A Research Model for the Economic Assessment of Inner Source Software Development

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Abstract

Inner source is the use of open-source practices within companies. It enables more efficient software development, shortens time-to-market, and lowers costs through increased company-internal collaboration. While existing studies examine social and organizational impact factors on inner source adoption, only a few have looked at measuring and economically assessing inner source. This article presents an overview of current research regarding inner source, its measurement, economic assessment, and impact on businesses and their processes. Based on a systematic literature review we build a research model for economic inner source assessment. This research model shows thematic dependencies between the economic impact of inner source and its measurement. Additionally, it proposes research questions and hypotheses on measuring, economically assessing, and subsequently adopting inner source.

Keywords: Inner source, open source, economic assessment, systematic literature review, research model

1. Introduction

When companies make use of inner source for their software development, they apply open-source practices within their organization (Capraro & Riehle, 2016). This means they open their repositories for internal re-use and incentivize developers of other teams and organizations to contribute to their software (Gruetter et al., 2018). In inner source, companies do not develop publicly available repositories as common in open source, but adopt its peer-review characteristics and early feedback cycles (Edison et al., 2020).

Inner source brings various advantages not only for development but also for organizational and general business aspects of companies. One important reason for adopting inner source is the higher code quality (Stol & Fitzgerald, 2015). It also increases employee satisfaction (Capraro, 2020; Riehle et al., 2016) and makes overall development, especially of software platforms (Riehle et al., 2016), more efficient. As a result, overall development time can be shortened, and costs reduced (Capraro & Riehle, 2016; Edison et al., 2020). Even though inner source is getting more popular recently (Edison et al., 2020), it is not widespread yet. The reason lies in both the development and business-operation side of organizations. On the one side, social and cultural challenges of inner source adoption are widely researched, but metrics are not (Edison et al., 2020). On the other side, inner source contributions are made at a high frequency, making it hard for businesses to adapt their processes accordingly (which our review also showed).

Previous research already made first attempts at measuring inner source collaboration (Capraro et al., 2018) and quantifying it for economic purposes (Buchner & Riehle, 2022). Nevertheless, only some work in the measurement domains exists, as Edison et al. (2020) found in their literature review. They called for more research on inner source metrics and real-life validation. In our research (in contrast to existing work), we look deeper into the topic of inner source metrics, especially related to economic challenges. The focus of this research is on the economic assessment of inner source, which can be defined as the quantification of inner source development work and its artifacts for economic business purposes (e.g. planning and operation). As this is done inadequately in current research, we asked the following research questions:

RQ1: What is the current state of research in economic inner source assessment?

RQ2: What are current challenges of economically assessing inner source and how can they be tackled?

This research briefly presents the economic impact of inner source and its measurement. Understanding this also helps mitigate risks that arise when inner source is

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not properly applied and measured.

One of the most important risks of using inner source is being accused of profit shifting (Buchner & Riehle, 2022). Moreover, various important business processes and basic organizational principles are affected by the cross-boundary collaboration pattern of inner source and need to be adopted, as our research shows. Therefore, our paper provides not only an overview of the current research situation, but can also be important for avoiding greater risks in software engineering and management through increased collaboration across organizational and international boundaries.

The remainder of the article is structured as follows: Section 2 discusses related work followed by Section 3 describing the methodologies. Section 4 shows the result of the literature review. Section 5 then explains the research model builds on top of the review. After that, the results are discussed in Section 6. In the end, possible future research topics are shown in Section 7, followed by a conclusion in Section 8.

2. Related work

On a basic level, inner source is already well defined by numerous researchers (e.g. Carroll et al. (2018), Cooper and Stol (2018), Morgan et al. (2011), and Stol et al. (2014), Stol et al. (2011)). The same is true regarding benefits, challenges, and industry perspectives (Capraro & Riehle, 2016; Froment & de Lohéac, 2021; Morgan et al., 2021; Stol et al., 2011).

During our literature review, we looked into the impacts of inner source on measurement-related processes and metrics within businesses. In related business domains, previous work also defined many commonly used methods relevant to or affected by inner source.

In taxation for example the OECD and UN already defined commonly used methods for calculating the value of the intellectual property (IP) flowing between tax boundaries (the so-called transfer price) and related challenges for digital businesses (OECD, 2015, 2017; United Nations, 2014). For inner source, the first algorithms were designed to calculate such a value based on code contributions (Buchner & Riehle, 2022).

Accounting is one topic affected by inner source which is in general already well defined in industry and research e.g. by The International Federation of Accountants (IFAC, 2009). Especially cost-related processes are already well defined for contexts outside of inner source (e.g. absorption costing (Aurora, 2013)). However, research already proposed accounting models for software platforms (Kornberger et al., 2017), but not for inner source.

Additionally, management-related metrics and software engineering processes are well defined. For example, various KPIs exist to measure software engineering progress (Cheng et al., 2009), but not specifically for inner source. Beyond general software management practices (Jones, 2004; Quinnan, 1980; Verner & Cerpa, 2005) risk management is widely researched (Ebert et al., 2008; Kwak & Stoddard, 2004; Roy, 2004).

While various topics of central importance for companies (taxation, management, accounting) are generally well defined, only a few have directly considered inner source (e.g. transfer pricing). Our work lays the foundation for more work in those domains. Edison et al. (2020) already identified missing inner source metrics as future research topics. However, they only proposed general future research domains (e. g. inner source adoption, governance/management, methodologies, and practical application). In contrast to existing work, our literature review goes beyond showing the current state of inner source research in general but focuses on algorithms for effort estimation and prediction in businesses and how they are related to inner source businesses and their processes.

We saw in our first iteration of this work that measuring inner source is a topic placed between algorithmic implementation principles and economic impacts within businesses. In this paper, we not only briefly show the results of a systematic literature review that was conducted, but more importantly, we go beyond it. We mention additional implications and insights with a research model for economic inner source assessment. Our goal is to build a unified view based on the systematic literature review, connecting algorithmic and business perspectives on inner source measurement.

Consequently, our research:

- Provides a brief overview of the current research state of economic inner source assessment
- Connects the algorithmic/metric and business perspectives in inner source research
- Creates a research model showing the relations between the algorithmic and business perspectives
- Proposes future research based on the research model

3. Research method

For our research, we used the systematic literature review (SLR) approach of Kitchenham (2004) in combination with thematic analysis from Braun and Clarke (2006). Both emphasized an iterative/non-linear character, which we utilized by conducting three overall iterations.

3.1. Systematic literature review

Kitchenham (2004) divides the literature review process into several steps. It starts with several planning steps in advance of the review ((1) Identifying the need for a review, (2) specifying research questions, (3) developing and evaluating research protocol). Afterwards, the main research is conducted ((4)Identification of literature, (5) literature selection, (6) quality assessment, (7) data extraction and synthesis). At last, the results are reported (done here).

The research was conducted following the details of the research protocol typical for an SLR. Besides the already presented research questions and showing that a need to review exist, it contained the following aspects:

Databases: Our searches were conducted using Google Scholar, IEEE Xplorer, ACM Digital Library, Springer Link, Ebscohost, Wiley, and Scopus.

Identification process: We conducted three iterations. During our first iteration, we were able to identify that economic assessment in inner source is based on the two research domains business and algorithmic, which use different search terms and journals. The following iterations looked separately into each domain. This separation also shows in the results of the paper. Another important part of literature identification was forward and backward searches from previously found literature. Overall, the literature identification for inner source measurement and metrics is (especially due to the several research domains involved) more exploratory than common literature review based on a large data being narrowed down.

Quality criteria: Papers were included if they were peer-reviewed and in English. Additionally, contributions of recognized organizations (e.g. the OECD) were accepted. Papers were accepted if they meet the rigor and relevance criteria proposed by Ivarsson and Gorschek (2011).

Keywords: The used keywords were also different for business and algorithmic search domains. We saw early in our research that in the domain of measuring inner source almost no research exists leading to a large variety of keywords combinations. As our research is also not only touching one single domain, the insights of previous iterations helped to add more keywords for the next iterations. The following search terms were used to specify the development methods:

(Inner source OR open-source OR collaborative development OR cross-boundary collaboration OR cross border collaboration OR internal open-source OR software engineering OR software development OR DevOps OR agile OR platform)

These keywords were then combined with a variety of specific keywords for each search domain. For the business domain, the keywords are:

(business processes OR management OR accounting OR controlling OR taxation OR transfer pricing OR organization OR businesses OR enterprises OR organizational principles OR organization forms OR absorption costing OR cost calculation OR project management OR risk management OR product management)

For the algorithmic domain:

(Software development OR programming OR ((cost OR effort) AND (calculation OR prediction OR estimation OR measuring OR quantifying OR computing OR calculating)) OR measurement OR KPI)

Inclusion & exclusion criteria: We included papers which are either measurement-related inner source papers or business process papers affected through cross-boundary collaboration. Moreover, we included cost/effort calculations. We excluded papers that showed algorithms not being reproducible or applicable to the cross-boundary pattern of inner source. This mainly affects machine learning papers.

3.2. Thematic analysis

Thematic analysis by Braun and Clarke (2006) is a method for qualitative data analysis based on previously identified data sources (literature in our case). The goal is to identify common patterns in the data (called codes) and to classify them (called themes).

Braun & Clarke propose several ways on how the data analysis can be conducted. In our case, we chose a deductive approach as we come from a research question and look step by step closer at the business and economic topics. Additionally, we also made use of the iterative/non-linear pattern they described.

Overall, the thematic analysis consists of six steps: (1) getting familiar with the data, (2) generating initial codes, (3) creating candidate themes, (4) reviewing themes, (5) defining and naming themes, and (6) producing the report.

We conducted our research on two mainly independent coding processes, as the literature from the SLR showed the algorithmic and business differentiation, which also manifested in the created codes and themes.

3.3. Research method combination

We performed in our research a combination of SLR by Kitchenham and thematic analysis by Braun &

Clarke as they complement each other.

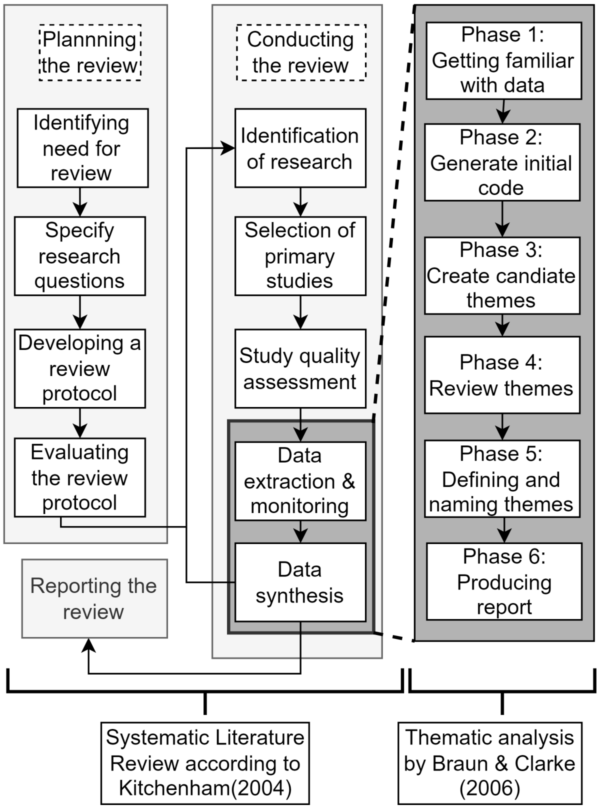

Figure 1. Overview of combined research process

Kitchenham sets a strong focus on identifying and selecting suitable literature but does not go into all detail about data analysis in their data extraction and synthesis steps. Braun & Clarke is solely focusing on data analysis. Therefore, we use thematic analysis embedded as data analysis within the systematic literature review. Figure 1 shows the research steps we performed and how the two used methods fit together. There we can also see the iterative character of the approach.

Combining the two methods also aligns well with the iterative approach we used. The result of each iteration was a network of themes and codes. Those were then used to identify missing aspects and literature. In the following iteration, especially literature in the missing domains was searched and included in the next coding phase. The overall process was performed until no new themes were found.

4. Systematic literature review results

Our review showed that economic assessment of inner source is embedded into the two domains of business and algorithms. In each domain, inner source relevant work gets published but in a largely isolated context. We found that only a small amount of published work applies to the high-frequency, cross-boundary collaboration pattern of inner source. Our combined SLR and thematic analysis process explored both domains independently from each other. However, during the data analysis process, important insights connecting the business and algorithmic domains showed up which will be explained later.

Overall, we looked at 49 papers. Figure 2 shows in which year the selected publications were published. We can see that many more recent papers were analyzed (especially inner source and algorithmic papers), but also some older papers set economic basics.

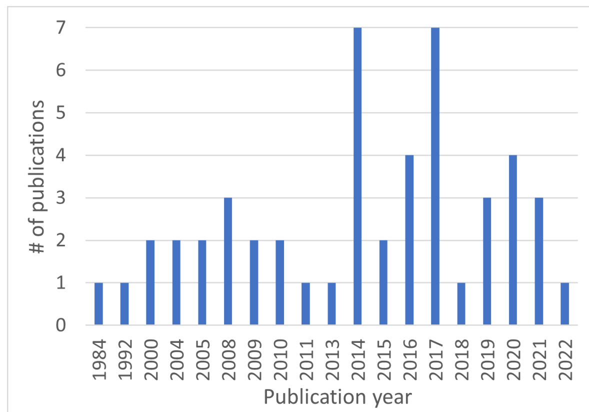

Figure 2. Number of publications per year

The codes and themes that emerged from the literature can be seen in Figure 3. Table 1 shows how many and which literature was used for which theme.

4.1. Business domain

From a business point of view, we found that inner source is embedded within various typical organization forms (matrix, functional, platform organization) affecting used software engineering methods (e.g. DevOps or agile development (Capraro, 2020; Wiedemann et al., 2019)). Additionally, inner source is extensively utilizing cross-boundary collaboration (Buchner & Riehle, 2022). We classified those three aspects (software development, cross-boundary collaboration, and organization forms) as theme *Business foundations*.

Besides the general embedding into the business, we were also able to identify three major domains which get affected when using inner source: Accounting (e.g. Astromskis et al. (2014) and Kornberger et al. (2017)), taxation (e.g. OECD (2017)), and management (e.g Jones (2004)). Those domains are not only a key part of successful business operations but also heavily

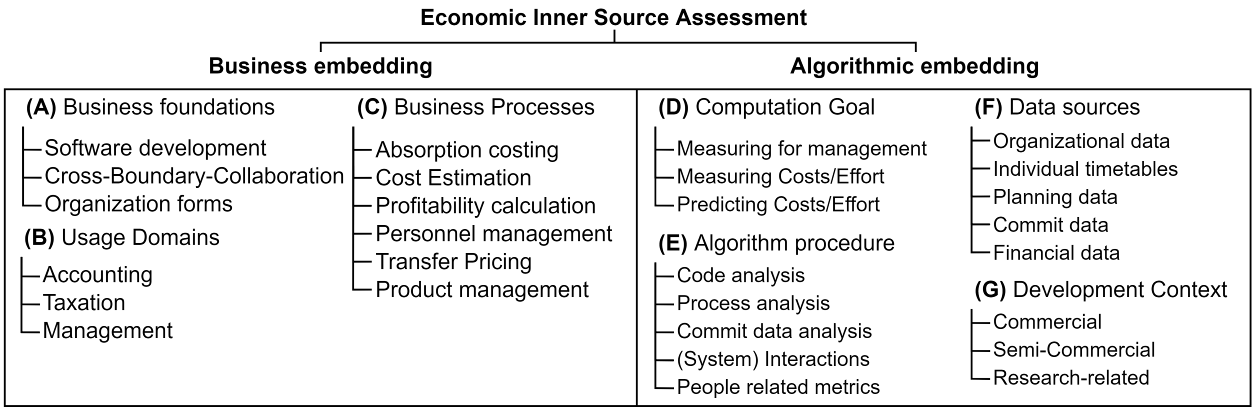

Figure 3. Themes and codes resulting from the thematic analysis in the form of a hierarchical code system

dependent on exact measurements of procedures taking place within the business. Theme *Usage domains* represents those domains in our review.

The reason why the domains of theme *Usage domains* are especially affected by inner source is due to the underlying daily business processes (Theme *Business processes*). We identified various example processes which are especially affected through the cross-boundary collaboration pattern of inner source. The already well-established models (see Section 2) can't be applied sufficiently anymore as cost calculation gets inaccurate with inner source. We identified operational processes (e.g. absorption costing (Aurora, 2013), profit calculations (IFAC, 2009), general cost estimations (Usman et al., 2014), transfer pricing (Buchner & Riehle, 2022)) and also more strategic business processes like personnel management (Riehle et al., 2016) and product management (Ebert, 2014).

4.2. Algorithmic domain

From an algorithmic perspective, our review looked at how applicable the reviewed algorithms were for inner source and related business challenges.

We identified different goals of individual algorithms (Theme *Computation goal*). While some algorithms are designed to measure management-related aspects (e.g. Basili et al. (2010) and Cheng et al. (2009)), some others do calculate costs or effort in general. Moreover, cost/effort-related calculations were often designed for either measuring historic data (e.g Gousios et al. (2008)) or making predictions (e.g. Karna et al. (2020).

Related to the computation goals we identified a variety of procedures to fulfill the different goals (Theme *Algorithm procedure*). While some algorithms analyze the written code itself (Astromskis et al., 2014), others look at the commit history (Buchner & Riehle, 2022; Moulla et al., 2021), related development and business processes (e.g. Dueñas et al. (2021) and Karna et al. (2020)), or system interactions (e.g. Wu et al. (2016)). Additionally, some papers identify or process metrics related to the developers themselves (Moulla et al., 2021; Qi et al., 2017).

The analyzed algorithms are using a variety of data sources (Theme *Data sources*). Most of them are well assessable and retrievable with a business context: commit data, financial data, organizational data, planning data, or individual timetables.

Lastly, we also found that algorithms were either created by commercial vendors (making it harder to reproduce e.g. PRICE Systems (2021)), semi-commercial (from commercial vendor published in a research paper e.g Boehm (1984)), or developed in research without industry background (Theme *Development context*).

4.3. Important findings

During the analysis, we showed that the domains related to inner source measurement (business and algorithmic) cannot be completely separated from each other. Even though literature originates from different research domains and shows different logical findings (codes), they also have some important underlying aspects in common.

One example is that investigated algorithms, specifically their development goals (Theme *Computation goal*) align with the processes affected by inner source (Theme *Business processes*). The business processes can also be classified as the goals most algorithms target. This shows us that both research domains are not only connected but depending on each other. The algorithms usable for cross-boundary collaboration are designed to fulfill specific business needs. On the other hand, businesses can only provide their services if they have algorithms available for their

Theme	# of Sources	Sources
Business foundations	17	Capraro (2020), Capraro and Riehle (2016), Edison et al. (2020), Feller and Fitzgerald (2000), Ford and Randolph (1992), Fuller (2019), Gruetter et al. (2018), Hobday (2000), Leite et al. (2020), Lindvall et al. (2004), OECD (2015), Riehle et al. (2016), Šmite et al. (2017), Stol et al. (2014), Stol et al. (2011), and Stol and Fitzgerald (2015), Wiedemann et al. (2019)
Usage domains	17	Astromskis et al. (2014), Aurora (2013), Buchner and Riehle (2022), Ceran et al. (2014), Ebert et al. (2008), Gruetter et al. (2018), Jones (2004), Kornberger et al. (2017), Kwak and Stoddard (2004), Mazur (2016), OECD (2015, 2017), Olbert and Spengel (2017), Plesner Rossing et al. (2017), IFAC (2009), United Nations (2014), and Verner and Cerpa (2005)
Business processes	18	Antolic (2008), Aurora (2013), Basili et al. (2010), Bilgaiyan et al. (2017), Buchner and Riehle (2022), Capraro (2020), Cheng et al. (2009), Ebert (2014), Karna et al. (2020), Neumann (2019), OECD (2015, 2017), Riehle et al. (2016), Stol et al. (2014), IFAC (2009), United Nations (2014), Usman et al. (2014), and Wu et al. (2016)
Computation goal	12	Antolic (2008), Astromskis et al. (2014), Basili et al. (2010), Bilgaiyan et al. (2017), Boehm (1984), Cheng et al. (2009), Gousios et al. (2008), Karna et al. (2020), Qi et al. (2017), Robles et al. (2014), Usman et al. (2014), and Wu et al. (2016)
Algorithm procedure	15	Antolic (2008), Astromskis et al. (2014), Basili et al. (2010), Bilgaiyan et al. (2017), Buchner and Riehle (2022), Cheng et al. (2009), Dueñas et al. (2021), Gousios et al. (2008), Kang et al. (2010), Karna et al. (2020), Moulla et al. (2021), Qi et al. (2017), Robles et al. (2014), Usman et al. (2014), and Wu et al. (2016)
Data sources	19	Antolic (2008), Astromskis et al. (2014), Basili et al. (2010), Buchner and Riehle (2022), Cheng et al. (2009), Dueñas et al. (2021), Kang et al. (2010), Karna et al. (2020), and Moulla et al. (2021)
Development context	3	Bilgaiyan et al. (2017), Boehm (1984), and PRICE Systems (2021)

Table 1. Overview of sources per theme

assessment. This is especially important for measuring and introducing inner source in companies, as the current state is not sufficient yet.

Moreover, the historic and predictive differentiation of algorithms (in theme *Computation goal*) is also visible on the business side. Cost estimation and management-related calculations are rather predictive while cost calculations are historic.

Another important finding is that even though we selected only algorithms generally applicable to inner source (Theme *Algorithm procedure*), only a few of them can easily be applied to it. Best suitable are algorithms directly capable of measuring cross-boundary collaboration (e.g. using commit data). However, numerous algorithms might give supportive information or need to be adapted to apply to inner source (e.g. analyzing process data is not adapted to cross-boundary collaboration in software engineering).

Overall we can see that less work on combining measurement and its economic impact on businesses and their processes exist for the inner source domain.

5. Inner source research model

5.1. Basics

In this section, we are showing an inner source research model built on the insights of the SLR. We found that algorithms are suitable for assessing inner-source-related operational and strategic processes. Here we channel back the insights to research by building an inner source research model for economic assessment topics. The goal is to build a unified understanding of challenges coming with measuring inner source development.

Based on the insights of the literature review, we created a research model. Palvia et al. (2006) identified several types of research models: Descriptive models, which are minimum models listing variables, and more complex prescriptive models with (hierarchical) relationships. We created a prescriptive model, an influence diagram in particular. We followed the formalization of Petter et al. (2007) for creating theoretical constructs and hypotheses. Those constructs are the basic aspects that define the research model, connected by hypotheses that need to be proven. In our case, constructs are theories in inner source and economic assessment which base on the codes on themes of the thematic analysis. The hypotheses show how the constructs influence each other.

The research model can be seen in Figure 4. Our model was developed in accordance with the themes and codes of our SLR. The structures and mentioned implicit connections there (e.g. Themes *Business processes* & *Computation goal*) also manifest in the research model: The differentiation between the algorithmic perspective (left side of the research model) and the business perspective (right side of the research model). Additionally, the frequently recognized difference between historic and predictive algorithms as well as the strategic and operational business processes can also be seen in the model.

The research model illustrates how the different perspectives (algorithmic/business, historic/predictive, strategic/operational) belong together. It consists of four basic hierarchies (from left to right): The first one is the algorithms on the left, being the basis for a larger inner source economic assessment model (middle hierarchy), which influences the strategic/operational business processes (right hierarchy). The fourth hierarchy (furthest to the right) shows a potential influence of our measuring inner source on inner source adoption. The hypotheses are those that need to be investigated in future research. In the following, we will explain those and their origin in more detail.

5.2. Research model

Algorithmic view: Our literature review shows different algorithm types for different use-cases/goals (Themes *Computation goal* & *Algorithm procedure*). We found out that only a few types of algorithms are suitable for assessing inner source. Mainly those, who make it possible to assess individual cross-boundary code flows (e.g. Code *Commit data analysis*) can be used for economic inner source assessment. However, algorithms not designed to handle cross-boundary collaboration (see especially Code *People related metric*) may only be used partly for inner source assessment. The thematic analysis revealed the connection of algorithmic procedures to a variety of business processes (Theme *Business processes*) manifesting as hypotheses that we will explain now.

While performing the thematic analysis, we were able to identify that examined algorithms looked into retrospectively-oriented and predictive purposes. Theme *Computation Goal* implicitly already introduced that timely differentiation. Hypotheses H1 and H2 build on that differentiation.

*H1: The ability to use development-, system and process data to **measure** software development correlates positively with the ability to economically assess IP transfer between organizational units*

The first important basis we identified were algorithms for measuring (retrospectively) historic software development characteristics, whereas these measurements might also include management-related metrics of historical performance (e.g. KPIs, GQM).

In this research model we propose based on our insights of the SLR that measuring (historic) software development and its processes (specifically adapted to the cross-boundary collaboration pattern) is an important part of the wider-spread economic assessment of IP transfer between organizational boundaries.

*H2: The ability to use development-, system- and process data to **predict** software development correlates positively with the ability to economically assess IP transfer between organizational units*

Complementary to H1, predictive procedures for inner source are also important for economic inner source assessment. The ability to predict software development work in various ways for different (previously explained) purposes solves problems which cannot be realized by only measuring historic data.

Business view: The algorithmic view differentiates between measuring historic and predicting future costs based on the insights of theme *Computation goal*. That differentiation also shows on the business side at theme *Business processes* and its codes. A comprehensive economic measurement model for software development can contain more than measuring costs e.g. various management metrics or inner source-specific metrics. An extensive evaluation of possible metrics still has to be made there.

We saw that measuring inner source is important for operational and strategic decisions (Theme *Usage domains*). Therefore, measuring inner source is not only important for operational business processes but also for long-term business success. The operational and strategic differentiation shown with the codes of the thematic analysis (especially theme *Business processes*) is the basis of Hypothesis H3 and H4 utilizing the algorithmic insights of H1 and H2.

*H3: The ability to economically assess IP transfer between organizational units correlates positively with the usability of economically assessed inner source development for **strategic** business purposes*

From the strategic perspective, we were able to identify that the lack of metrics and the middle management's fear of losing their performance goals (Riehle et al., 2016) is a driving force for assessing inner source. With management being important for adopting inner source, solving strategic inner source challenges can help thriving its adoption. Economically assessing inner source might lower its adoption boundaries by easing financial-related problems (Themes *Usage domains* & *Business processes*). Moreover, providing a better overview of historic development activities and making more precise predictions also enables easier inner source adoption.

Various challenges coming from inner source in

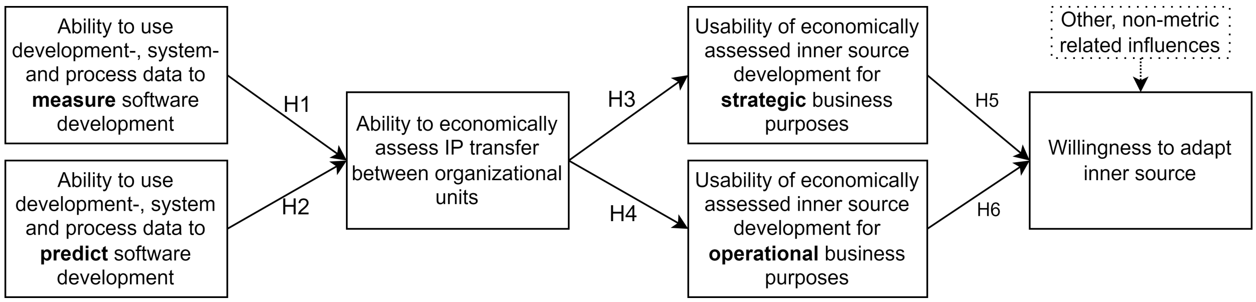

Figure 4. Inner source research model

businesses (see Theme *Business processes*) fit the strategic perspective covered by our model. The challenges originate from the domains of product management (estimating product-related aspects), personnel management (calculating workflow and performance of teams), and strategic management (better insights into achieved goals).

H4: The ability to economically assess IP transfer between organizational units correlates positively with the usability of economically assessed inner source development for ***operational*** *business purposes*

From an operational perspective, economically assessing inner source might help to keep established processes (Themes *Usage domains* and *Business processes*) applicable to the inner source paradigm. We showed with our SLR that inner source influences business processes within the whole organization, especially those related to cost calculation. Moreover, we explained how algorithms help to financially assess inner source development.

Inner source adoption: We saw a rising number of challenges within various domains (particularly accounting and taxation), which impact the inner source adoption rate due to long-term uncertainties such as the fear of unintended profit shifting (Buchner & Riehle, 2022). Consequently, overcoming corresponding organizational and strategic challenges may improve inner source adoption rates. Hypotheses H5 and H6 show that in the research model.

H5: The usability of economical assessed inner source development for ***strategic*** *business purposes correlates positively with the willingness to adapt inner source*

Edison et al. (2020) identified various influencing factors for inner source adoption by reviewing multiple studies. These factors include various domains outside of inner source measurement (e.g. knowledge management, cultural and management-related aspects). The research model might provide additional tools and insights from a strategic business perspective making inner source adoption more efficient.

H6: The usability of economical assessed inner source development for ***operational*** *business purposes correlates positively with the willingness to adapt inner source*

Similar to the strategic business perspective the ability to measure inner source for operational business purposes also might increase the willingness to adapt inner source.

6. Discussion

6.1. Implications

We asked two research questions for this paper. RQ1 (current state on economic inner source assessment) was answered through the SLR (Section 4). RQ2 (challenges in inner source assessment and how to tackle them) can be answered by looking into the details of the proposed research model.

Generally, our research model gives an overview of thematic connections between the business and algorithmic topics affected by inner source and identified through our SLR (Hypotheses H1 to H4). It shows how challenges coming from inner source (identified through the SLR) can be systematically tackled by looking into the proposed hypotheses.

For industry, the research model shows that algorithms used in business, their goals, and their design are closely related to how businesses are organized. They affect software development as well as how strategic and operational business decisions are conducted. This is important for inner source as it is deeply integrated into the company's organizational structure and software development. Therefore, inner source not only affects development but also strategic and operational decisions based on the yet-to-determine measurement and prediction algorithms.

Our research model also shows that measuring inner source is important beyond directly measurable strategic/operational processes. It sets the basis for more general software engineering measurement. Holistic inner source measurement might be an integral part of improving inner source adoption.

For research, the model not only provides an overview of potential future research (Section 7), but answers/discusses some open topics of past research. Edison et al. (2020) already defined inner source metrics as a field of interest for research. The research model builds on top of that providing additional insights including various business and economic details. Our research model provides additional value by deeply looking into the dependencies of algorithms in effort estimation and their connection to inner source business, which was not done in past research.

Measuring inner source is also an important factor for overcoming some of the identified inner source adoption challenges (e.g. middle managers' fear of losing their performance goals Riehle et al. (2016)) providing basic tools for all mentioned process-related challenges that lower inner source adaption rate.

Proving the hypotheses of the research model and developing an inner source measurement tool can provide a basic tool for future research. All kinds of software engineering-related hypotheses can be built on top of an inner source measurement model, even outside the inner source scope.

6.2. Limitations

We mainly looked at inner source measurement from a research point of view, as the goal was to develop a research model. Our research did not include primary data from the industry. Industry input was indirectly included through research papers working with industry. This allowed us to consider the industry perspective in an already evaluated way without losing focus on our literature review and analysis. We propose future work to explicitly consider industry perspectives through case studies or interviews.

Additionally, our research model took only literature related to the economic measurement of inner source into relation. Other influence factors, especially social factors impacting inner source and its measurement have not been considered. We specifically chose our research scope like that to keep focus during literature selection and analysis.

7. Future research

The research model also provides an overview of domains of particular interest for future research. The proposed areas of future research follow the logical outline of the research model and therefore are structured in the same way as Figure 4. By utilizing the proposed research model, future researchers have a plan at hand regarding which areas they might want to examine (algorithms in inner source, their integration into the businesses, and measuring and improving inner source adoption). Future research can then prove the hypothesis e.g. by conducting case studies where inner source is measured (measuring code repositories and other development artifacts), economically assessed (e.g. calculating costs and benefits of inner source), and integrated into improved business processes.

For the algorithmic side of inner source measurement (based on H1/H2 in the research model), we saw a need to develop algorithms better suitable for cross-boundary collaboration in general or inner source software engineering in specific. We also saw that future research needs to build new artifacts on top of those algorithms.

Additionally, future research needs to integrate developed inner source algorithms and tools into existing development processes for daily usage.

For the economic side of inner source measurement (based on H3/H4 in the research model), future research needs to identify strategic and operational requirements for a holistic strategic and operational inner source measurement model.

Moreover, future research needs to develop either new tools or adapt existing ones for various inner source affected domains and processes (accounting, tax, management, based on themes *Usage domains* & *Business processes*) to meet the identified requirements. Important is also to connect future inner source management tools and business process tools to those used for software engineering to provide a unified view of inner source and its effects.

Furthermore, we propose to use inner source measurement tools to investigate the effects of inner source on business performances. Comparing the results to traditional development might also be of interest to not only confirm increased development efficiency through inner source but also to identify domains where inner source still can be improved.

In the domain of inner source adoption (see Hypotheses H5 and H6), we propose future research to look into how inner source measurement affects and can improve inner source adoption. On top of that, we suggest researching methods and guides that practitioners can use to improve inner source within their businesses.

8. Conclusions

In this paper, we discussed a structured literature review on the topic of inner source, especially its measurement and economic assessment. We looked into the business process and algorithmic areas to get a comprehensive overview of related topics.

Of the literature review we conducted a thematic analysis to classify concepts and identify important relationships between those topics (codes and themes). We found that outside of software development inner source affects businesses in various aspects. We recognized that inner source mostly influences cost-related processes, mainly within accounting, management, and tax. However, even though many algorithms for measuring and predicting effort exist, only a few of them are suitable for the application within inner source. Existing algorithms need to be adapted to apply to inner source. Based on those measurements, more tools and algorithms need to be developed.

To bring the open topics in the algorithmic and business side of inner source measurement together we build a research model for economic inner source assessment. It shows the connection and relationship between algorithmic measurement, its impact from a business perspective as well as inner source adoption in the long place.

Moreover, we gave a brief overview of possible new research topics based on our research model. Therefore, our research sets the basics for better measurement of software engineering and understanding its implications for future research and industry.

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