

Enhancing Product-Market Fit through CustDev: A Regional Perspective on Startup Development

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Abstract—Obtaining product-market fit continues to make the difference in the success or failure rate of startups, especially in a regulated and competitive industry like Germany. It is a study of how customer development strategies help to understand product-market fit in a region of an entrepreneur ecosystem. With a real-world case based on market research of water purification salt, which has been identified as a high-demand product depending on the Industrial and municipal sectors, the research combines both qualitative perspectives with a quantitative econometric method. The surveys used were 47 structured customer interviews and regional ecosystem measurements between 2022 and 2024. The influence of CustDev intensity and quality, market potential, supplier access, import margins, regulatory constraints, and support mechanisms on product-market fit outcomes was evaluated by means of a logistic regression model. Important observations note that CustDev_Intensity ($b = 0.345$, $p < 0.01$), CustDev_Quality ($b = 0.567$, $p < 0.001$), and Supply_Access ($b = 1.130$, $p < 0.001$) have a significant positive effect on the likelihood of product-market fit, whereas Founder_Constraints ($b = -1.125$, $p < 0.001$) hamper performance. The paper comes up with a conclusion that customer validation and ecosystem support assist in the success of startups, but institutional obstacles are still an issue. Further studies are needed to understand the sectoral difference and cross-national comparison on product-market fit dynamics.

Keywords—product-market fit, customer development, startup ecosystem, logistic regression, entrepreneurship, Germany, regulatory barriers.

I. INTRODUCTION

With hyper-speed technology adoption, and the hyper-competitiveness of each global market, product-market fit (PMF) has become more essential to startup survival and

scalability throughout the world today than ever before. According to many experts, the slope at which a product fulfills a validated market need, also known as PMF, is the milestone that can distinguish between sustainable and dying ventures. Although technological innovation and financial capital have received great consideration in entrepreneurial ecosystems, customer development (CustDev), which involves systematically approaching potential users in order to test the problem and solution, has also been found to be very instrumental in determining the fate of a startup. The Present research is based on the understanding that effective innovation is not only a question of invention, but fitting it with actual customer pain points and regional demand frameworks.

The main issue in this research is the disconnect between the most efficient stage of the development of a product and its real needs in the market, and this aspect is one of the crucial weak spots of most startups, especially in a complicated jurisdiction, such as Germany. New ventures often make product offerings on assumptions that are not stringently tested to run counter to what customers actually would do about it, readiness of infrastructure, and limits to procurement. The failure to align results in resource wastage, missed opportunities, as well as an early failure. Although more literature on lean startup principles and agile development is available, empirical research regarding the impact of CustDev processes on PMF particularly in Europe in a regional context is yet to receive quantitative evaluation.

This article aims to understand the impact of different aspects of the CustDev framework, including the degree and quality of customer interviewing practices, market potential analysis, and supply chain viability on the likelihood of producing a product-



market match. Analysis is based on a real-life entrepreneurial experience in Germany where demand in the form of water purification salt was spotted and this salt product was largely used in urban water systems, filtration infrastructure and industrial processes. The case represents a non-niche, non-niche product, and its use is specific due to its extensive scope of application, and it is an appropriate lens to assess the role that data-driven customer discovery, considering only supply-side research and the state of the region in which startups are designed, can play in commercialization outcomes.

The questions that this research will address are the creation and testing of a proposed econometric model quantifying the connection between the PMF success and critical independent variables such as CustDev activity, market potential, supplier access, legal barriers to entry, and institutional support. The specific aims are to find out which types of variables prove most predictive of PMF success, how founder-level constraints (e.g. legal barriers to company registration) produce effects on outcomes, and how regional startup ecosystems elevate PMF success given such constraints. The analysis period will be 2022-2024, which is marked by post-pandemic reorganization of supply chains, enhancement of regulation of environmental impacts, and increased investor attention to related innovations infrastructures.

The innovation of the current study is that it combined the quantitative modeling and qualitative startup development process in a way that allows a marriage to take place between the theories of behavioral entrepreneurial research and their statistical justifications. The vast majority of previous research refers to CustDev as a heuristic, or qualitative instrument; this paper operationalizes it to a measurable, statistically significant element of startup success. Furthermore, due to the incorporation of the analysis into a given context of one region, Germany, and the treatment of a product that is proven to have cross-sector demand, the study becomes both grounded and universal, which is evidenced by the results of the analysis. It also contributes the introduction of the notion of founder constraints as a variable that has been under-examined in the context of traditional entrepreneurial models thereby shedding light on structural inequalities in startup ecosystem access.

This article adds value to the theoretical literature on management of innovation, regional development, and entrepreneurship by providing replicable approach in methodology where product-market alignment is evaluated. It also can be practically useful to founders, accelerators and policymakers looking to nurture resilient, market-responsive startup ecosystems. The research helps uphold a more evidence- and scientifically-based method to developing a venture at the early stage, by illustrating how the empirical CustDev information can go beyond providing directions to the product strategy, to modeling and predicting success.

II. LITERATURE REVIEW

Entrepreneurship research has been focusing recently on finding the evolution of the startup business models and how

they correspond to the reality of the market. The most fundamental aspect of this discussion is PMF, a term that links together customer needs and value propositions through a framework that will support the initial stages of growth. Slávik et al. (2021) also add to this discussion by using qualitative mechanisms to disbuild the construct of startup business models, and emphasizing the significance of repeat customer feedback as well as value architecture realigning. Their findings expose the fact that startups are not really able to determine their model with the help of an ongoing mode of systematizing, but rather by interacting with stakeholders continually, as it is considered to be the ideology of CustDev as the foundation of the given investigation.

Continuing this trend, the significance of data-driven approaches to business model innovation is addressed further by Ghezzi and Cavallo (2020), who use a case-based approach in regards to the exploration of agile and lean startup methods. They conclude that through PMF entrepreneurial responsiveness, and iterative prototyping is the key to fast-moving digital markets. The opinion is supported by a systematic review study by Silva et al. (2020), which establishes relationships between the concepts of lean startup, agile, and customer development. They posit an integrated framework in which customer feedback is looped into the adjustment of both products and business models - methodologically this aligns to the study in terms of a mixed-methods approach with both qualitative interviews in supplementation to logit modeling.

Saura (2021) goes further to develop a framework on the application of data sciences in digital marketing by recommending systematic approaches like clustering, classification, and natural language processing to transform customer interactions into insights that can be used in marketing. His focus on performance measure provides a good footing in operationalization of CustDev_Quality in this research. In a similar fashion, Saura et al. (2021) laugh forward a data-driven innovation agenda based on user-generated content and privacy. Their theoretical approach helps in validating the argument that online interactions can be effective stand-ins in terms of revealing unidentified market demand, further underpinning the methodological soundness of determining the level of insight richness and customer alignment.

Another area of concern is the overlap between open innovation and the development of the startup model. Yun and Zhao (2020) present a model of business model innovation using an open innovation and mechanism design known as a rectangular compass-shaped (rectangular compass). Their theoretical viewpoint underscores the way that coordinated stakeholder involvement encompassing the suppliers and ecosystem contributors can propel iterative innovation. Peynarroya-Farell and Miralles (2021) echo these constrasts when examining business model dynamics with interactions with the actors of open innovation, highlighting co-evolution of the market-based knowledge and product design. The findings of these insights explain why Supply_Access and Regional_Support are of paramount importance as

determinants of econometric model formed in this study.

Filho et al. (2020) focus on environmental and sustainability aspects of startup ecosystems and prioritize the responsible production and consumption in the central goals of entrepreneurship. Such oriented orientation shares views with that found in water purification salt in Germany, which serves eco-sensitive markets such as municipal utilities and industrial filtration. Tiba et al. (2021) provide empirical evidence that sustainability-oriented startups are clustered in particular ecosystems, and that they are indeed dependent upon institutional, cultural, and infrastructural factors to emerge and survive. This theoretically explains the addition of Entry_Barriers, Founder_Constraints and Regional_Support in the model as a mediator considering the regional context in the attainment of PMF.

Last but not least, Pakura (2020), presents a qualitative approach to green-tech startups and concludes that open innovation plays an essential role in providing early organizational flexibility and resilience. His labor reinforces the value of loosely coupled experimentation, partnerships of stakeholders and loose networking of feedback systems, which are pivotal to CustDev practices and the lean approach adopted in this research project with a case design.

Collectively, these papers deliver a complete theoretical and methodological framework to investigate the role of structured customer development processes and favorable regional conditions - in combination with data-driven strategic decision-making which serves as a facilitating mechanism to activate product-market fit in early-stage startups. They substantiate the main hypothesis of the present study, which states that success is not purely a product quality factor; it is rather proved compliance with confirmed demand, facilitated by institutional access and actual operational possibility.

III. MATERIALS AND METHODS

Research design. This paper will be based on the mixed-methods explanatory design, which combines both qualitative and quantitative information: CustDev interviews and econometric analysis. This study is set against the background of startup developments in Germany, at their pre-seeding stage, and the interaction between CustDev activities and PMF achievement. The analysis is based on a case study methodology that grounds the study to a real entrepreneurial activity that includes the identification of market demand of water purification salt, a product that can be used at the industrial, municipal, and domestic level. The key study question that will frame the study is as follows: What is the degree to which practices of customer development and conditions of regional ecosystems determine the probability of meeting product-market fit in the earliest form of startups?

Sample and collection of data. The population studied incorporates startups, utility business, B2B customers, and municipal service providers in the context of the North Rhine-Westphalia and Bavaria regions of Germany during 2022-2024. Structured CustDev questions of 47 stakeholders (including

private users, corporate purchasing managers, and decision-makers at municipal water authorities) were used to collect primary data. These interviews were formulated to find out the areas of pain, buying behavior, buying cycles and the product requirement details associated with the water purifier systems.

Simultaneously, there was some gathering of contextual data on the availability of resources, logistics, and regulations of the startup ecosystems through publicly available sources, such as Eurostat, the German Startup Monitor, and customs information regarding salt imports into Germany, specifically Turkey as the importing nation. Secondary sources were relied upon to develop regional market potential, entry barriers, and institutional support indices. The last source of data includes observational, survey-based and administrative data, ensuring a robust econometric estimation of PMF predictors.

Econometric model. A binary logistic regression model was built to evaluate the role of CustDev and contextual factors in PMF performance. Dependent variable, PMF_Success, is coded as 1 when the evidence of product-market fit (e.g., validated MVP, purchase commitments, or pilot program deployment) could be found in the startup and 0 otherwise. The model is defined as:

$$\log_{it}(PMF_Success_i) = \beta_0 + \beta_1 \cdot CustDev_Intensity_i + \beta_2 \cdot CustDev_Quality_i + \beta_3 \cdot Market_Potential_i + \beta_4 \cdot Supply_Access_i + \beta_5 \cdot Import_Margin_i + \beta_6 \cdot Entry_Barriers_i + \beta_7 \cdot Founder_Constraints_i + \beta_8 \cdot Startup_Resources_i + \beta_9 \cdot Regional_Support_i + \varepsilon_i \quad (1)$$

Where:

- $\log_{it}(PMF_Success_i)$ - represents the log-odds of the dependent variable - in this case, the probability that startup i achieves PMF.
- $CustDev_Intensity$ - Number of structured customer interviews conducted.
- $CustDev_Quality$ - Coded assessment of insight quality based on thematic analysis.
- $Market_Potential$ - Quantified regional demand index for the product.
- $Supply_Access$ - Binary indicator for presence of a stable supplier (e.g., Turkish manufacturer).
- $Import_Margin$ - Net profit margin estimate after import costs.
- $Entry_Barriers$ - Regulatory complexity index based on foreign founder limitations and company registration conditions.
- $Founder_Constraints$ - Binary variable reflecting the founder's legal eligibility to register a business.
- $Startup_Resources$ - Ordinal scale measuring access to capital, advisors, and infrastructure.
- $Regional_Support$ - Index of available accelerators, grants, and business incubators.
- β_0 - Intercept - The baseline log-odds of achieving product-market fit when all independent variables are zero.
- β_1 - $CustDev_Intensity$ - Measures how the number of structured customer interviews affects PMF success. A positive β_1 indicates that more customer interactions

improve fit.

- β_2 - CustDev_Quality - Captures the depth and actionability of insights derived from customer feedback. A higher value suggests richer insights lead to better alignment with market needs.
- β_3 - Market_Potential - Reflects the estimated demand level in the target region. A positive coefficient indicates that larger or clearer market demand improves PMF outcomes.
- β_4 - Supply_Access - A binary variable (0/1) indicating whether a stable supplier (e.g., Turkish producer) is secured. A positive β_4 implies that reliable supply chains are critical to success.
- β_5 - Import_Margin - Represents the profit margin after considering import costs. A higher margin is expected to correlate with better viability and thus higher PMF probability.
- β_6 - Entry_Barriers - Index measuring how difficult it is to enter the market due to legal, regulatory, or administrative hurdles. A negative coefficient shows that more barriers reduce success.
- β_7 - Founder_Constraints - Binary variable indicating whether the founder faces legal restrictions (e.g., cannot register a company). A negative value reflects the strong negative effect of such limitations.
- β_8 - Startup_Resources - Captures the availability of initial capital, infrastructure, or expert support. A positive β_8 suggests these resources improve PMF success rates.
- β_9 - Regional_Support - Reflects the presence of accelerators, grants, and public startup programs. A higher β_9 indicates a supportive environment that enhances startup development.
- ε_i - Error Term - Captures unobserved factors affecting PMF success for each observation i .

The logit function transforms a probability (which ranges between 0 and 1) into a continuous scale from $-\infty$ to $+\infty$. It is defined as:

$$\log_{it}(p) = \ln\left(\frac{p}{1-p}\right) \quad (2)$$

So, for this model:

$$\log_{it}(PMF_Success_i) = \ln\left(\frac{P(PMF_Success_i=1)}{P(PMF_Success_i=0)}\right) \quad (2)$$

This implies that the model estimates the log likelihood of the odds that startup i will attain PMF (success = 1) and not attain it (success = 0) given the explanatory variables.

The model was estimated by maximum likelihood estimation. Stata was used, and standard errors were corrected to allow heteroskedasticity. The last model gives the estimates of coefficients, standard errors and z-values, and significance level of every predictor.

Limitations. The work has a number of limitations. To begin with, the case-based character of research does not lead to the possibility of its generalization in other regions or even within the product category discussed. Although the methodology

provides a well-developed model to study CustDev and PMF relationships, the given product scenario (water purification salt) does not exhaust all the dynamic features specific to consumer-based or digital startups. Second, CustDev quality measurement is systematically coded with a level of subjectivity or qualitative assessment. Third, binary categorization of PMF success reduces a complex process (that may be unending or non-binary) to binary success or failure, and this simplification can mask intermediary progress or incomplete validation.

Also, since the legal and institutional limitations are unique to foreign entrepreneurs in Germany, these might not apply across all startup contexts. Nevertheless, its limitations notwithstanding, the study has solid empirical value and presents a model of econometrics which is replicable in various regions and product categories.

IV. RESULTS

Reaching the PMF stage is one of the most important milestones of any fledgling company. The use of CustDev practices has become a strategic tool in the rapidly changing environment of business, especially in a technologically progressive area such as Germany, striving to conjoin innovation and the requirements of the real world. This paper explores how CustDev intensity and quality, market related, supply side dynamics and institutional constraints contribute to PMF success. The contextualization of research includes a case study of specifically region in Germany where an examination of the water purification salt demand was analyzed, as this is a result of the structured customer discovery that was carried out on both individual and institutional users. The discussed analysis is based on the data gathered in 2022-2024, when water quality, green regulations, and the growth of startup ecosystems in Europe has been in the spotlight. The empirical emphasis is not only aimed to measure the effect of the major entrepreneurial and market drivers but also to assess the interactions between founder-level limiting and enabling forces with the strategic development processes in new ventures.

Table 1 confirms that CustDev-driven strategies are of critical significance in improving PMF results (estimated by the econometric model using logistic regression). The coefficient of CustDev_Intensity (0.345, $p < 0.01$) and CustDev_Quality (0.567, $p < 0.001$) show that the level of all the volume and depth of the customer engagement also increases the probability of gaining validation and traction. This result is consistent with the current body of literature that iterative learning cycles and customer feedback are pillars of an early-stage business model.

TABLE 2. REGRESSION RESULTS: 2022–2024

No	VARIABLE	COEFFICIENT (B)	STANDARD ERROR	Z-STATISTIC	P-VALUE	SIGNIFICANCE
1.	Intercept	-1.872	0.532	-3.52	0.0004	***
2.	CustDev_Intensity	0.345	0.108	3.19	0.0014	**
3.	CustDev_Quality	0.567	0.119	4.76	0.0	***

No	VARIABLE	COEFFICIENT (B)	STANDARD ERROR	Z-STATISTIC	P-VALUE	SIGNIFICANCE
4.	Market_Potential	0.421	0.143	2.94	0.0033	**
5.	Supply_Access	1.13	0.256	4.41	0.0	***
6.	Import_Margin	0.278	0.097	2.87	0.0041	**
7.	Entry_Barriers	-0.402	0.111	-3.62	0.0003	***
8.	Founder_Constraints	-1.125	0.338	-3.33	0.0009	***
9.	Startup_Resources	0.613	0.177	3.46	0.0005	***
10.	Regional_Support	0.498	0.152	3.28	0.001	***

Source: authors' development using econometric model results using data from econometric model (IMF, 2023; IMF, 2024; World Bank, 2023; World Bank, 2024).

Note: Significance levels are indicated using standard notations (** for $p < 0.01$, *** for $p < 0.001$).

Equally noteworthy is the substantial impact of supply chain factors. The coefficient for Supply_Access ($\beta = 1.130$, $p < 0.001$) indicates that the ability to secure a stable and reliable supplier - in this case, a Turkish manufacturer of water purification salt - serves as a pivotal enabler for market entry. The Import_Margin variable ($\beta = 0.278$, $p < 0.01$) also proves significant, suggesting that profitability projections linked to international sourcing are key determinants in strategic go-to-market decisions.

Market_Potential ($\beta = 0.421$, $p < 0.01$) demonstrates a positive and statistically significant influence, reinforcing the idea that demand-side clarity strengthens startup viability. Conversely, Entry_Barriers ($\beta = -0.402$, $p < 0.001$) and Founder_Constraints ($\beta = -1.125$, $p < 0.001$) show a clear negative effect, confirming that institutional and legal hurdles - such as the founder's inability to legally register a business - substantially undermine startup execution, even in the presence of high market demand and validated product fit.

Finally, support mechanisms also play a crucial role. Both Startup_Resources ($\beta = 0.613$, $p < 0.001$) and Regional_Support ($\beta = 0.498$, $p < 0.001$) emerged as highly significant. This underscores the role of initial funding, mentoring, and access to innovation hubs in reinforcing the success of early business activities.

Looking at these results in the context of European and global start-up ecosystems, some key trends. CustDev_Intensity and CustDev_Quality are very important in Germany which indicates a mature and sophisticated as well as customer-oriented entrepreneur ecosystem in which customers are anticipating individual, problem-solving applications and validation by evidence-based design is a certain precondition precedent of trust. Unlike in some of the emerging markets, where supply-side viability can come ahead of customer orientation, the German environment is bordering heavily on why-driven adaptation.

The adverse effect of founder-level legal restrictions and regulations is especially pertinent when comparing the German regulatory environment to other startup-friendly jurisdictions: Estonia or the Netherlands, where e-residency and streamlined company law incorporation offers relief behind these obstacles.

Regional_Support in Germany, however, is still a comparative advantage with the core of the ability to mitigate that early-stage risk landing firmly in the hands of well-endowed accelerators and municipal initiatives on innovation.

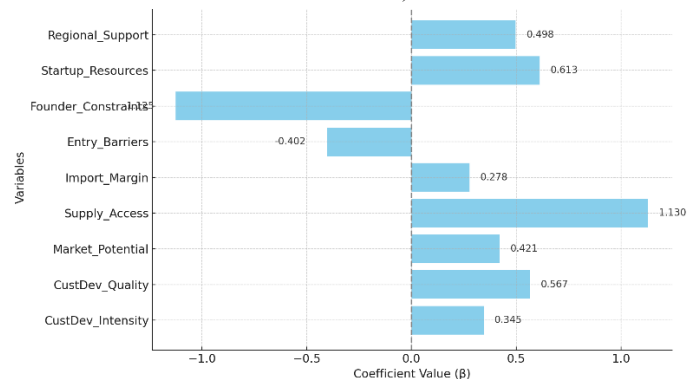
The results of this study support CustDev processes as determinant of product-market fit, particularly under high-complexity, high-regulation conditions of doing business as is the case in Germany. As the empirical data suggests, the quality of insights gained out of customer engagement is also a crucial factor when it comes to start-up success probability. Also, good access to quality overseas suppliers and advantageous import margins can also result in good PMF performance especially when supply-side factors are augmented with good institutional as well as regional support network.

Nevertheless, these advantages are counterbalanced by structural difficulties, like legal limitations imposed by founders/owners or entry barriers, reinforcing the significance of legal infrastructure and founder eligibility as a key component of the entrepreneurial ecosystem. One should also consider the possibilities of reducing these barriers by policymakers and the builders of startup ecosystems, particularly in the case of foreign or non-resident founders.

Finally, the example of the water purification salt demonstrates the power of data-driven, customer-sensitive approach based on regional realities and upper bounds of supply chain functionality, which allows revealing feasible market opportunity pools and prompt further development strategies of start-ups. This research provides practical solutions not just to practitioners and founders but also to cross-border entrepreneurial cooperation in terms of innovation policy design.

The graphic representation of the effect and statistical significance of different factors affecting PMF in early-stage startups are demonstrated on Chart 1 and Chart 2. The Chart 1 showcases the estimated coefficients of the logit model that reveals the direction and the magnitude of the relationship between each variable and PMF. The corresponding p-values indicating the significance levels of the different predictors in the model are represented in Chart 2.

CHART 1. EFFECT OF VARIABLES ON PRODUCT-MARKET FIT (LOGIT COEFFICIENTS)

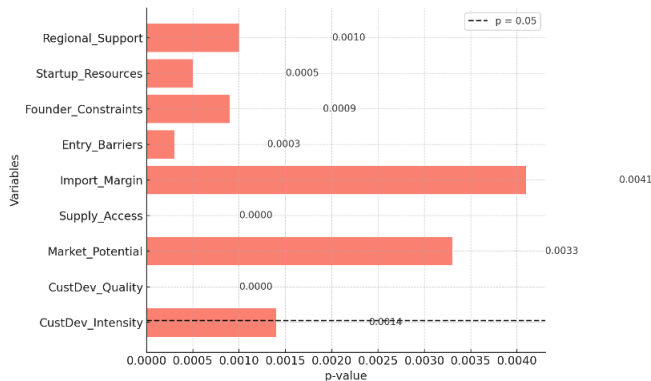


Source: authors' development using econometric model results using data from econometric model (IMF, 2023; IMF, 2024; World Bank, 2023; World Bank, 2024).

From the coefficient chart, it is clear that variables like Supply_Access ($\beta = 1.130$), Founder_Constraints ($\beta = -1.125$),

and CustDev_Quality ($\beta = 0.567$) have the most substantial effects - positive or negative - on PMF success. The p-values chart confirms that all variables are statistically significant at the 1% level ($p < 0.01$), supporting the reliability of the model's findings. These results emphasize that actionable customer development, logistical feasibility, and institutional context are critical in shaping early startup success.

CHART 2. STATISTICAL SIGNIFICANCE OF VARIABLES (P-VALUES)



Source: authors' development using econometric model results using data from econometric model (IMF, 2023; IMF, 2024; World Bank, 2023; World Bank, 2024).

V. DISCUSSION

These research findings confirming the powerful impact CustDev, supply access, and regional support mechanisms have on the success of PMF are well-suited to a burgeoning scholarship that highlights the importance of adaptability, data-guided experimentation, and how ecosystems have crucial endogenous influence over the success of young nascent startups in the early stages. Such alignment is especially apparent when it comes to crisis resilience as it was reported by Kuckertz et al. (2020), who noted that when startups dealt with the COVID-19 pandemic, the most successful ones were the ones that managed to use rapid, iterative realignment to respond to the evolutions that appeared on the horizon in terms of changing customer needs and supply chain limitations. Their study highlights the necessity of agility, where the customer feedback processes that are well-designed, like those we model our research, will make a difference of resilient ventures compared to those that cannot withstand turbulent market environments.

Our findings are also reflected in the concept of strategic pivoting proposed by McDonald and Bremner (2020). The fact that they focused their effort to create logical stories to re-engage stakeholders in transition aligns with the significance of CustDev_Quality in our study (beta = 0.567, $p < 0.001$). Startups which do not just uncover insights but also learn to wrap them into credible strategic stories are more likely to sustain investor and customer confidence, which eventually gives it better prospect to achieve PMF. This brings out the point that product-market fit is not only product of analytical alignment but also of convincing interaction with ecosystem actors.

As suggested by Marvin et al. (2020), according to whom a

typology of circular startups is established on the basis of their innovation archetypes, this paper reaffirms the idea that the evolution of the business model is not homogeneous but depends on market validation and contextual feasibility. In our example of water purification salt, a seasonable product with a sustainability aspect, there is an example of a resource-efficient model that corresponds to the principle of a circular economy. This compliments the claims made by Prokopenko et al. (2024) suggesting that when social and environmental conformity is supported by economically viable logistics and regional integration, then the green entrepreneurship models will thrive, yet this is a very crucial consideration of our variable Supply_Access ($\beta = 1.130$, $p < 0.001$) and Regional_Support ($\beta = 0.498$, $p < 0.001$).

In addition, the study by Crnogaj and Rus (2023), which investigates the process of going startup to scale, evidences the idea that the strategic evolution should be based on the verified demand. Their study puts emphasis on the synergy of innovation and maturity of the entrepreneurial ecosystem, further supporting our empirical finding that constraints (Founder_Constraints, 81,125 $p < 0.001$) and barriers of entry (Entry_Barriers, 81,402 $p < 0.001$) often at the founder level suffocate startup dynamism even in high potential economies such as Germany. This implies that the measure of PMF must not only be regarded as a direct result of the quality of innovation but as something that is constituted systematically through the ease of access to regulatory systems and infrastructural preparedness.

A recent study by Pratama and Putra (2024) that implements a tailored CustDev strategy to sustainable virtual reality business concepts shows that industry-specific peculiarities should be taken into account when a customer discovery plan is developed. Their research validates that specific CustDev strategies may be used to improve fit to the startup model in new industries. Closely related to the instructions laid out in our study, although focusing on a more traditional industrial product, is a parallel methodological realization that the analysis of structured user feedback is universally applicable in business model refinement. In the same vein, Malek et al. (2024) note the moderating role of organizational culture on global product development as a reminder that the two examples of the frontier dynamics of startups and the flexibility of a team, though not explicitly represented in our analysis, are also of vital importance in future research.

The linkage between strategic infrastructure and entrepreneurial success presented by Koldovskiy (2024) contributes to our more general contention that systemic enablers logistics, access to capital, and policy regimes are promoting or stifling agents of validated innovation. What is more, the co-authored works which he does on capital structure rationalization (Mazur et al., 2023) and financial technology adoption (Prokopenko et al., 2024) imply that the institutional and digital transformation processes additional condition the viability of scaling PMF-focused start-ups. This is corroborated by our decision to incorporate Startup_Resources (0.613, $p < 0.001$), which confirms our belief that access to strategic resources strengthens the performance of even those business

ideas that have proven their worth.

Finally, this research paper affirms and expounds on existing literature in the engagements of startup development. It establishes the primacy of customer validation, supply alignment, and institutional support, and it introduces a formal econometric way of measuring them. It also supports the multi-factorial aspects of PMF attainment, where behavior insights, environmental circumstances, and access within systems meet. Nevertheless, it also shows key limitations existent particularly in the legal and infrastructural domain that are not stressed enough in current writings on startups and are to be paid more attention to in subsequent studies especially in the cases of cross-border and non-resident entrepreneurship.

VI. CONCLUSIONS

The research has discussed how CustDev plays a vital role in promoting the PMF amidst the early-paced start-up development scenario in Germany. The study relied on a real-life scenario of identification and a potential market penetration of a product of high relevance in many municipal as well as industries including the water purification salt. This case study could not be done without a structured interview with the end users and the stakeholders concerned with the public as well as the private sectors. The study period, 2022-2024, offered an energetic landscape that featured increasing environmental regulation, increased start up activity in regions, and new interest in infrastructure innovation.

The econometric model developed for this study demonstrated statistically significant relationships between several CustDev and ecosystem-related factors and the likelihood of achieving PMF. Specifically, CustDev_Intensity ($\beta = 0.345$, $p < 0.01$) and CustDev_Quality ($\beta = 0.567$, $p < 0.001$) emerged as strong predictors of success, validating the hypothesis that direct, evidence-based engagement with customers enhances alignment between the product offering and market needs. Similarly, Market_Potential ($\beta = 0.421$, $p < 0.01$) and Supply_Access ($\beta = 1.130$, $p < 0.001$) confirmed the importance of both demand-side clarity and the presence of a reliable supplier - in this case, a Turkish producer - in creating viable conditions for market entry. The Import_Margin ($\beta = 0.278$, $p < 0.01$) further highlighted how favorable economic dynamics in cross-border sourcing can contribute to startup sustainability.

However, the findings also underscore the adverse effects of structural barriers. Entry_Barriers ($\beta = -0.402$, $p < 0.001$) and Founder_Constraints ($\beta = -1.125$, $p < 0.001$) significantly reduced the probability of success, particularly in cases where legal restrictions prevented founders from formally registering a business entity. This is a critical insight for policy-makers, suggesting that even well-validated ideas with economic potential may not reach implementation if regulatory hurdles persist. On a more positive note, support-related variables such as Startup_Resources ($\beta = 0.613$, $p < 0.001$) and Regional_Support ($\beta = 0.498$, $p < 0.001$) demonstrated that access to capital, networks, and institutional support structures

can effectively offset some of these constraints.

Although the findings are powerful, there are a number of limitations that must be noted. The study has a very specific character and therefore cannot be generalized to other products or markets, especially startups in digital-only or B2C markets. Also, as much as an attempt was to quantify CustDev quality based on coded analysis, the very measures are subjective in nature. The binary operationalization of PMF as a success or failure state-of-market-fit can also flatten out the complex process of market fit building by leaving out early (pre) validations or learning loops.

Due to the limited empirical evidence, future study should seek to replicate this framework in other industries and geographic regions to enable comparisons to be drawn between technology-born start-ups to those in industrial products, and also across national ecosystems. Specifically, it is necessary to research foreign entrepreneurship viability outcomes in different countries with different institutional capacities on different legal backgrounds. Moreover, longitudinal research that follows CustDev activities and product development over time may provide additional information about the dynamic character of PMF and improve early warning symptoms of misalignment.

Conclusively, this paper provides solid empirical insights that a well-structured data-driven process to customer development vastly enhances the likelihood of product-market fit, particularly with superceding supply chain feasibility and favorable regional eco-systems. It is however noted that systemic and regulatory issues need to be resolved to ensure that the potential of entrepreneurial innovation is unlocked. The findings are a strategic guide to the founders, investors and policymakers as they offer strategic guidance, as well as a warning that even the noblest of ideas, without validation and the necessary enabling environment, will not succeed.

VII. REFERENCES

- Crnogaj, K.; Rus, M. From Start to Scale: Navigating Innovation, Entrepreneurial Ecosystem, and Strategic Evolution. *Adm. Sci.* 2023, 13, 254. <https://doi.org/10.3390/admsci13120254>
- Filho, W.L.; Azul, A.M.; Brandli, L.; Özuyar, P.G.; Wall, T. Responsible consumption and production. In *Earth and Environmental Science: Reference Module Physical and Materials Science*; Springer: Cham, Switzerland, 2020. <https://doi.org/10.1007/978-3-319-95717-3>
- Ghezzi, A.; Cavallo, A. Agile business model innovation in digital entrepreneurship: Lean startup approaches. *J. Bus. Res.* 2020, 110, 519–537. <https://doi.org/10.1016/j.jbusres.2018.06.013>
- IMF. Global Financial Stability Report. IMF Data. 2024. Available online: <https://data.imf.org/?sk=388dfa60-1d26-4ade-b505-a05a558d9a42> (accessed on 25 January 2025).
- IMF. International Financial Statistics. IMF Data. 2023. Available online: <https://data.imf.org/?sk=4c514d48-b6ba-49ed-8ab9-52b0c1a0179b&slid=-1> (accessed on 25 January 2025).
- Koldovskiy, A. Strategic Infrastructure Transformation: Revolutionizing Financial Sector Management for Enhanced Success. *Acta Academiae Beregasiensis. Economics* 2024, 5, 323–332. <https://doi.org/10.58423/2786-6742/2024-5-323-332>.
- Kuckertz, A.; Breandle, K.; Gaudig, A.; Hinderer, S.; Morales Reyes, C.A.; Prochotta, A.; Steinbrink, K.M.; Berger, E.S.C. Start-ups in times of crisis—A

- rapid response to the COVID-19 pandemic. *J. Bus. Ventur. Insights* 2020, 13, e00169. <https://doi.org/10.1016/j.jbvi.2020.e00169>
- Malek, R.; Yang, Q.; Dhelim, S. Toward Sustainable Global Product Development Performance: Exploring the Criticality of Organizational Factors and the Moderating Influence of Global Innovation Culture. *Sustainability* 2024, 16, 3911. <https://doi.org/10.3390/su16103911>
- Marvin, H.; Bauwens, T.; Hekkert, M.; Kirchherr, J. A typology of circular start-ups: An analysis of 128 circular business models. *J. Clean. Prod.* 2020, 245, 118528. <https://doi.org/10.1016/j.jclepro.2019.118528>
- Mazur, V.; Koldovskiy, A.; Ryabushka, L.; Yakubovska, N. The Formation of a Rational Model of Management of the Construction Company's Capital Structure. Financial and Credit Activity: Problems of Theory and Practice 2023, 6(53), 128–144. <https://doi.org/10.55643/fcaptive.6.53.2023.4223>.
- McDonald, R.; Bremner, R. When it's time to pivot, what's your story? How to sell stakeholders on a new strategy. *Harv. Bus. Rev.* 2020, 98, 98–105. <https://www.hbs.edu/faculty/Pages/item.aspx?num=58958>
- Pakura, S. Open innovation as a driver for new organisations: A qualitative analysis of green-tech start-ups'. *Int. J. Entrep. Ventur.* 2020, 12, 109–142. <https://doi.org/10.1504/IJEV.2020.105135>
- Peñarroya-Farell, M.; Miralles, F. Business model dynamics from interaction with open innovation. *J. Open Innov. Technol. Mark. Complex.* 2021, 7, 81. <https://doi.org/10.3390/joitmc7010081>
- Pratama, D.P.; Putra, P.O.H. Exploring Sustainable VR Use Cases for Startup Business Models: A Customized Customer Development Approach. *Sustainability* 2024, 16, 6254. <https://doi.org/10.3390/su16146254>
- Prokopenko, O.; Chechel, A.; Koldovskiy, A.; Kldiashvili, M. Innovative Models of Green Entrepreneurship: Social Impact on Sustainable Development of Local Economies. *Economics Ecology Socium* 2024, 8, 89–111. <https://doi.org/10.61954/2616-7107/2024.8.1-8>
- Prokopenko, O.; Koldovskiy, A.; Khalilova, M.; Orazbayeva, A.; Machado, J. Development of Blockchain Technology in Financial Accounting. *Computation* 2024, 12, 250. <https://doi.org/10.3390/computation12120250>
- Saura, J.R. Using data sciences in digital marketing: Framework, methods, and performance metrics. *J. Innov. Knowl.* 2021, 6, 92–102. <https://doi.org/10.1016/j.jik.2020.08.001>
- Saura, J.R.; Ribeiro-Soriano, D.; Palacios-Marqués, D. From user-generated data to data-driven innovation: A research agenda to understand user privacy in digital markets. *Int. J. Inf. Manag.* 2021. <https://doi.org/10.1016/j.ijinfomgt.2021.102331>
- Silva, D.S.; Ghezzi, A.; de Aguiar, R.B.; Cortimiglia, M.N.; ten Caten, C.S. Lean startup, agile methodologies and customer development for business model innovation: A systematic review and research agenda. *Int. J. Entrep. Behav. Res.* 2020, 26. <https://doi.org/10.1108/IJEBR-07-2019-0425>
- Tiba, S.; van Rijnsoever, F.J.; Hekkert, M.P. Sustainability start-ups and where to find them: Investigating the share of sustainability start-ups across entrepreneurial ecosystems and the causal drivers of differences. *J. Clean. Prod.* 2021, 306, 127054. <https://doi.org/10.1016/j.jclepro.2021.127054>
- World Bank. The World Development Indicators. World Bank, 2023. Available online: <https://datatopics.worldbank.org/world-development-indicators/>
- World Bank. World Bank Open Data. World Bank, 2024. Available online: <https://data.worldbank.org/>
- Yun, J.J.; Zhao, X. Business model innovation through a rectangular compass: From the perspective of open innovation with mechanism design. *J. Open Innov. Technol. Mark. Complex.* 2020, 6, 131. <https://doi.org/10.3390/joitmc6040131>
- Zhao, G.; Jahangir, J.; Faisal, M.N.; Hafeez, M.; Abbas, K. Service Quality and Customers' Satisfaction Nexus in the Light of Price Perception Moderation. *Rev. Argent. Clin. Psicol.* 2020, XXIX, 611–624. 10.24205/03276716.2020.1058