Università degli Studi di Firenze

Dipartimento di Ingegneria dell'Informazione
Tesi di Laurea Magistrale in Ingegneria Informatica

Analysis of the Evolution of Code Technical Debt in Microservices Architectures

Candidato
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Anno Accademico 2022/2023

Concetti chiave: Microservices Architecture, Code Technical Debt, Software Evolution

Analysis of the Evolution of Code Technical Debt in Microservices Architectures

Methodology: Empirical quantitative study

Topics: TD: *short term expedients impacting maintainability*

MSA: *widespread scalable and flexible architecture*

Motivation: Lack of studies in literature

Background: Preliminary case study[1]

Aims: Insight on TD evolution and management in MSA

[1] R. Verdecchia, K. Maggi, L. Scommegna, and E. Vicario, "Tracing the Footsteps of Technical Debt in Microservices: A Preliminary Case Study," in International Workshop on Quality in Software Architecture (QUALIFIER), 2023.

Research Questions

RQ$_1$: *What is the evolution trend of Code Technical Debt in a microservice-based software-intensive system?*

H$_0^{1.1}$: *Technical Debt evolution does not change in time*

H$_0^{1.2}$: *Technical Debt evolution does not present periodic trend*

RQ$_2$: *Is there a relation between Code Technical Debt evolution and number of microservices?*

H$_0^{2}$: *Technical Debt evolution does not depend on number of microservices*

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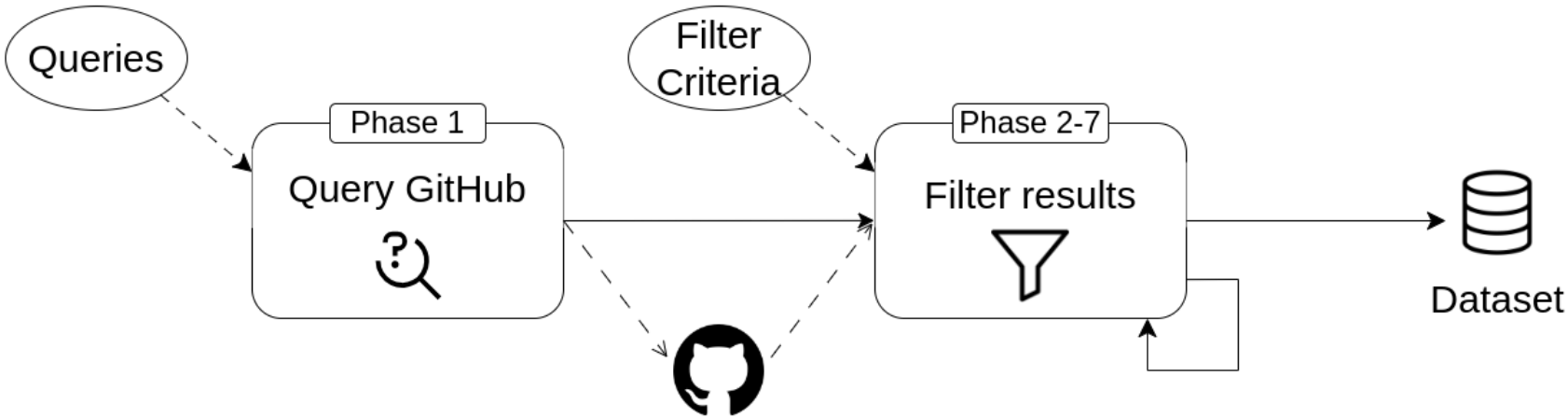
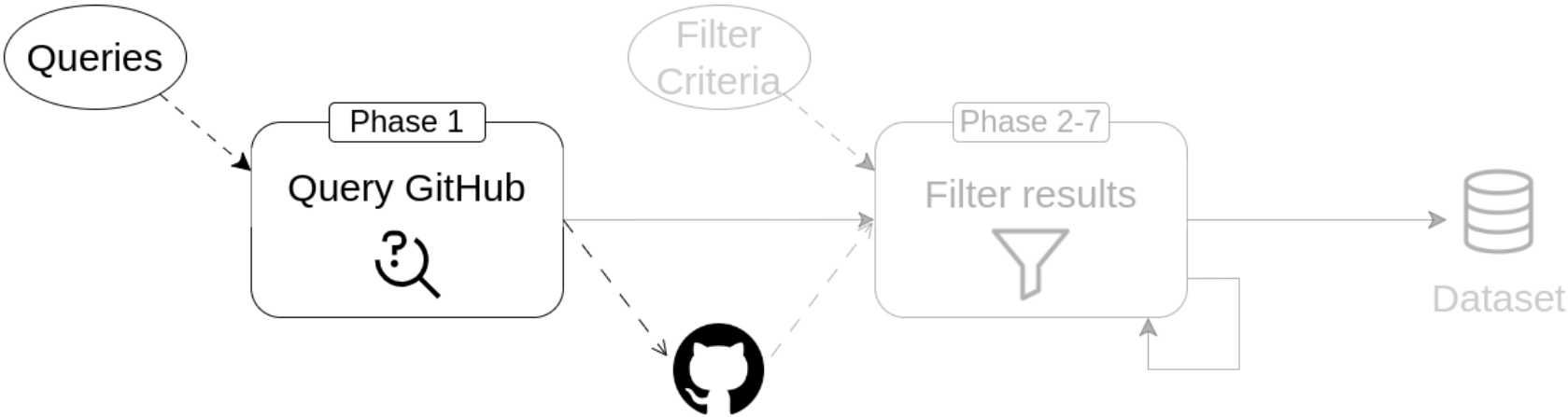
Research Process

Dataset Creation

Workflow



Querying


Queries
Phase 1
Query GitHub
Filter Criteria
Phase 2-7
Filter results
Dataset

Querying

$$language \in \{Java,\ Python,\ C\#,\ Go,\ TypeScript,\ JavaScript\}$$

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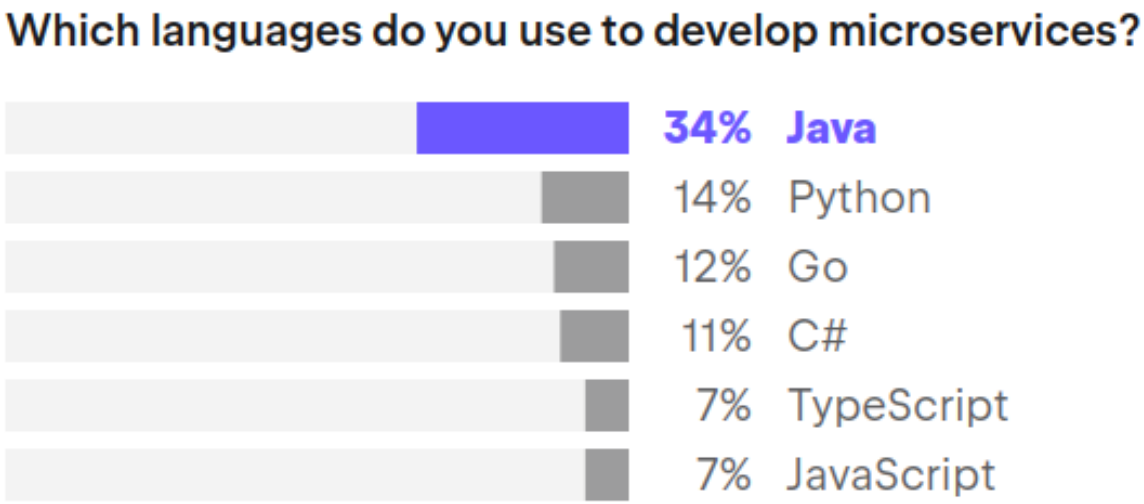
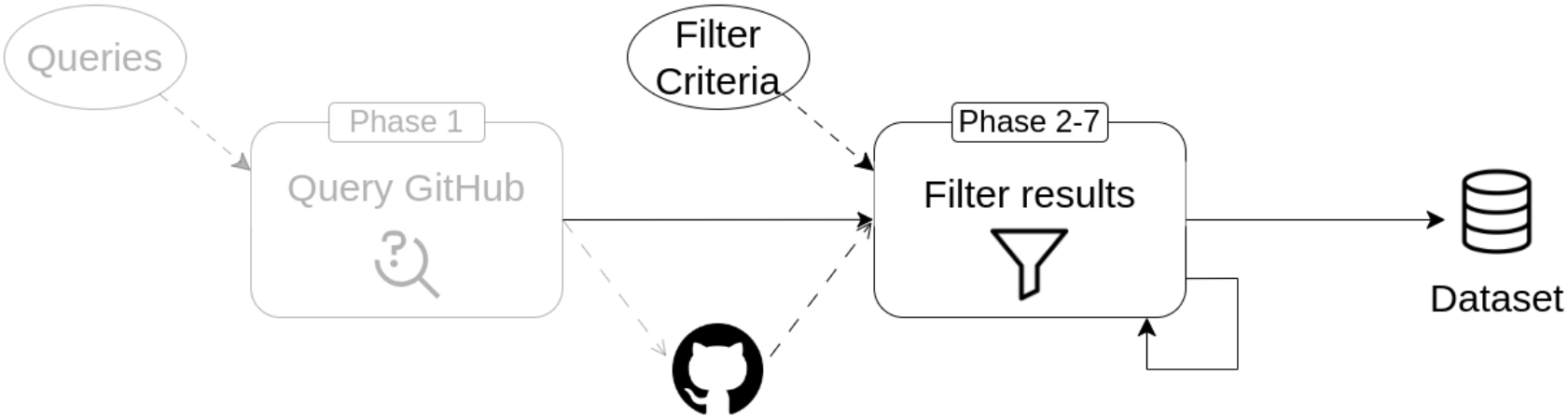


[2] Jetbrains survey (29,269 developers), "The state of developer ecosystem 2022", 2022

Filtering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Filtering

→ **2491** results from query

- long-living
- industrial-like development
- use of *Docker*
- real-world MSA or industrial MSA demo

→ **46** meet requirements

Filtering

→ **2491** results from query

→ **46** meet requirements

- **interesting evolution** in microservices:
  - enough microservices
  - not too flat evolution
  - microservices since begin

→ **15** selected

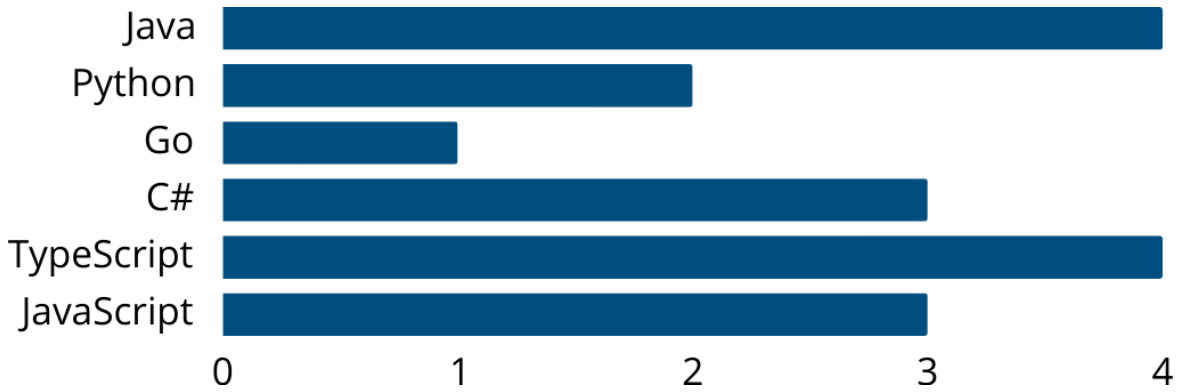
Filtering

→ **2491** results from query

→ **46** meet requirements

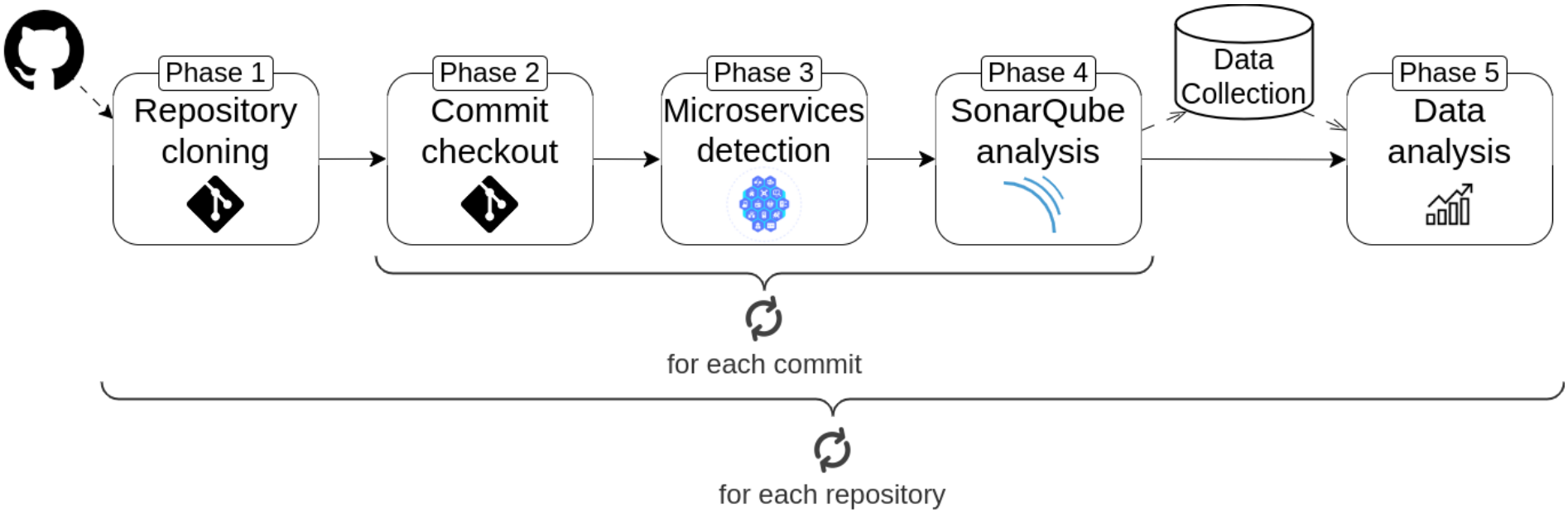
→ **15** selected

AVG # ms: 6,8

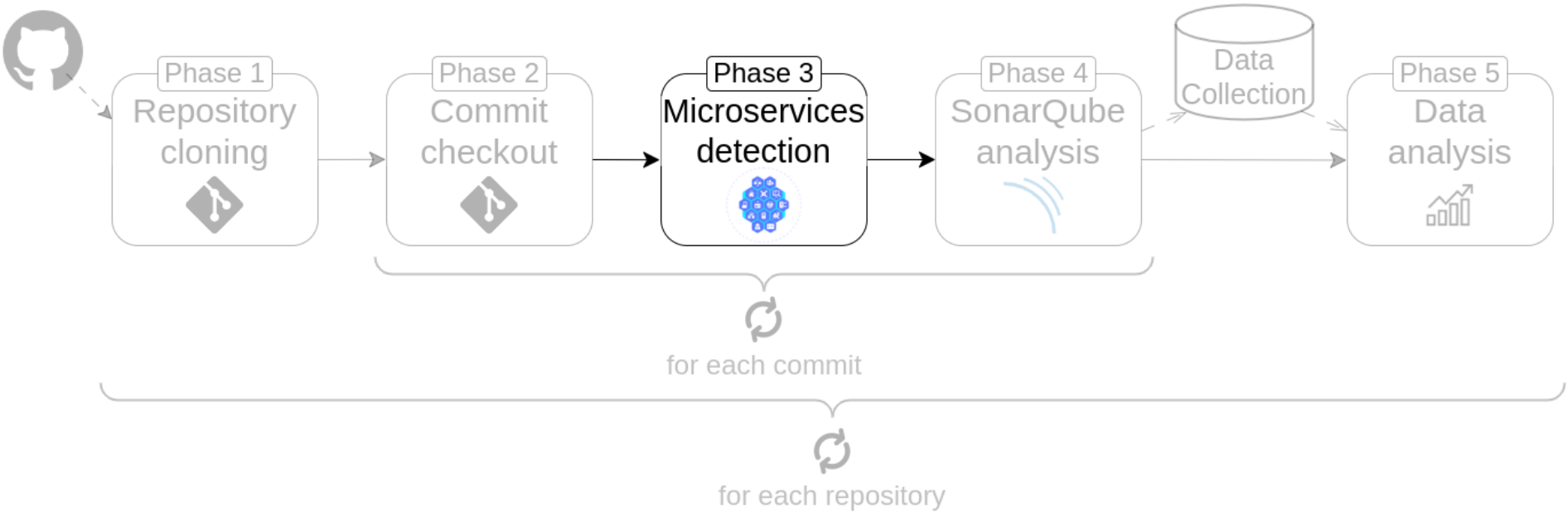


Dataset Analysis

Workflow



Microservices detection



Microservices detection

Problem: enumeration of microservices in a MSA

State of Art: unsuitable or inaccurate methods in literature

Solution: **improving state of art** with a new method

Approach: adoption of a *lightweight static black-box* approach based on parsing of Docker configuration files

Effectiveness: high accuracy from preliminary evaluation

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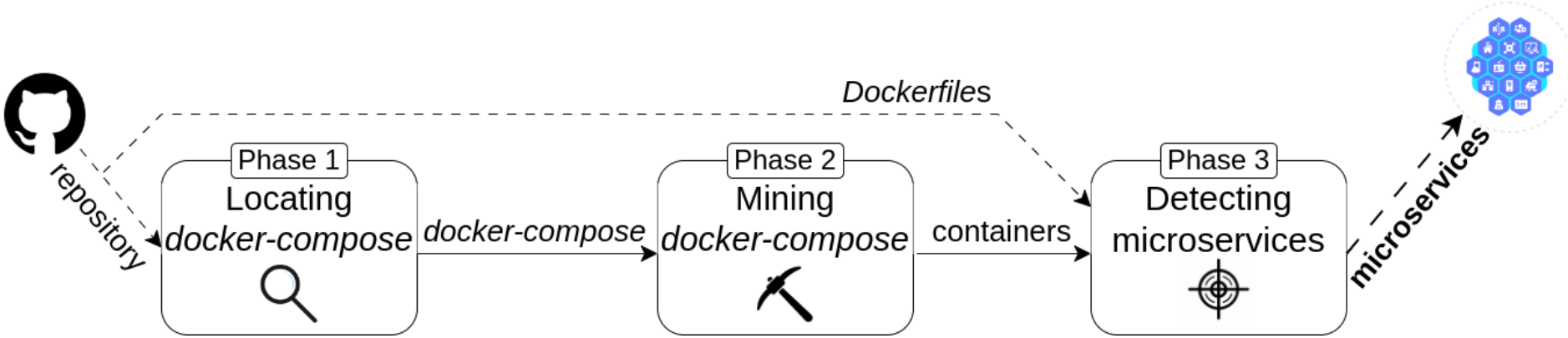
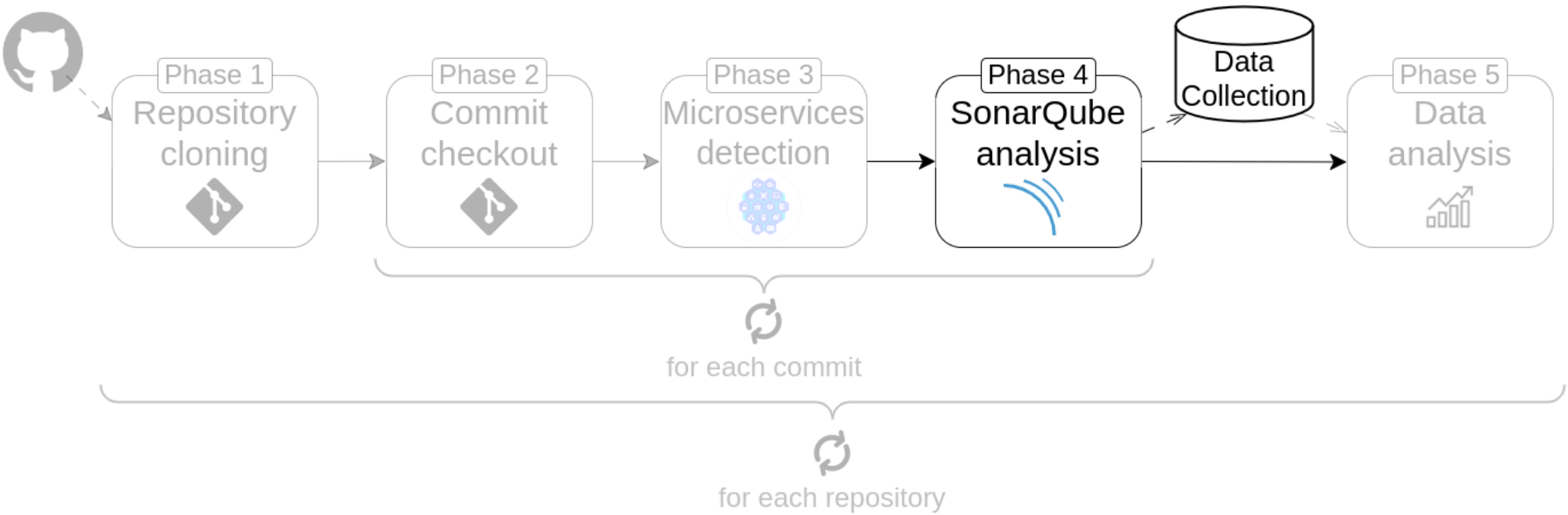


Code Quality Analysis



Code Quality Analysis

1. **Compilation** (only Java and C#)

   → Forced to ignore non-blocking error: $< 1\%$ commits missed

2. **SonarScanner Analysis**

3. **SonarQube server results**

   → Technical Debt expressed with SQALE index[3]

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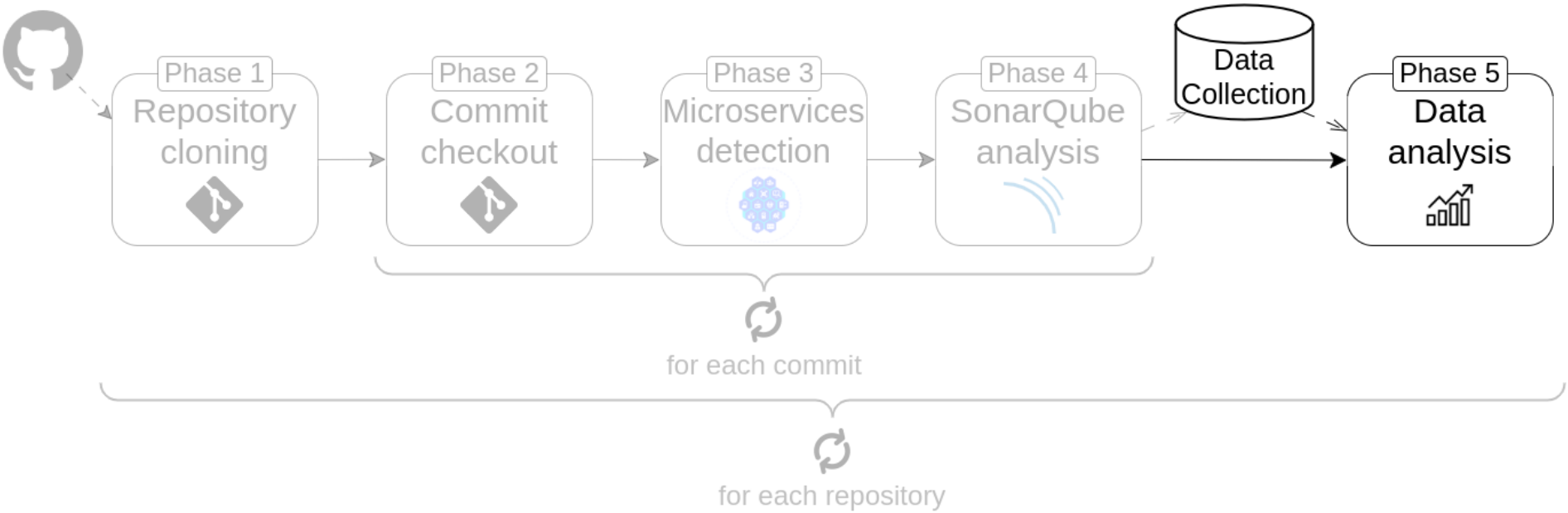

Data Analysis

RQ_1:

- *Mann-Kendall* **test for trend**
  - *LOESS regression* for **graphical means analysis of trend**
- **manual inspection** of top TD hotspots
- *Ollech&Webel* combined **test for seasonality**
  - *STL* **decomposition** of TD evolution

RQ_2:

- *Cross*-**Correlation between TD and microservices**
  - *Granger Causality* **test for causal relationship**
- *Cross*-**Correlation between TD growth rate and microservices**

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RQ_1: trend

General (very) strong trend to grow

# systems	Trend
8	very strong growing
3	strong growing
1	slight growing
1	slight shrinking

$H_0^{1.1}$: *Technical Debt evolution does not change in time*

$\rightarrow$ **REJECTED**

RQ_1: trend

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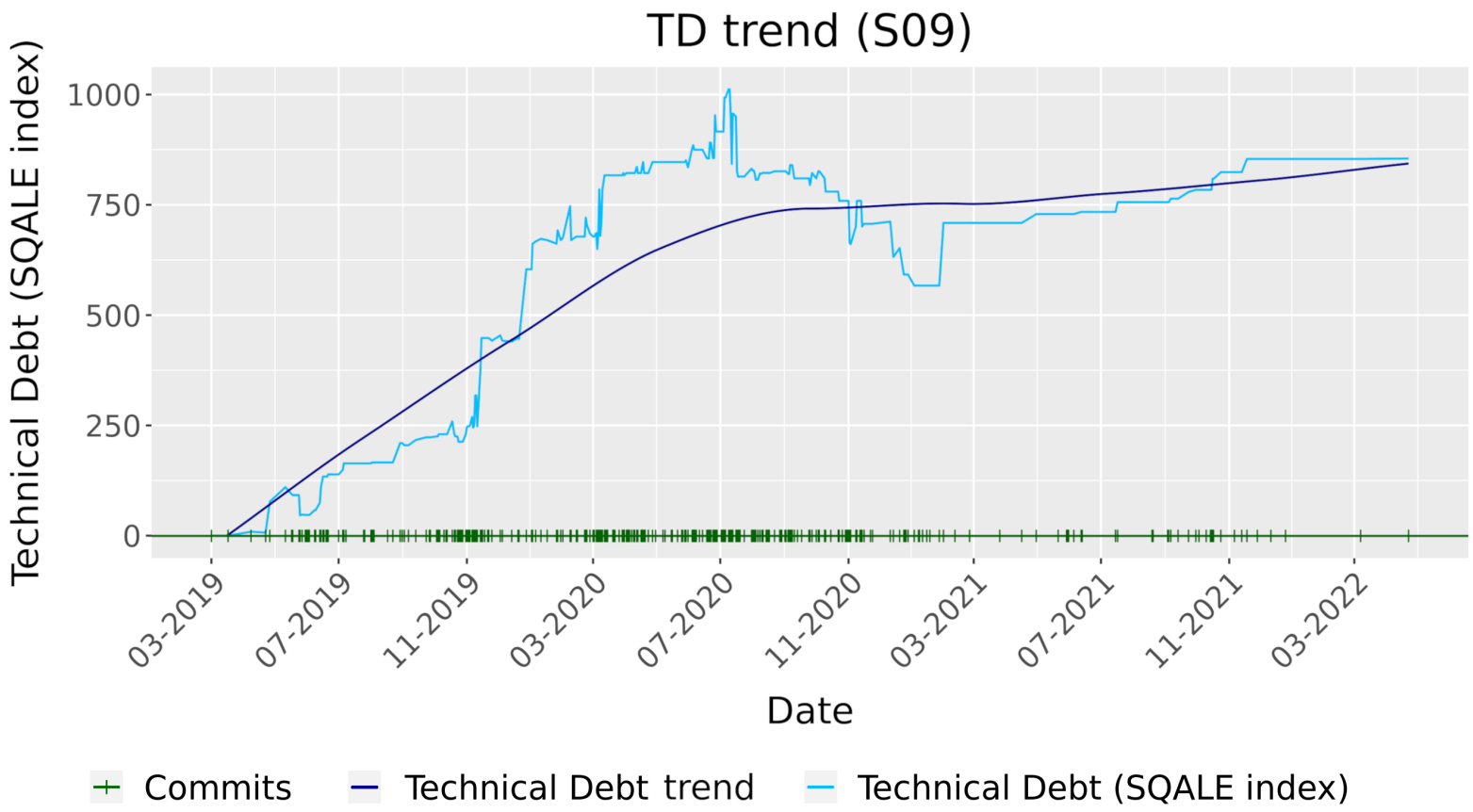
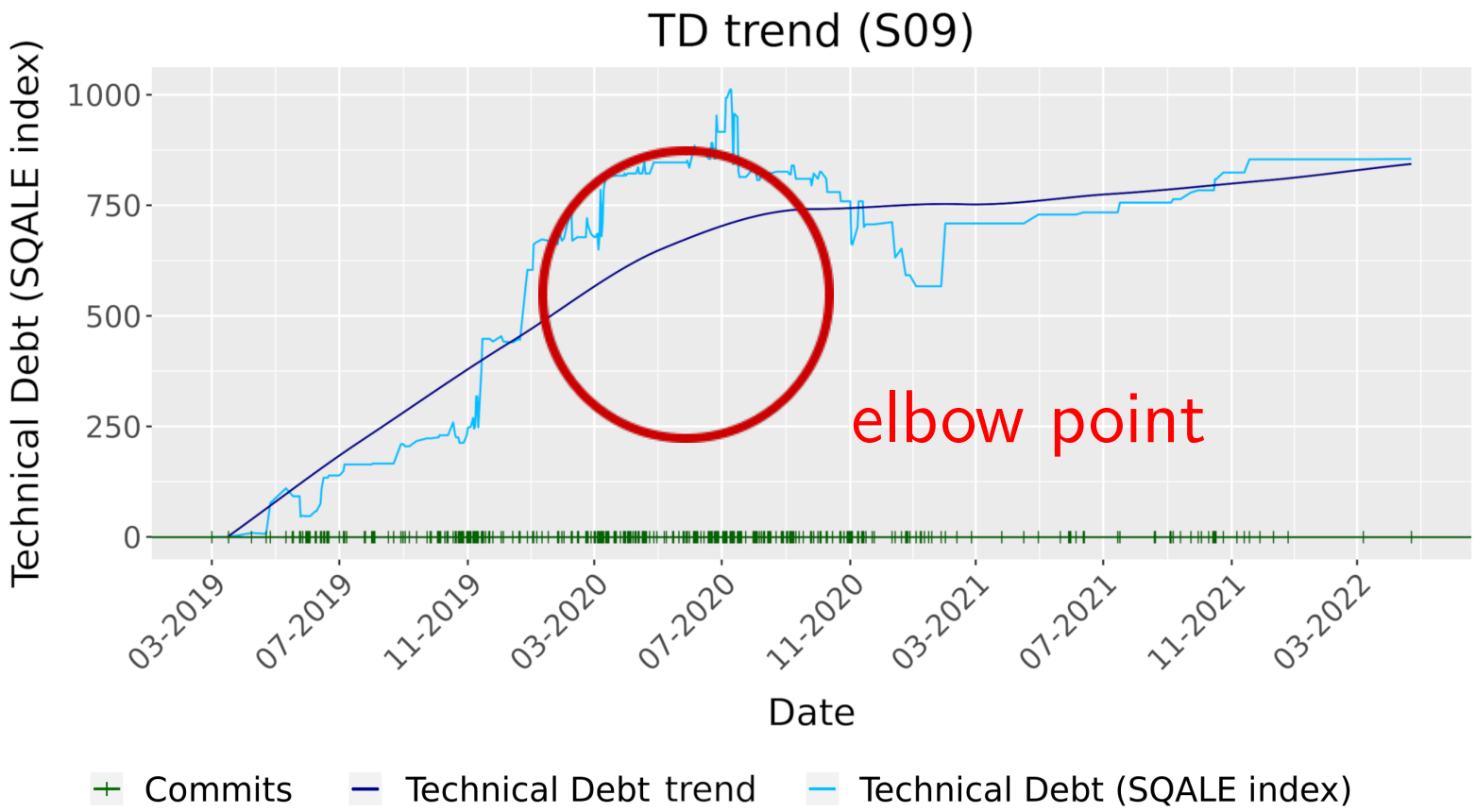
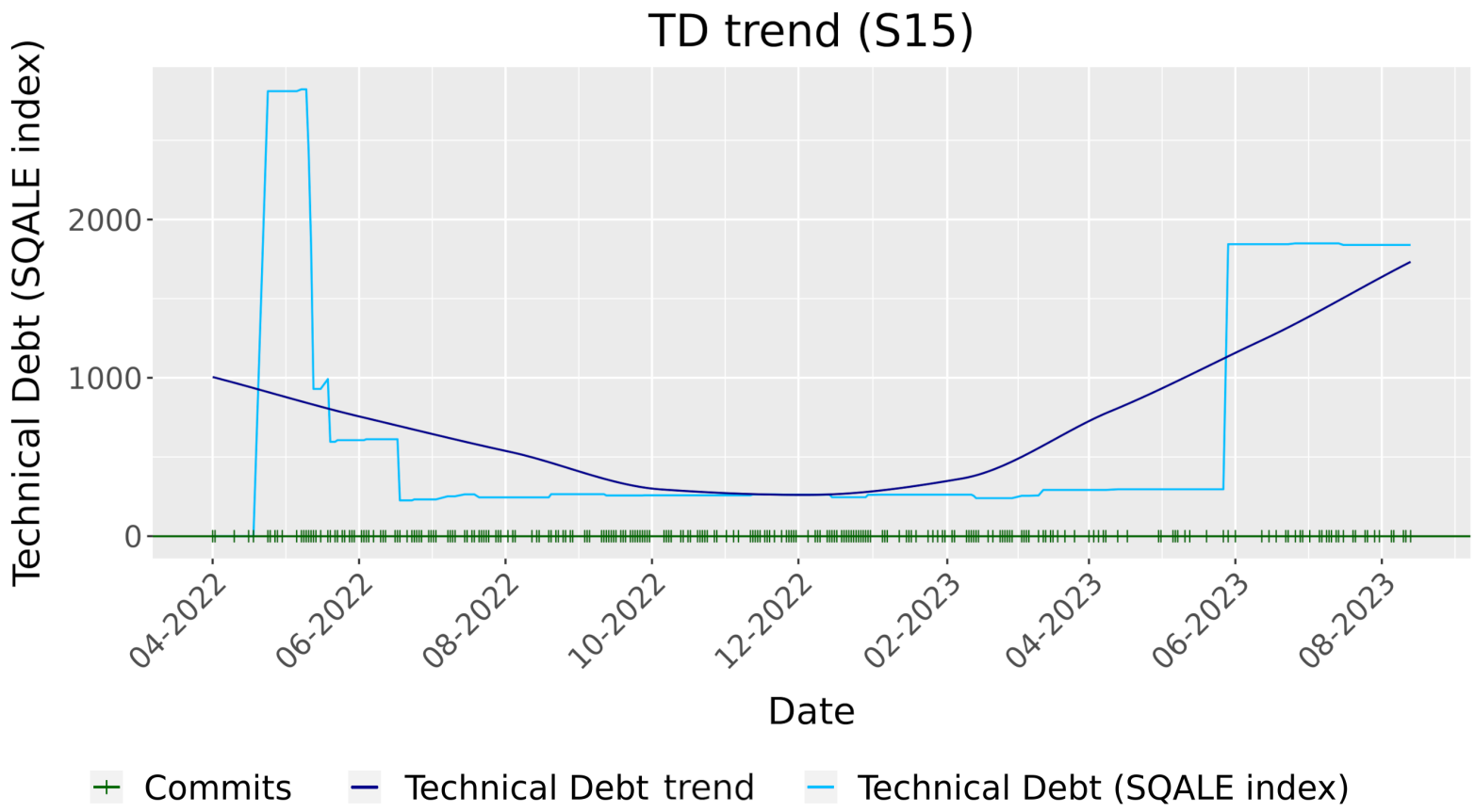

TD trend (S09)
Technical Debt (SQALE index)
1000
750
500
250
0
03-2019
07-2019
11-2019
03-2020
07-2020
11-2020
03-2021
07-2021
11-2021
03-2022
Date
Commits
Technical Debt trend
Technical Debt (SQALE index)

RQ_1: trend



Conjecture: passage from development to maintenance phase
Evidences: reduced commit frequency, notable plateaus

RQ_1: trend


TD trend (S15)
Technical Debt (SQALE index)
2000
1000
0
04-2022
06-2022
08-2022
10-2022
12-2022
02-2023
04-2023
06-2023
08-2023
Date
Commits
Technical Debt trend
Technical Debt (SQALE index)

RQ_1: hotspots investigation

Activities that can introduce TD:

- **add components** (microservices, infrastructural elements, UI, ...)
  `add implementation for policy-service`
  `dashboard service initial release`
- **evolve business logic**
  `make update sequence atomically updated [...]`
  `update product rest api`
- add/upgrade dependencies
  `refactor remote catalog/config events to not require dependency [...]`
  `disable jaeger`
- refactoring
  `refactor comx`
  `code refactoring`

"Size" of commits: apparently no strong correlation with TD variations

RQ_1: seasonality

No seasonality in any systems

> $H_0^{1.2}$: *Technical Debt evolution does not present periodic trend*
>
> → **ACCEPTED**

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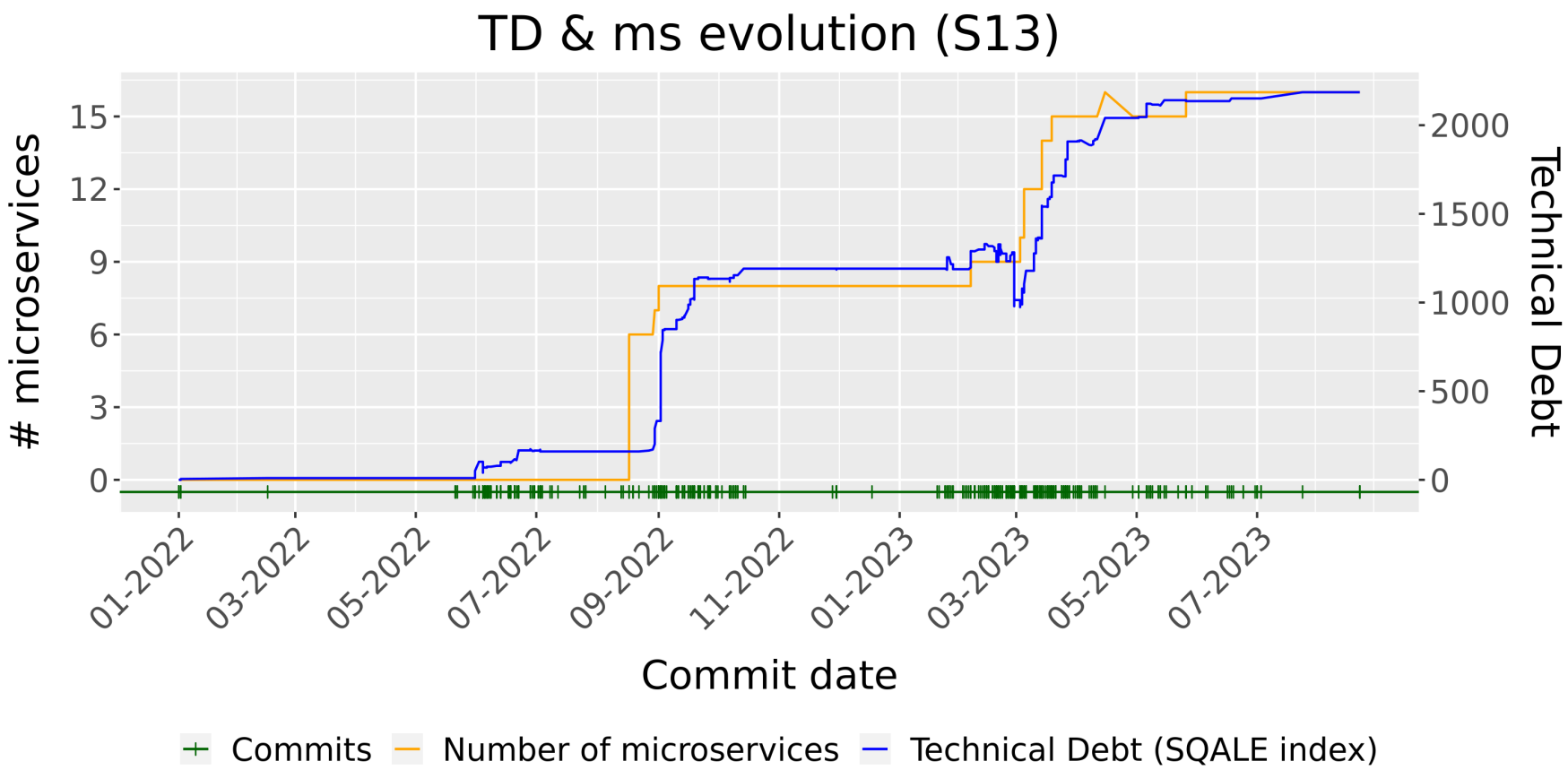
RQ_1 answer

RQ_1 answer (*Technical Debt evolution trend in MSA*)

- Technical Debt **overall increasing trend in time**, above all in the initial development phase
- Technical Debt **variations caused by a variety of activities**, first of all adding components and evolving business logic
- Technical Debt presents **no seasonality**

RQ_2: correlation?



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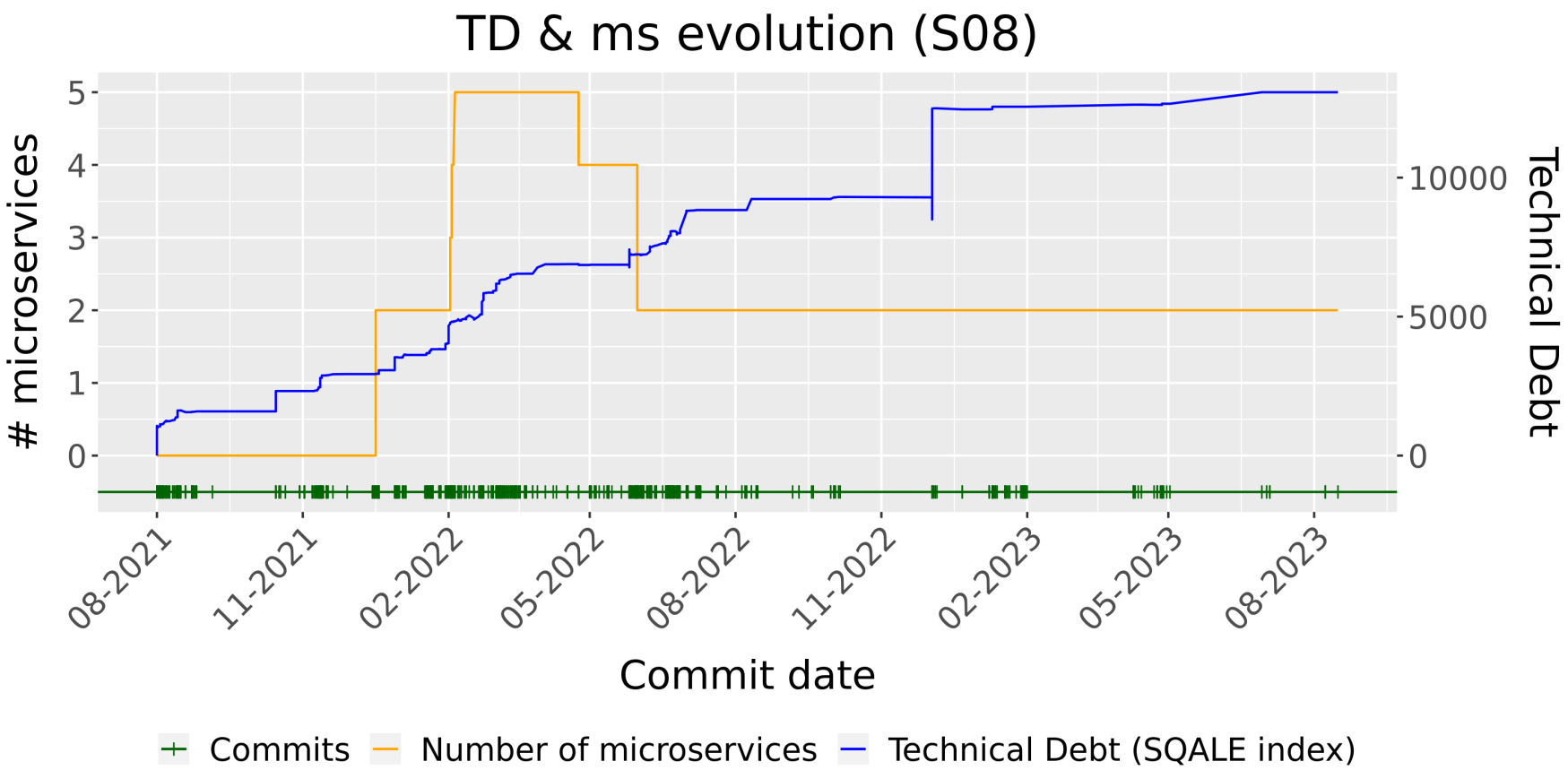

RQ_2: correlation and causality

General correlation (with phase shift) between TD and microservices

# systems	Correlation
5	very strong
4	strong
4	absent or very weak

Not general causality between TD and microservices

# systems	Granger causality
4	Yes
5	No

H_0^2: *Technical Debt evolution does not depend on number of microservices*

$\rightarrow$ **REJECTED**

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$\rightarrow$ **REJECTED**

RQ_2: correlation (growth rate)

Not significant correlation between TD growth rate and microservices

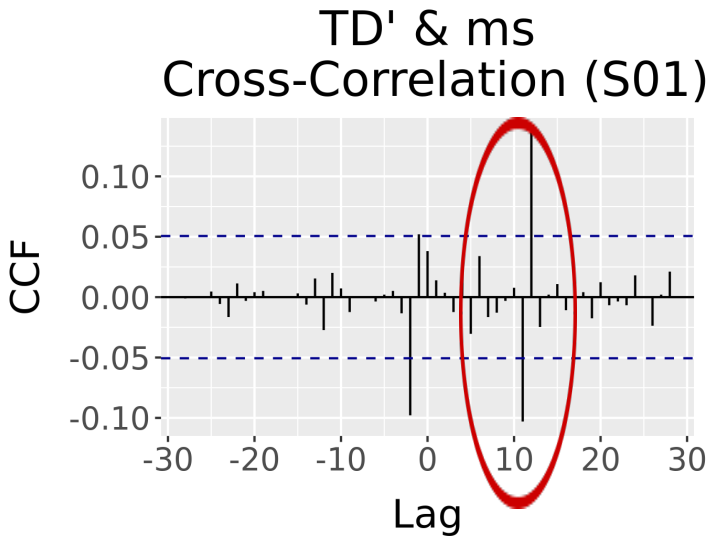
# systems	Cross-Correlation
3	very strong
3	strong
7	absent or very weak

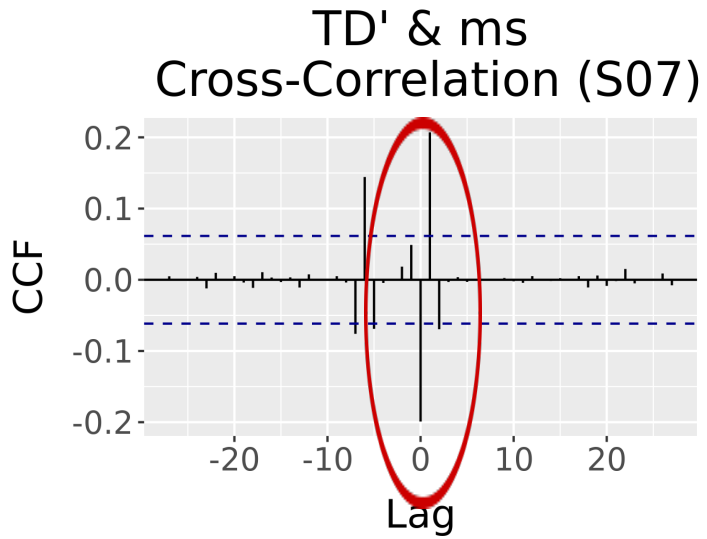
Conjecture: consequence of adherence to MSA principle of independence

RQ_2: correlation (growth rate)

Not significant correlation between TD growth rate and microservices

# systems	Cross-Correlation
3	very strong
3	strong
7	absent or very weak





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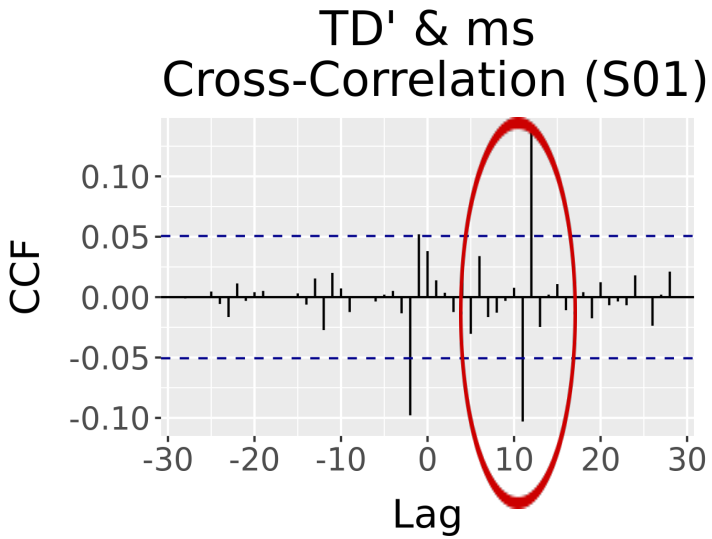

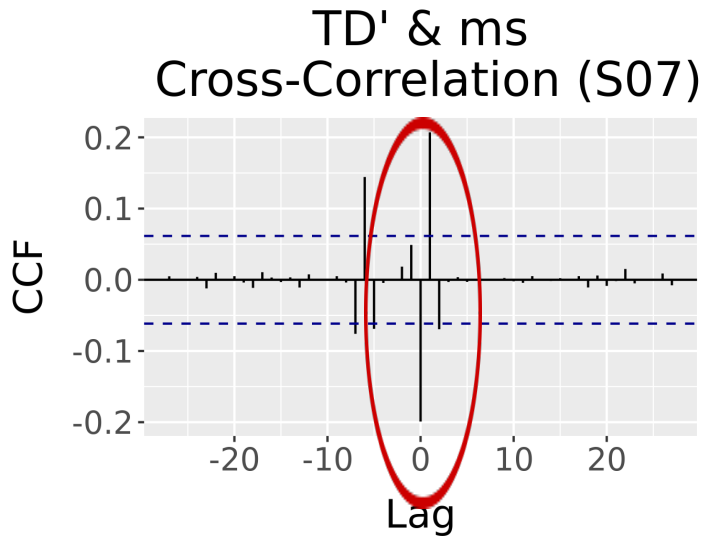

Conjecture: consequence of adherence to MSA principle of independence

RQ_2 answer

RQ_2 answer (*Relation between Technical Debt and microservices*)

- Technical Debt and microservices number are **generally strongly correlated** (with a phase shift)
- In some cases also **a causality relation exists**
- **Addition or removal of a microservice does not impact** the growing rate of Technical Debt

Conclusion

Discussion:

- **maintaining a consistent level of TD is possible by monitoring it**, but its increase might be inevitable as the system grows
- developers should be **aware of the potential TD they incur with a variety of development activities**
- adherence to MSA principles can help to **keep TD compartmentalized within microservices**

Future Work:

- systematic evaluation and comparison of microservice detection method
- individual contribution of each microservice
- in-depth systematic analysis of TD hotspots

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Beyond this thesis

The "Cloud Native GeoServer" case study

Extension[4] with interview to leading developer just submitted:

- **results confirmed** also from its point of view
- **introduced TD monitoring** into its pipeline

"*The quantitative analysis was quite **enlightening to me**. I wanted to include a static code analysis for a long time. And maybe it would have never happen [...] if I didn't have this feedback from you*".

[4] R. Verdecchia, K. Maggi, L. Scommegna, and E. Vicario, "Technical Debt in Microservices: A Mixed-Method Case Study," *Under review*.

Grazie per l'attenzione

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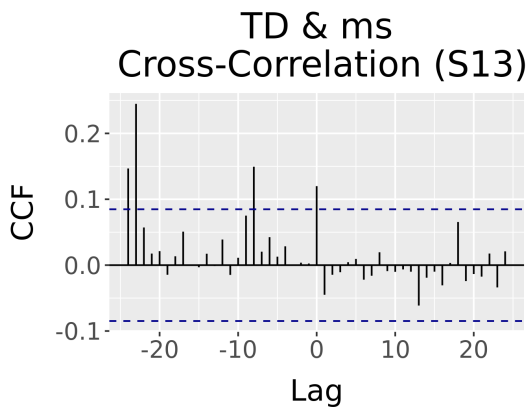
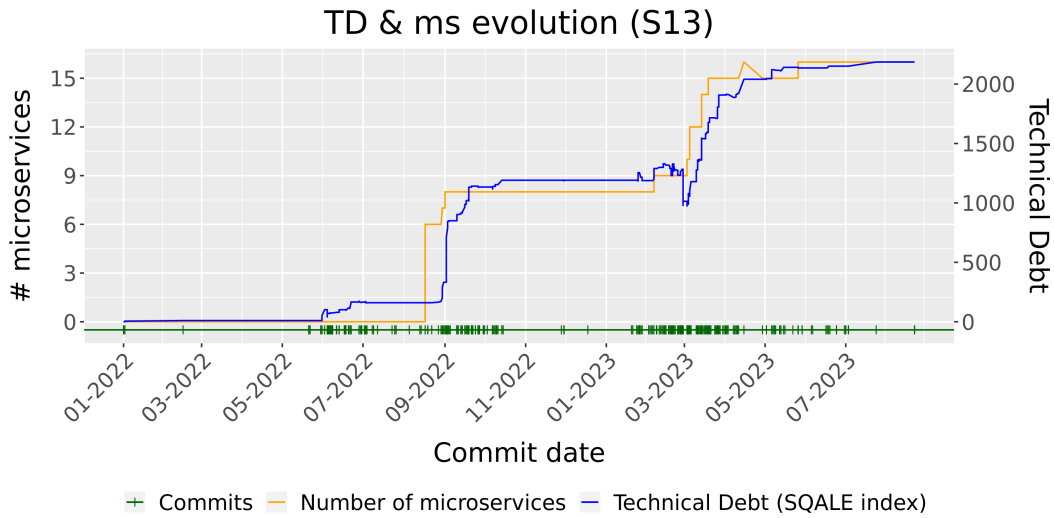
Mann-Kendall trend test

ID	Kendall's τ
$S01$, $S02$, $S03$, $S04$, $S07$, $S08$, $S10$, $S13$	$\tau \geq 0,79$
$S05$, $S09$, $S12$	$0,49 \geq \tau \geq 0,59$
$S14$	$\tau = -0,58$
$S15$	$\tau = 0,23$

Cross-Correlation TD/microservices

ID	Cross-Correlation (at some lag)
$S01$, $S02$, $S09$, $S10$, $S15$	very strong ($>>$ confidence level)
$S07$, $S12$, $S13$, $S14$	strong ($>$ confidence level)
$S03$, $S04$, $S05$, $S08$	absent or very weak ($<$ *or* $\approx$ confidence level)





Granger Causality test

ID	Granger causality
$S01$, $S07$, $S10$, $S15$	Yes
$S02$, $S03$, $S09$, $S12$, $S13$	No

Cross-Correlation TD growth rate/microservices

ID	Cross-Correlation (at some lag)
*S*07, *S*09, *S*10	very strong ($>>$ confidence level)
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