# THE WORK ECOSYSTEM: SOFTWARE TECHNOLOGY DIVERSITY AND THE VALUE OF OCCUPATIONS

SHIYAN ZHANG
Stevens Institute of Technology
1 Castle Point
Hoboken NJ 07030

BEI YAN
Stevens Institute of Technology

JUSTINE HERVÉ
Stevens Institute of Technology

JEFFREY V. NICKERSON
Stevens Institute of Technology

## ABSTRACT

This study examines the effects of software technology diversity on the value of occupations measured by wages. Two forms of technology diversity are examined — technology separation and technology disparity. Technology separation refers to the span of the function of the technologies in an occupation. Technology disparity is the distribution of technology categories in an occupation. Our results show that technology separation is negatively associated with wages while technology disparity is positively associated with wages. This study expands our understanding of the effects of technology on the future of work and has implications for the development of skills and career trajectories.

## INTRODUCTION

Technologies are essential for task performance in occupations and are part of the way occupations are defined in the labor market (Frey and Osborne 2017). When studying the impact of technologies on occupations, existing research tends to focus on the consequence of particular technology adoptions, most recently the adoption of artificial intelligence (Acemoglu and Restrepo 2019; Brynjolfsson, Liu, and Westerman 2022). Unlike these studies, this paper considers the technology categories that are used in each occupation , drawing from the increased availability of digital trace data and new methods for analyzing text.

Specifically, this paper looks at how the diversity of technology categories in an occupation relate to the value of that occupation. Diversity has been much studied in relation to the way organizations work (van Knippenberg and Schippers 2007; Carte and Chidambaram 2004; Kearney, Gebert, and Voelpel 2009; Zhang et al. 2007), but less so with respect to the effects of technology. Many theories of innovation are based on ideas of stochastic variance which value diversity (Louçã 2014; Sutton 2001), but the issue at hand here is more complex, because the variation of technologies used in an occupation is far from random — instead, this variation stems from the activities of the occupation. This work thus allows us to better understand how the use of technologies within occupations relates to the value of occupations.

Two forms of technology diversity are discussed: separation and disparity. Separation and disparity have been described before in the context of organizational studies (Harrison and Klein 2007). In the context of occupations, high technology separation in an occupation indicates that technologies used in the occupation are highly distinctive from one another. Technology disparity captures the evenness of the technology category's importance in an occupation. These two indices are calculated using standard deviation and Gini coefficient functions, respectively. Technology separation is calculated based on the semantic embeddings of category descriptions, whereas technology disparity is calculated based on the distribution of products used within categories.

We conducted a regression analysis using occupation-level data from O*NET and the Bureau of Labor Statistics to examine the association between our measures — technology separation and technology diversity — and occupational value as measured by average wage. We find that technology separation is associated with lower occupation value while technology disparity is associated with higher value.

We contribute to the literature by characterizing and measuring separation and disparity of technologies within occupations with a goal of understanding the impacts of such diversity measures on the value of occupations. This issue is related to the longstanding and still current concern in both the information systems and management literature related to how humans interact with technology in job settings.

## THEORY DEVELOPMENT

The construct of diversity and its role in the ecosystem are widely studied in biology (Elmqvist et al. 2003). More recently, diversity has also been studied in the evolutionary process of social artifacts like technology and economic systems (Lipieta and Pliś 2022; Andriani and Cattani 2016). The diversity of technology used in an occupation reflects the collective decision by the profession on technology adoption, as well as the current state of technology products.

In this paper, we measure the value of an occupation using wages. Prior research has shown a significant relationship between technological skills and wages (Autor 2010; Goldin and Katz 2007; Brynjolfsson and McAfee 2012; Alekseeva et al. 2021), however, to our knowledge no study has investigated how the interaction of different technologies within occupations shape occupations' values. Filling this gap, we formalize technology diversity in occupations using the framework developed by Harrison and Klein (2007), which categorizes the diversity in three distinctive types: separation, variety, and disparity. In this study, we consider two types of diversity, separation and disparity, as they are conceptually the most distinct. Both have straightforward interpretations in the context of technology use. We develop two hypotheses related to each of the two technology diversity measures and their relationship to the value of occupations.

*Technology separation* is the functional span of technology categories used to perform an occupation. High technology separation can occur when an occupation has several important but very different tasks to perform, and technology vendors supply products that help with each.How can technology separation influence the value of an occupation? First, technology separation might increase the training requirements for an occupation, which might in turn decrease the value of the occupation, as manifested in lower average wages.

Second, although little research has directly investigated the association between separation and occupational wages, the existing literature implies a negative impact of separation on earnings (Dobrev, Kim, and Hannan 2001; Hannan 2005; Hsu and Hannan 2005). The general intuition is that too much separation spreads workers too thin, and discourages the building of specialization, which since the time of Adam Smith has been thought important in the design of organizations.

Third, at the market level, population ecology theory suggests that compared to organizations that span a many sub-industries, organizations that have a narrow niche, or only focus on a small number of products or services, are more likely to create a unique identity that differentiates them from competitors and increase their survival rate in the market (Dobrev, Kim, and Hannan 2001; Hannan 2005; Hsu and Hannan 2005). Applying this logic to occupations, high technology separation may make it hard for the occupation to construct a unique identity, which might decrease the visibility and bargaining power of workers in that occupation, and in turn allow firms to keep wages low.

In conclusion, having a system with a variety of unrelated knowledge components might be detrimental to its collective performance. In the context of occupations, it suggests that workers in occupations with high technology separation may be less productive, have fewer job options, and ultimately lower wages than workers in more specialized occupations. This motivates the following hypothesis:

> *Hypothesis 1: Technology separation in an occupation is associated with lower value in an occupation.*

*Technology disparity* in an occupation is the distribution of software products across technology categories used in the occupation. We posit that technology disparity in occupations is positively related to occupational wage. Research on teams showed that teams with a more centralized communication structure, such as when a few members dominate the communication, perform better in problem solving as the structure facilitates communication and coordination (Argote, Aven, and Kush 2018). Likewise, if an occupation has the same technology separation as another occupation but a much higher technology disparity, the tasks in the occupation may be better structured and coordinated, because there is a common language all workers share.

From an evolutionary perspective, technology disparity may enhance the value of occupations by strengthening the occupational identity. Occupational identity is a social identity formed around one's occupation (Abbott, 1993). It helps distinguish the occupations and is central for members of the occupation to make sense of their job (Ibarra & Barbulescu, 2010). Occupational identity can affect members' commitment to their occupations and how the market evaluates the occupation, thus shaping the evolution and existence of occupations.

Having high technology disparity implies that most tasks entailed in the occupation can be completed through a large number of products distributed in a small number of technologies. This feature can promote occupational identity since it is easier for members of the occupation to make sense of what they do and communicate their work to others. This leads to the following hypothesis:

> *Hypothesis 2: Technology disparity in an occupation is associated with higher value in an occupation.*

## DATA AND METHODS

We apply the technology skills dataset released by the Department of Labor in the form of the O*NET database. It contains technology categories associated with each occupation. Specific software products associated with the occupations collected from interviews are classified into these technology categories by the Department of Labor based on the United Nations Standard Products and Services Code (UNSPSC). The UNSPSC creates a hierarchy of technology categories that goes from the very general to the most granular. The most granular is called a commodity. O*NET adopts the term commodity, and further differentiates between general tools (which include mechanical technologies like engines) and software. In total, O*NET encodes 127 unique software technology commodities.

**Technology Separation**

This metric measures the semantic separation of the technology categories within each occupation. More specifically, we embed the titles and descriptions of all technology categories using the Universal Sentence Encoder (Cer et al. 2018). We then calculate the standard deviation (SD) of these vectors within each occupation. In this case, we use the SD to measure the semantic distances of technology categories associated with occupations. Therefore, it reflects the separation of technology skills of each occupation. The mean of the separation measure is 0.77, and the standard deviation is 0.07.

**Technology Disparity**

Technology Disparity measures the extent to which one or few technologies dominate the occupation. For example, an occupation in which there are four technology categories each with two example products would exhibit low disparity since the technology categories have similar numbers of representative technologies. Disparity is calculated using the Gini coefficient. In this context, high disparity usually indicates the occupation has products that predominantly occur in a few technologies. The mean of the disparity measure is 0.29, andthe standard deviation is 0.19.

**Regression framework**

Using median annual wage data from the Bureau of Labor Statistics (BLS), we regress occupational wages on our two measures of technology diversity. We include the following variables in the covariate set. First, we account for supply-side wage determinants at the occupational level by including education, training, work experience, and the number of technology categories within each occupation in the set of covariates, treating education, training, and work experience as categorical variables. Then, to account for demand-side wage determinants, we include occupation-level employment to the control set. Data sources for the control variables are BLS and O*NET. We also run variance inflation factor (VIF) tests on all models. The results suggested no multicollinearity issues.

## RESULTS

While both measurements represent aspects of technology diversity, they have opposite effects on the wages of occupation. The technology separation index is negatively correlated with the dependent variable — median annual wage ($p < 0.01$), while the technology disparity index is positively correlated with the dependent variable ($p < 0.001$). The effects remain stable whether we test the measurements in separate models or in the same model. All main effects are also statistically significant through all regression models.

The result on separation is consistent with the hypothesis that high technological separation might be interpreted as low specialization, which in turn might hinder productivity in a given occupation and lead to lower wages. Additionally, the finding that disparity increases wages aligns with the hypothesis that higher centralization of technological tasks might lead to productivity gains and a more clearly defined occupational identity, which might translate into higher wages.

**Effects of Technology Diversity in Sub-Occupation Groups**

Wages are also commonly studied with respect to the nature of work. Manual labor tends to be paid less than cognitive labor (Autor et al., 2006). Because past literature has focused on this distinction, we decided to test if the distinction interacted with our results. Using two additional ratings from O*NET on work activities, we extracted three sub occupation groups: technical, physical, and mixed. The two ratings for measuring levels of technical and physical work activities are “Interacting With Computers” and “Performing General Physical Activities”, respectively. We divided each rating by the median. For occupations with higher-than-median ratings on the computer activity and lower-than-median ratings on the physical activity, we considered them technical occupations. For occupations that rate the computer activity lower than the median and the physical activity higher than the median, we considered them physical occupations. Finally, we considered the occupations that rate both activities higher than the median mixed occupations. We ran the same regression models in the sub occupation groups with the same control variables.

Technical occupations and mixed occupations follow the same trends as the main regression. In the physical occupation group, however, the effects of both the technology separation index and technology disparity index are not significant ($p = 0.27$ and $p = 0.51$, respectively). In other words, what we learned about technology diversity and occupational wage apply to occupations with stronger technology components. This may be due to the limited amount of technologies being used in physical occupations.

## DISCUSSION

From an ecological point of view, technological diversity within occupations relates to the concept of specialization, and can impact the fitness value of the occupations in the labor market. Smith (1937) argued that the specialization of workers’ duties into a set of highly connected skills often lead to greater productivity; others have made this observation in a modern context (Barnard, 1938; Simon, 1997). Similarly, lower technology separation can be seen as a signal of more specialization in the sense that the technologies associated with an occupation are less dispersed, and therefore that workers will not be forced to acquire disparate sets of domain knowledge to perform that occupation. Higher disparity is related to higher specialization in that most of a worker’s attention will be concentrated on one or a few technology categories. Since the regression results indicate that technology separation and technology disparity are negatively and positively associated with higher wages, respectively, our results are consistent with Adam

Smith's observations and the empirical work that followed: a concentration on a small set of similar technology categories can lead to higher wages.

## CONCLUSION

Labor markets match skills provided by the supply side with tasks demanded by firms. Technologies can be important multipliers of productivity, even more so in some occupations than others. Workers augmented by technology can become more productive, raising their marginal product. This might increase competition between firms for these workers and force them to increase wages. While this is well understood, what is less well understood is how relational structures of technologies in an occupation are related to its fitness value, as reflected by the wages.

This study looks at the diversity of technologies, specifically separation and disparity, in an occupation. The study controls for well-known drivers of wages on both supply and demand sides — education, training, experience, and occupational employment. We find that technology separation is negatively associated with wages, while technology disparity is positively correlated with wages. The effects are stronger in occupations with more technology components.

These findings are one step toward better understanding the factors governing the evolution of labor markets, which are increasingly affected by rapid change in software technology. As Dornbusch observed, some things happen more slowly than expected, until they happen more quickly than expected. Studying the occupational ecosystem has always been challenging, but new sources of data and new techniques now allow researchers to better understand the structure of this ecosystem. This understanding may be important in helping us design a future we want to work in.

## REFERENCES AVAILABLE FROM THE AUTHORS