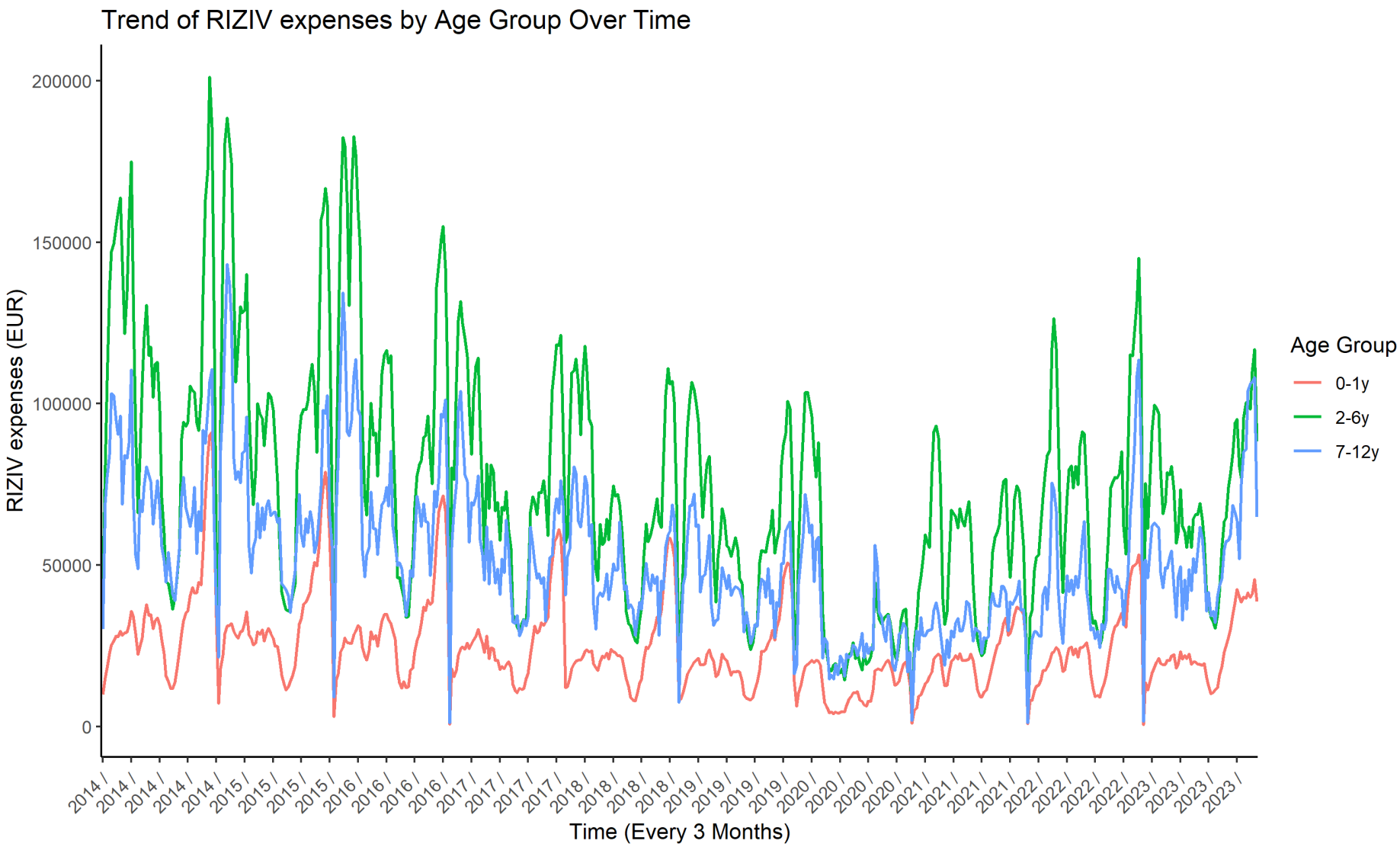

Trend of Delivered Packages by Gender Over Time
Number of Delivered Packages
20000
10000
0
Time (Every 3 Months)
2014 | 2014 | 2014 | 2014 | 2014 | 2015 | 2015 | 2015 | 2015 | 2016 | 2016 | 2016 | 2016 | 2017 | 2017 | 2017 | 2017 | 2018 | 2018 | 2018 | 2018 | 2019 | 2019 | 2019 | 2019 | 2020 | 2020 | 2020 | 2020 | 2021 | 2021 | 2021 | 2021 | 2022 | 2022 | 2022 | 2022 | 2023 | 2023 | 2023 | 2023 |
Gender
Female
Male

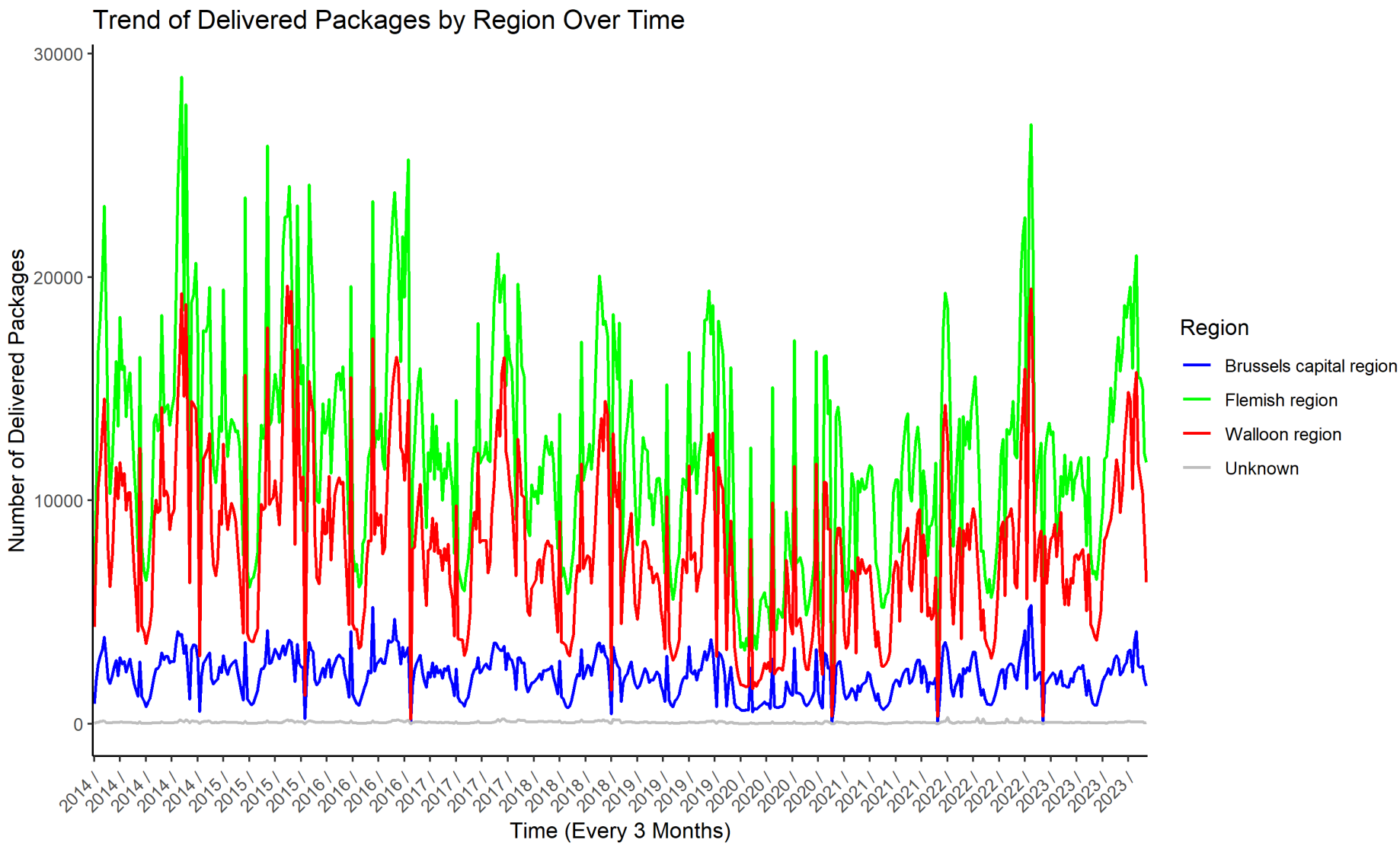

Trend of DDDs by Gender Over Time
Number of DDDs
100,000
50,000
0
Time (Every 3 Months)
2014 | 2014 | 2014 | 2014 | 2014 | 2015 | 2015 | 2015 | 2015 | 2016 | 2016 | 2016 | 2016 | 2017 | 2017 | 2017 | 2017 | 2018 | 2018 | 2018 | 2018 | 2019 | 2019 | 2019 | 2019 | 2020 | 2020 | 2020 | 2020 | 2021 | 2021 | 2021 | 2021 | 2022 | 2022 | 2022 | 2022 | 2023 | 2023 | 2023 | 2023 |
Gender
Female
Male

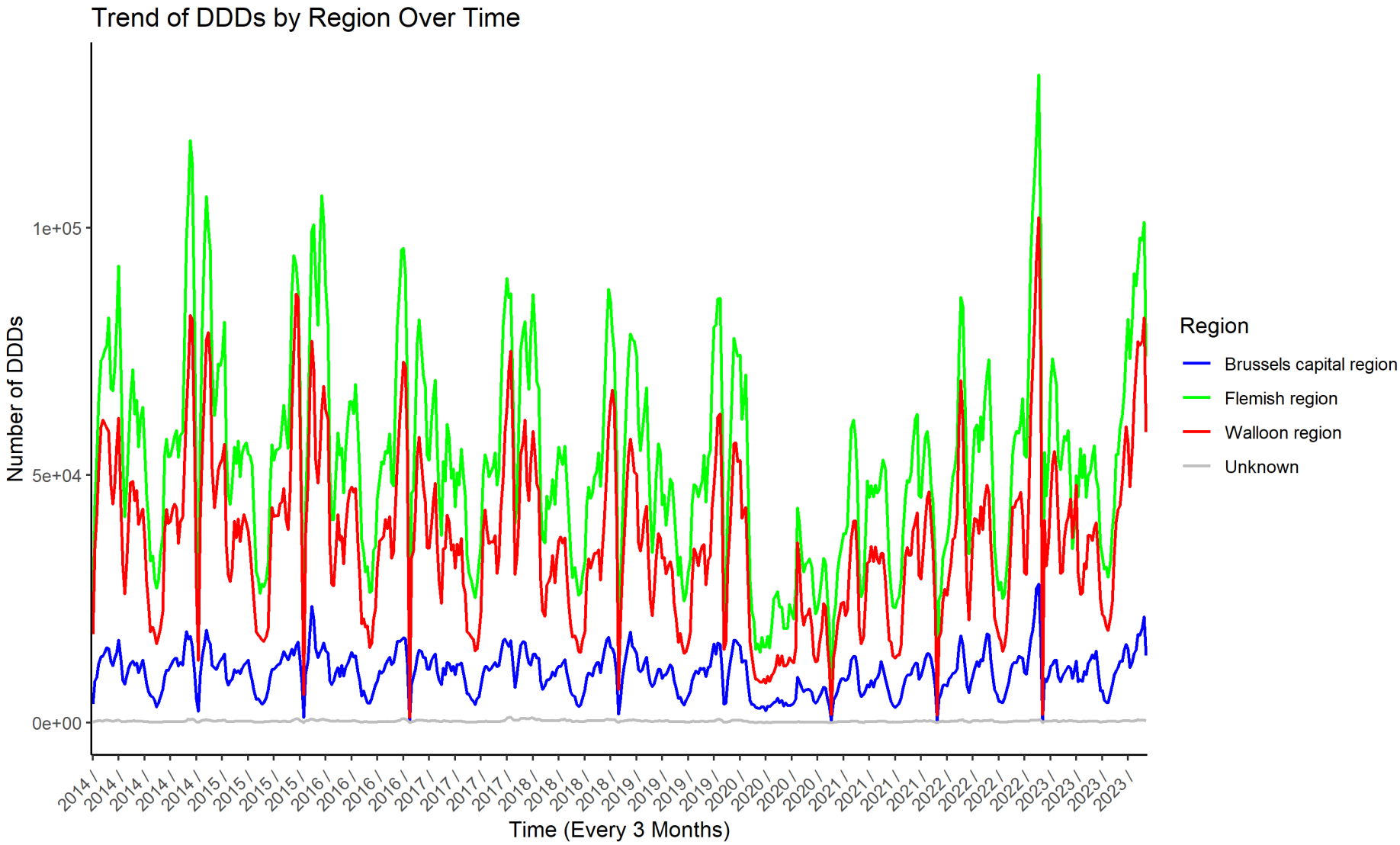

Trend of RIZIV expenses by Gender Over Time
RIZIV expenses (EUR)
200,000
150,000
100,000
50,000
0
Time (Every 3 Months)
Gender
Female
Male

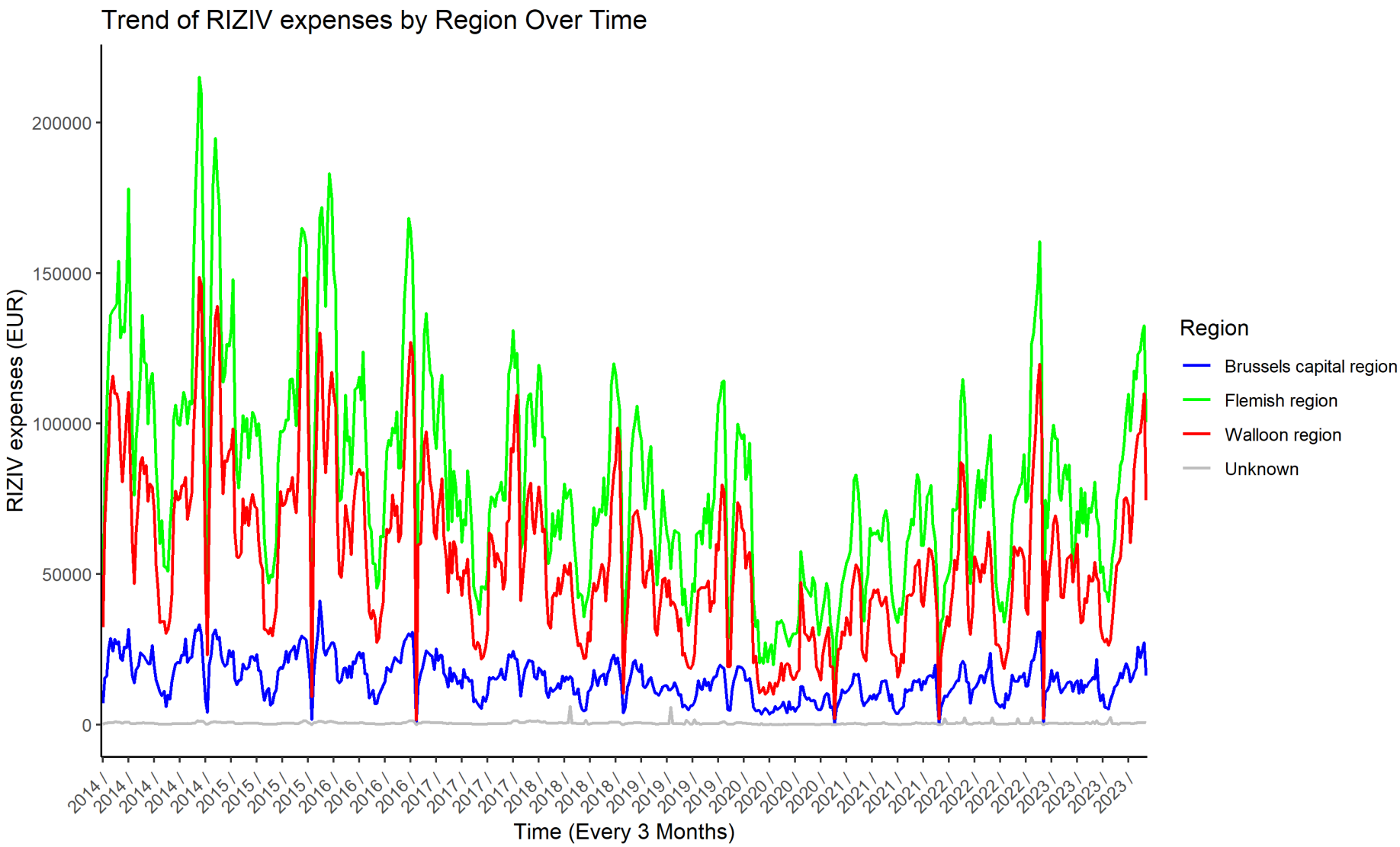

Trend of Delivered Packages by Age Group Over Time
Number of Delivered Packages
20000
10000
0
Time (Every 3 Months)
Age Group
0-1y
2-6y
7-12y

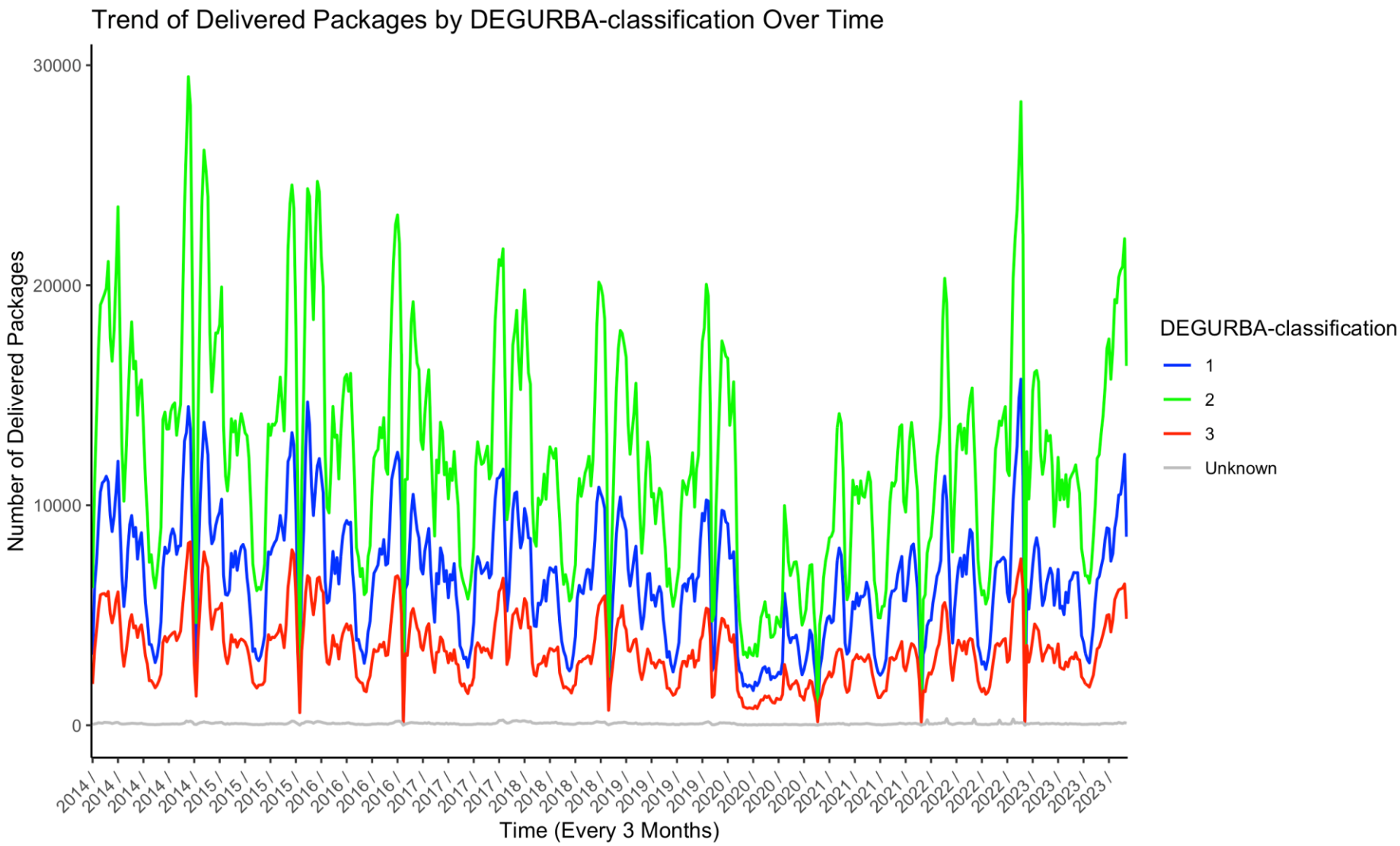

Trend of DDDs by Age Group Over Time
Number of DDDs
0
30000
60000
90000
Time (Every 3 Months)
2014
2015
2016
2017
2018
2019
2020
2021
2022
2023
Age Group
0-1y
2-6y
7-12y

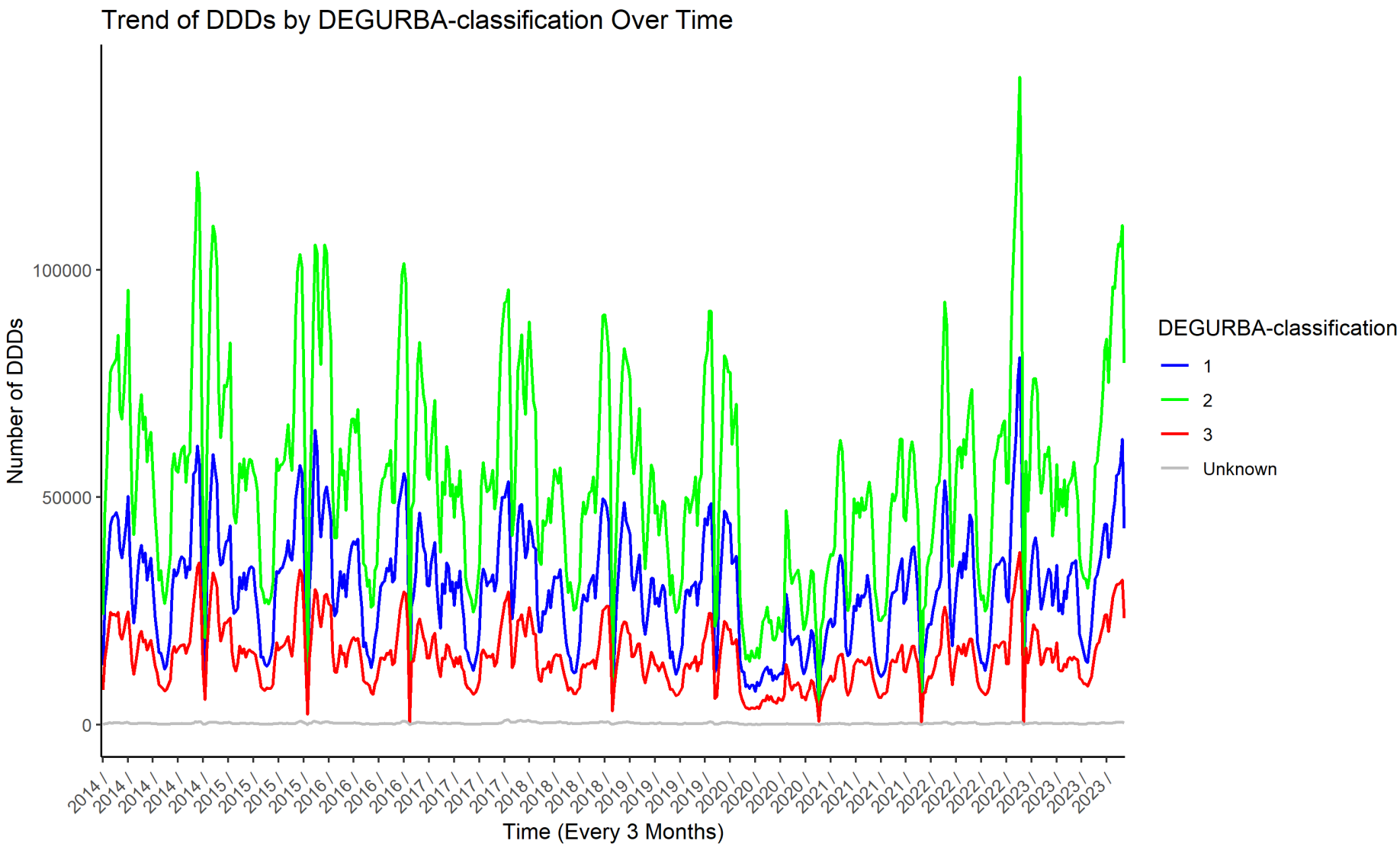

Trend of RIZIV expenses by Age Group Over Time
RIZIV expenses (EUR)
200000
150000
100000
50000
0
Time (Every 3 Months)
Age Group
0-1y
2-6y
7-12y

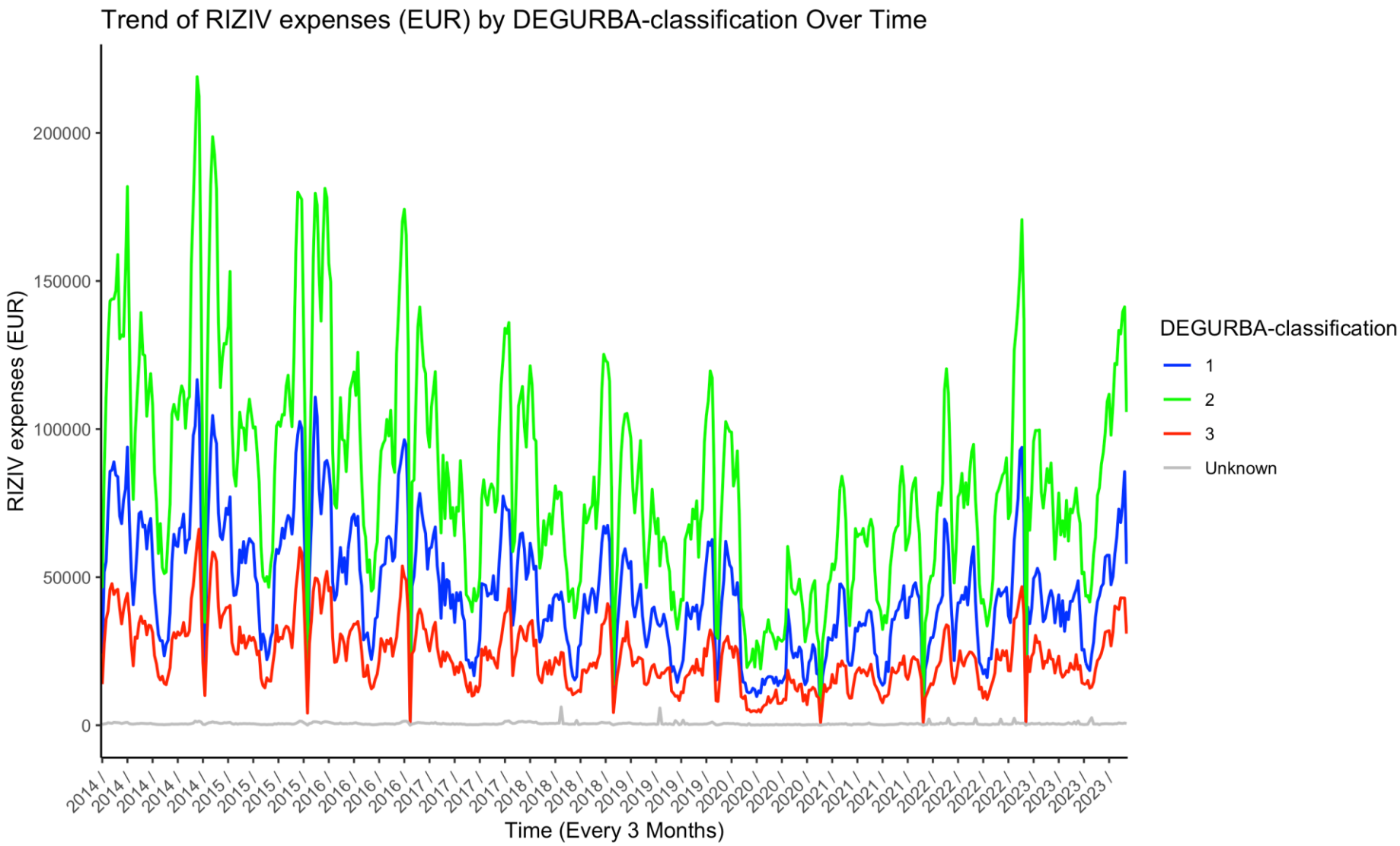

Trend of Delivered Packages by Region Over Time
Number of Delivered Packages
30000
20000
10000
0
Time (Every 3 Months)
Region
Brussels capital region
Flemish region
Walloon region
Unknown

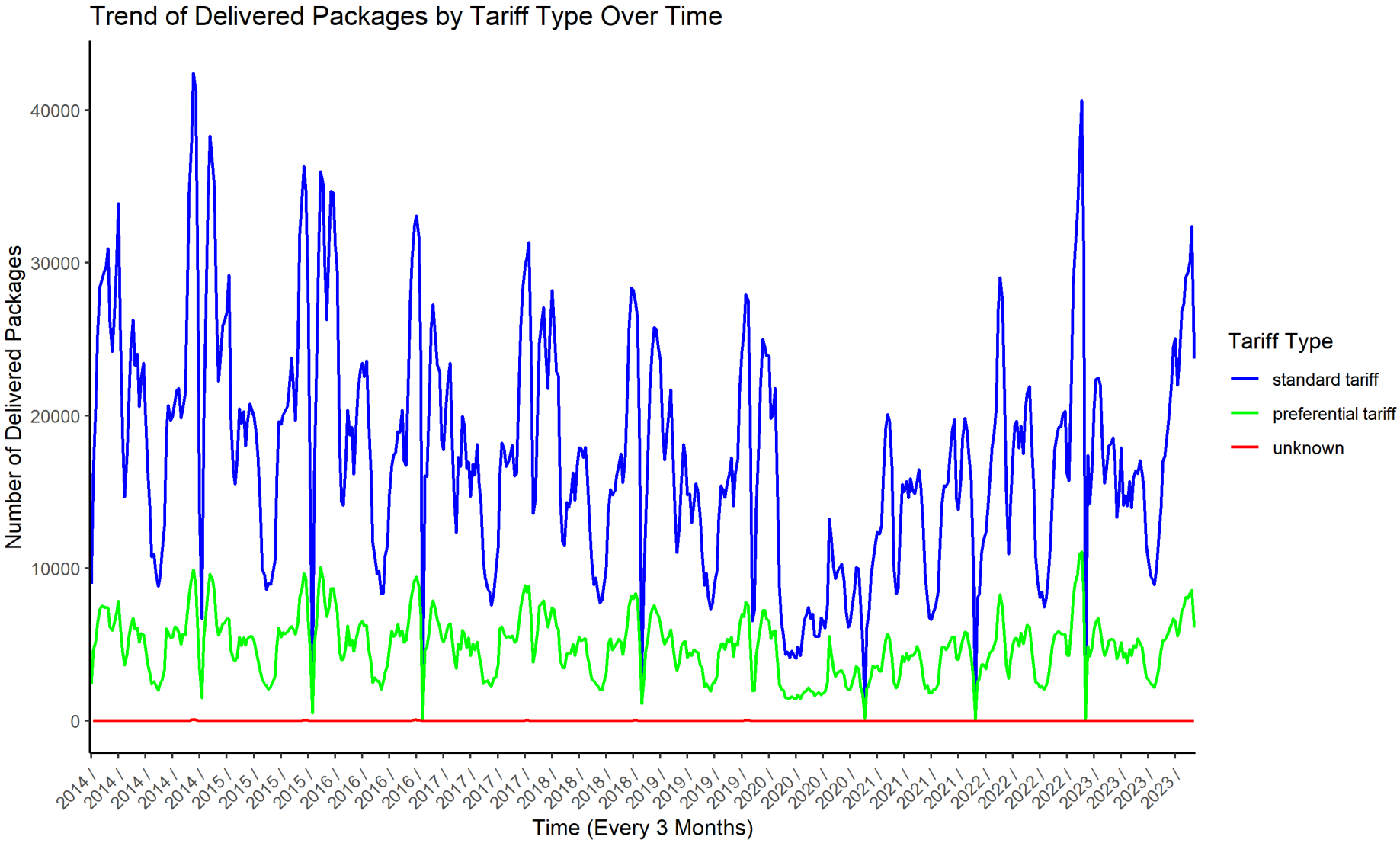

Trend of DDDs by Region Over Time
Number of DDDs
1e+05
5e+04
0e+00
2014
2015
2016
2017
2018
2019
2020
2021
2022
2023
Time (Every 3 Months)
Region
Brussels capital region
Flemish region
Walloon region
Unknown

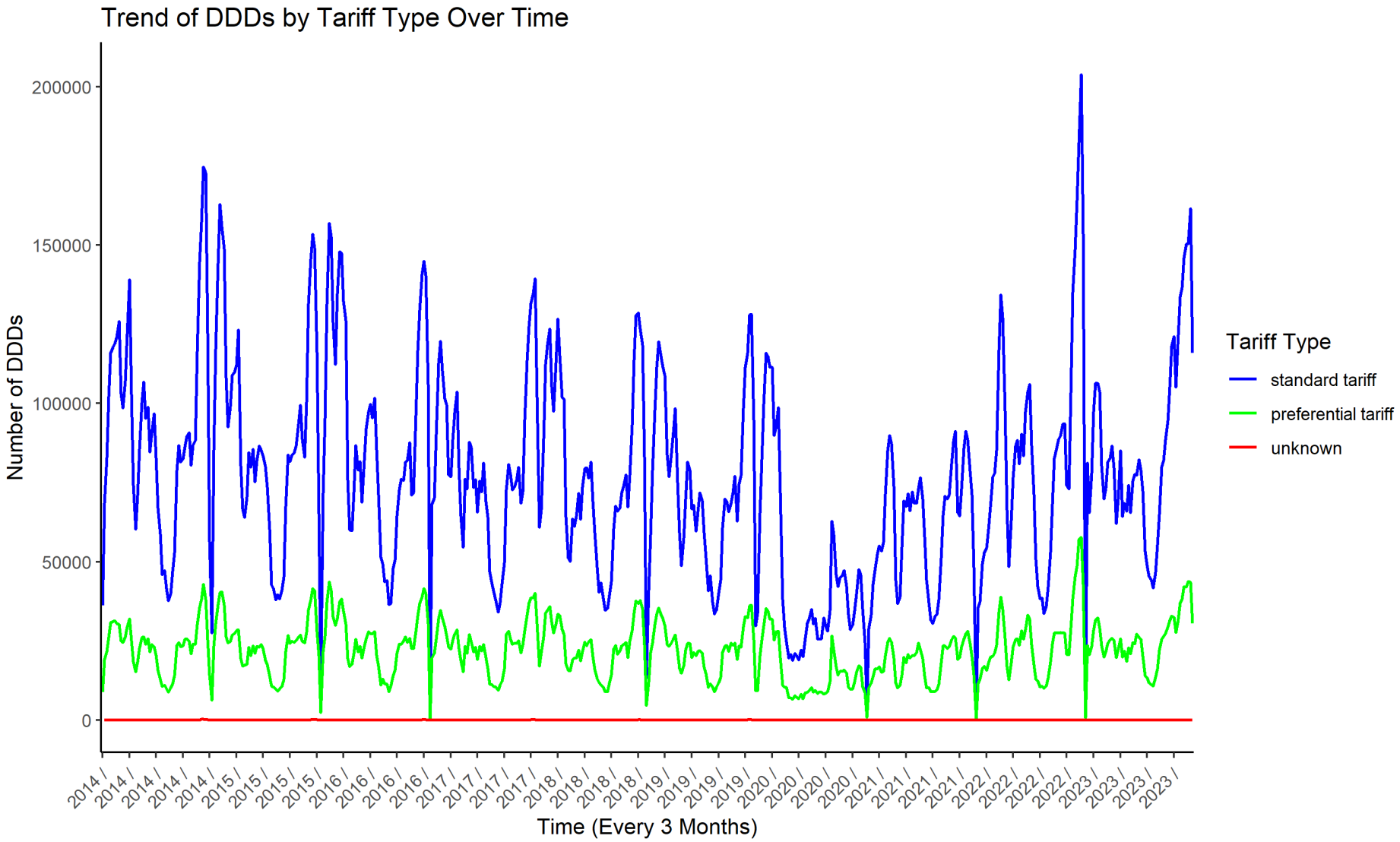

Trend of RIZIV expenses by Region Over Time
RIZIV expenses (EUR)
200000
150000
100000
50000
0
Time (Every 3 Months)
Region
Brussels capital region
Flemish region
Walloon region
Unknown

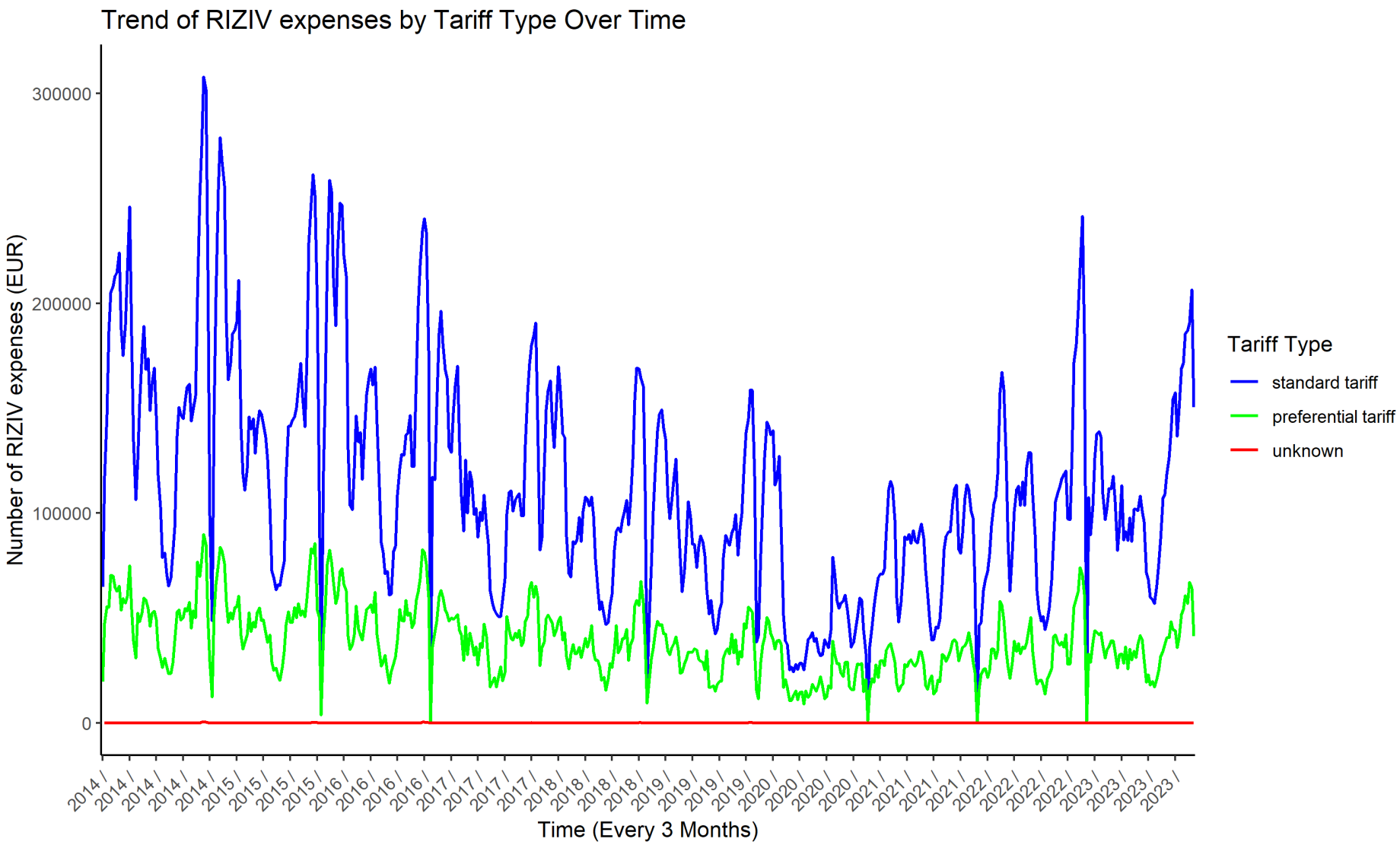

Trend of Delivered Packages by DEGURBA-classification Over Time
Number of Delivered Packages
30000
20000
10000
0
2014 | 2014 | 2014 | 2014 | 2014 | 2015 | 2015 | 2015 | 2015 | 2016 | 2016 | 2016 | 2016 | 2017 | 2017 | 2017 | 2017 | 2018 | 2018 | 2018 | 2018 | 2019 | 2019 | 2019 | 2019 | 2020 | 2020 | 2020 | 2020 | 2021 | 2021 | 2021 | 2021 | 2022 | 2022 | 2022 | 2022 | 2023 | 2023 | 2023 | 2023 |
Time (Every 3 Months)
DEGURBA-classification
1
2
3
Unknown


Trend of DDDs by DEGURBA-classification Over Time
Number of DDDs
100000
50000
0
2014 | 2014 | 2014 | 2014 | 2014 | 2015 | 2015 | 2015 | 2015 | 2016 | 2016 | 2016 | 2016 | 2017 | 2017 | 2017 | 2017 | 2018 | 2018 | 2018 | 2018 | 2019 | 2019 | 2019 | 2019 | 2020 | 2020 | 2020 | 2020 | 2021 | 2021 | 2021 | 2021 | 2022 | 2022 | 2022 | 2022 | 2023 | 2023 | 2023 | 2023 |
Time (Every 3 Months)
DEGURBA-classification
1
2
3
Unknown


Trend of RIZIV expenses (EUR) by DEGURBA-classification Over Time
RIZIV expenses (EUR)
200000
150000
100000
50000
0
Time (Every 3 Months)
DEGURBA-classification
1
2
3
Unknown


Trend of Delivered Packages by Tariff Type Over Time
Number of Delivered Packages
40000
30000
20000
10000
0
Time (Every 3 Months)
Tariff Type
standard tariff
preferential tariff
unknown


Trend of DDDs by Tariff Type Over Time
Number of DDDs
200000
150000
100000
50000
0
Time (Every 3 Months)
Tariff Type
standard tariff
preferential tariff
unknown


Trend of RIZIV expenses by Tariff Type Over Time
Number of RIZIV expenses (EUR)
300000
200000
100000
0
Time (Every 3 Months)
Tariff Type
standard tariff
preferential tariff
unknown