

Inequality in the Age of Pseudonymity

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Abstract

Inequality measures such as the Gini coefficient are used to inform and motivate policymaking, and are increasingly applied to digital platforms. We analyze how measures fare in pseudonymous settings that are common in the digital age. One key challenge of such environments is the ability of actors to create fake identities under fictitious false names, also known as “Sybils.” While some actors may do so to preserve their privacy, we show that this can hamper inequality measurements: it is impossible for measures satisfying the literature’s canonical set of desired properties to assess the inequality of an economy that may harbor Sybils. We characterize the class of all Sybil-proof measures, and prove that they must satisfy relaxed version of the aforementioned properties. Furthermore, we show that the structure imposed restricts the ability to assess inequality at a fine-grained level. We then apply our results to prove that popular measures are not Sybil-proof, with the famous Gini coefficient being but one example out of many. Finally, we examine dynamics leading to the creation of Sybils in digital and traditional settings.

1 Introduction

The measurement of economic equality is a cornerstone of social science, providing tools and data to inform public discourse and motivate government policy (Connell, Dorr, and Shin 2021; Auerbach 2025). Thus, it is unsurprising that inequality measures are used to study digital platforms (Nadler and Schär 2022; Feichtinger et al. 2024b). A famous example of such a measure is the Gini coefficient (GC) (Gini 1912), which ranges between a value of 0 (if all individuals have equal wealth) and 1 (if one entity holds all wealth). Alarming, some found that the inequality of a prominent digital platform, Bitcoin, is “like North Korea” (Weisenthal 2014), and “more unequal than any other human society” (Roubini 2018), owing to a GC of 0.88 (see Fig. 1). Similar findings have been used to argue for a critical need to change the incentive mechanisms and governance structures of decentralized payment systems and decentralized finance (DeFi) platforms to ensure they do not succumb to centralization (Gupta and Gupta 2018; Nadler and Schär 2022; Sai, Buckley, and Le Gear 2021; Feichtinger et al. 2024b).

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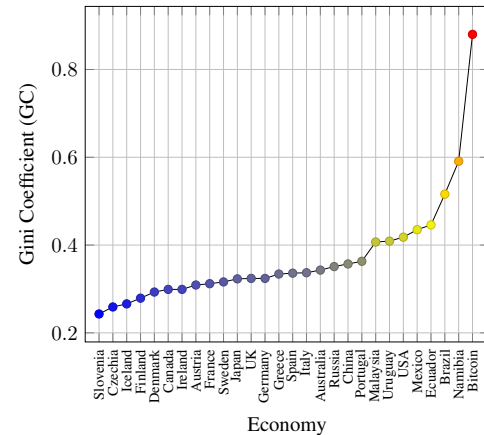


Figure 1: Some argue that Bitcoin’s GC equals 0.88 and is thus indicative of extreme inequality (Roubini 2018), as this value positions it above any other global economy. Country-level data obtained from (World Bank 2025).

However, applying classical measures directly to pseudonymous platforms overlooks a fundamental difference: the potential disconnect between observable identities and true economic actors. This disconnect is not a mere technicality but a first-order feature of digital economies that invalidates the core assumptions of traditional inequality analysis. Before we can answer how unequal these platforms are, we must first tackle a more fundamental question: *can we even measure their inequality reliably?*

1.1 This Work

This paper provides the first axiomatic answer to that question. To do so, we establish the theoretical foundations for inequality measurement in the age of pseudonymity.

We show that reliable measurements are inherently challenging to carry out in pseudonymous settings, as common to digital platforms. This is due to actors possibly holding their wealth across several Sybil identities, i.e., using multiple fictitious false names. In fact, empirical work on measuring inequality in practice shows that such considerations are generally applicable: consider how individuals may hold wealth across seemingly disparate shell corporations

to avoid taxes (Alstadsæter, Johannesen, and Zucman 2019; Lustig 2020; Martinangeli and Windsteiger 2024). Such behavior is common among sophisticated actors (Auerbach and Siegel 2000; Gruber and Saez 2002; Slemrod 2007; Gabaix et al. 2016; Auerbach 2025), making the setting applicable to non-pseudonymous markets.

To analyze the impact of Sybils, we use the literature’s canonical set of properties desired from inequality measures (Cowell 2011). Thus, measures should receive a scalar vector representing the distribution of wealth over an economy’s population, and ideally satisfy several axioms: 1. the transfer principle (i.e., given a population ordered by wealth, order-preserving wealth transfers from rich individuals to poorer ones reduce inequality), 2. symmetry (that is, invariance to permutations), 3. insensitivity to population size, and 4. scale independence (i.e., invariance under uniform scaling).

Before we elaborate on our results, we wish to illustrate that the impact of Sybils can be counterintuitive. One might assume that splitting wealth across multiple accounts would generally decrease measured inequality. That is, that observed inequality is a lower bound on the true one. This intuition is *false*. Consider a wealth distribution (10, 10), and suppose the second actor splits its wealth over two Sybil accounts, resulting in (10, 9, 1). This Sybil manipulation actually increases inequality when considering measures satisfying the transfer principle, such as the GC.

Having established this, we proceed to discuss our results. We begin our analysis by highlighting the tension between Sybil-proofness and the literature’s standard desired properties (Section 4). Our first main result is an impossibility: no Sybil-proof inequality measure can satisfy the transfer principle. While the transfer principle is a hallmark of inequality measures, one may be tempted to circumvent the impossibility by replacing it with a mild alternative. Thus, we consider the egalitarian zero principle, which requires that all egalitarian wealth distributions (i.e., where all entries are identical) should correspond to the lowest possible inequality value, while any other distribution would have strictly larger inequality. As we show, this again results in an impossibility.

Having delineated what is not possible, we map the design space for everything that is possible by fully characterizing the class of Sybil-proof measures (Section 5). As we show, this class is exactly the family of metrics which are *sum-dependent*, meaning that given an input wealth distribution, its inequality is calculated solely based on the sum of wealth. This is a natural companion to the impressive line of work characterizing decomposable measures (Bourguignon 1979; Shorrocks 1980, 1984; de la Vega, Urrutia, and Volij 2013; Heikkuri and Schief 2025), i.e., measures that, given aggregate information on two sub-populations, can calculate the inequality of their union. In a way, our sum dependent family considers a further condensed form of aggregation. As we prove, this is not only a feature, but also a necessity.

While we begin with our impossibilities and only then provide a complete characterization, it is possible, of course, to reverse this order. That is, one can start with the characterization and derive the impossibilities as corollaries. We have chosen this structure as this work’s central finding is the problem itself: the tension between robustness to

pseudonymity and the very properties that give inequality measures their meaning. This allows us to derive the impossibilities using the literature’s basic building blocks, without requiring the novel definitions and machinery used for the characterization. This then positions the characterization as *explaining* the structural limits that give way to the negative results, rather than *driving* the impossibilities.

We culminate by showing our results’ applicability to other settings and notable metrics. In total, we offer a toolbox covering a large class of measures, including the GC, coefficient of variation (CV), Atkinson measure (AM), generalized entropy (GE) metrics, and the Herfindahl-Hirschman (HH), Theil L (TL), and Theil T (TT) indices.

Structure We begin with an overview of related work in Section 2, and proceed to formalize the setting in Section 3. Then, we present our impossibilities in Section 4 and our full characterization of Sybil-proof inequality measures in Section 5. We culminate with a discussion on the generality of our results in Section 6. Full proofs of all results and a comprehensive overview of the related literature are both provided in the paper’s full version (Yaish et al. 2025).

2 Related Work

To the best of our knowledge, our work is the first to provide a theoretic framework for inequality measurement under pseudonymity. We contribute to several bodies of work, including the literature on the axiomatic approach to inequality measures, the limitations of such measures, and the analyses of both Sybils and collusion in economic settings.

Inequality Measures The axiomatic study of inequality includes the foundational (Gini 1912; Dalton 1920; Atkinson 1970), which establish the core properties desired in measures. Following are the elegant characterizations of (Bourguignon 1979; Foster 1983; Shorrocks and Foster 1987), that consider refinements and additions to the canonical desiderata, e.g., decomposability (a property which we discuss in Section 6). Decomposable measures that are given the within-group and between-group inequalities of two populations, can “staple” the two together to compute their union’s inequality. Work on the limitations of inequality measures includes analyses of sampling flaws, e.g., typing errors that affect the magnitude of sampled wealth (Cowell and Victoria-Feser 1996), incomplete representation of sub-populations (Korinek, Mistiaen, and Ravallion 2006), wealth under-reporting (Lustig 2020), and inconsistent data collection methodology (Atkinson and Brandolini 2001). We augment the existing substantial body of work by also considering Sybil-proofness and collusion-resistance in the context of inequality measures. The comprehensive (Cowell 2011; Stiglitz 2025) present a summa of the topic, and the thorough (Yitzhaki and Schechtman 2013) focuses on the GC.

Inequality and Pseudonymity Our theoretic framework for inequality measures in pseudonymous settings nicely complements empirical measurement studies. Thus, some have tried to empirically estimate inequality and heuristically identify Sybils in blockchain governance protocols (Fritsch, Müller, and Wattenhofer 2024). However, notable

works note that methods are hard to validate due to missing ground-truth data (Victor 2020), and that actors can create identities using cryptographic protocols that provide formal unlinkability guarantees (Wahrstätter et al. 2024). Other related studies consider social networks (Nielsen and Vaccari 2013), open-source communities (Chelkowski, Gloor, and Jemielniak 2016), peer-to-peer file-sharing (Hales et al. 2009), distributed payment systems (Ovezik et al. 2025), and DeFi platforms (Nadler and Schär 2022).

Sybils and Collusion The theoretic literature on collusion and Sybils (sometimes called “false names”) is extensive, and highlights the importance of these topics for digital settings (Conitzer and Yokoo 2010). However, no previous work considered inequality metrics. The literature studied auctions (Yokoo, Sakurai, and Matsubara 2004), voting (Wagman and Conitzer 2008), and consensus protocols (Chen, Papadimitriou, and Roughgarden 2019), among others. Also related are foundational works on rights arbitration (O’Neill 1982) and bankruptcy (Aumann and Maschler 1985), where manipulations include introducing new creditors (Dagan and Volij 1993), with later work showing that some classic solutions are Sybil-proof or collusion-resistant (Belotti and Moretti 2021). While the context and axiomatic frameworks differ, the literature demonstrates that these manipulations are recurring challenges across settings.

3 Reasoning About Hidden Economies

We consider the problem of measuring the inequality of an economy characterized by a disconnect between its underlying hidden distribution of wealth among real actors, and its observable wealth distribution. The two may differ as actors can report wealth using Sybil identities under false names.

3.1 The Economy

Agents The economy is populated by n real actors with a wealth distribution $w \stackrel{\text{def}}{=} (w_1, \dots, w_n)$, both n, w are hidden, and m identities whose wealth distribution $\rho \stackrel{\text{def}}{=} (\rho_1, \dots, \rho_m)$ is observable. Bridging the surface-level ρ and hidden w is an unobservable matrix $R \in \mathbb{R}_{\geq 0}^{n \times m}$, where $R_{i,j}$ is the fraction of wealth reported by actor i under identity j .

Manipulations We say a real actor $i \in [n]$ is *truthful* if and only if (iff) it reports its wealth using exactly one identity and does not create any identity with no wealth. However, actors need not be truthful. Thus, $i \in [n]$ can create *Sybils* by distributing wealth across several identities. Actors can also *collude* and pool wealth together, formally defined as a set $C \subseteq [n]$ with $|C| > 1$ and an identity $j \in [m]$ where $\forall i \in C : R_{i,j} > 0$. Finally, total observable wealth must match hidden wealth, per Definition 1. This permits decreasing hidden wealth, e.g., due to “burning” (Gafni and Yaish 2025), if observed wealth decreases equally.

Definition 1 (Wealth Conservation). *We say that a report matrix R conserves an economy’s wealth across its hidden*

and observable states iff both the following hold:

$$\begin{cases} \forall i \in [n] : 1 = \sum_{j \in [m]} R_{i,j} \\ \forall j \in [m] : \rho_j = \sum_{i \in [n]} (R_{i,j} w_i) \end{cases}$$

3.2 Inequality Measure Axioms

An inequality measure is a continuous function $\mathcal{I} : \bigcup_{k \in \mathbb{N}} \mathbb{R}_{\geq 0}^k \rightarrow \mathbb{R}$ mapping a wealth distribution, represented as a scalar vector of any size, to a scalar value. The axiomatic inequality measure literature specifies a core set of desired properties (Cowell 2011; Stiglitz and Rothschild 2025).

First, measures should be insensitive to the economy’s total amount of wealth or the units in which wealth is denominated, i.e., inequality should be invariant under uniform scaling. This is captured by Definition 2, which is attributed to (Atkinson 1970) by (Foster 1983).

Definition 2 (Scale Independence). *Measure \mathcal{I} is scale independent iff for any $\alpha \in \mathbb{R}_{> 0}$ and any wealth distribution $x = (x_1, \dots, x_k) \in \mathbb{R}_{\geq 0}^k$ where $k \in \mathbb{N}$, then: $\mathcal{I}(x) = \mathcal{I}(\alpha \cdot x)$. Scalar multiplication is defined in the standard way, i.e., $\alpha \cdot x = (\alpha \cdot x_1, \dots, \alpha \cdot x_k)$.*

Inequality should also be independent of an economy’s population size, per Definition 3, which (Foster 1983) attributes to (Dalton 1920). Intuitively, a wealth distribution is compared to a counterfactual synthesized by duplicating it. So, (5, 10) should have the same inequality as (5, 10, 5, 10).

Definition 3 (Population Insensitivity). *Measure \mathcal{I} is population insensitive iff for any $k \in \mathbb{N}$ and any wealth distribution $x = (x_1, \dots, x_k) \in \mathbb{R}_{\geq 0}^k$, the inequality of x is identical to that of $x \sqcup x$, i.e., x concatenated with itself:*

$$\mathcal{I}(x) = \mathcal{I}(x_1, \dots, x_k, x_1, \dots, x_k) = \mathcal{I}(x \sqcup x).$$

The axiom of symmetry, which we state in Definition 4, is assigned to (Dalton 1920) by (Atkinson 1970). This property postulates that an economy’s inequality should not change if its wealth distribution is permuted. E.g., a measure should compute the same inequality for both (5, 10) and (10, 5).

Definition 4 (Symmetry). *Measure \mathcal{I} is symmetric iff for any $k \in \mathbb{N}$, any permutation matrix $P \in \{0, 1\}^{k \times k}$, and any wealth distribution $x = (x_1, \dots, x_k) \in \mathbb{R}_{\geq 0}^k$, we have that inequality is invariant to permutation: $\mathcal{I}(x) = \mathcal{I}(Px)$.*

The next property, given in Definition 5, is emblematic of inequality measures: equality should increase by a rank-preserving “progressive” wealth transfer (i.e., the transfer is of a strictly positive amount, and the sender is wealthier than the receiver both before and after the transfer). This axiom sometimes called the Pigou-Dalton principle (Foster 1983), as it is traced to (Pigou 1912; Dalton 1920).

Definition 5 (Transfer Principle). *Measure \mathcal{I} satisfies the transfer principle iff for any $k \in \mathbb{N}_{\geq 2}$, any $x = (x_1, \dots, x_k) \in \mathbb{R}_{\geq 0}^k$, any $i, j \in [k]$ with $x_i < x_j$, and any $\delta \in \left(0, \frac{x_j - x_i}{2}\right]$, the inequality of x is strictly greater than that of $x' = (x_1, \dots, x_i + \delta, \dots, x_j - \delta, \dots, x_k)$, which is identical to x except a δ transfer from j to i : $\mathcal{I}(x') < \mathcal{I}(x)$. Given x, x' as before, the weak transfer principle holds iff post-transfer inequality is weakly lower: $\mathcal{I}(x') \leq \mathcal{I}(x)$.*

4 Impossibilities for Sybil-Proof Measures

We now derive the first batch of our main results, showing that it is impossible for measures to withstand Sybil manipulations and simultaneously satisfy subsets of the canonical set of desired properties. To do so, we enrich the canonical desiderata for inequality measures with Definition 6, a new axiom that captures the essence of Sybil-resistance.

Definition 6 (Sybil-Proofness). *A measure \mathcal{I} is Sybil-proof iff it is invariant under any wealth conserving Sybil manipulation. That is, for any $n \in \mathbb{N}$, any hidden wealth distribution $w = (w_1, \dots, w_n) \in \mathbb{R}_{\geq 0}^n$, and for any observable wealth distribution $\rho = (\rho_1, \dots, \rho_m) \in \mathbb{R}_{\geq 0}^m$ generated from w via a wealth-conserving report matrix $R \in \mathbb{R}_{\geq 0}^{n \times m}$ that involves Sybil manipulations, then we must have: $\mathcal{I}(w) = \mathcal{I}(\rho)$.*

Definition 6 considers “pure” Sybil manipulations, strengthening our results by showing that they hold irrespective of collusion. Moreover, we later show (e.g., in Section 5) that the structural impact of Sybils on inequality measures necessitates collusion-resistance.

4.1 The Transfer Principle

We now consider how the transfer principle (Definition 5) restricts robustness to Sybil manipulations. We start with a warm-up using several of the axiomatic properties, Proposition 1. Then, we show that an impossibility can be obtained using a minimal set of properties in Theorem 1.

Proposition 1. *No inequality measure can simultaneously satisfy the transfer principle, scale independence, population insensitivity, and Sybil-proofness.*

To prove this, we have to delicately apply properties to produce wealth distributions that could feasibly be created both with and without Sybil manipulations. Thus, we first apply the population insensitivity property to double the population. However, this effectively doubles the economy’s wealth, and so we use the scale independence property to halve the wealth back to the amount we started with. Then, we perform a series of transfers where all but one of the “original” and “doubled” identities are reconciled back into a single identity. This leaves us with two identities which are not reconciled. To wrap-up the proof, we consider how transfers between these identities impact inequality, and, via the transfer principle, reach a contradiction to Sybil-proofness.

Theorem 1. *No Sybil-proof measure satisfies the transfer principle.*

To prove this, we start from some initial hidden wealth distribution, and show the observable distribution obtained from the truthful report can also be obtained from a different hidden distribution and several distinct Sybil manipulations. To get towards an impossibility, we “tie” the manipulations together by showing they can be obtained by performing a sequence of progressive transfers between distinct real actors, starting from the initial truthful observable wealth distribution. By the transfer principle, the transfers must reduce inequality, reaching a contradiction.

While our proof applies to general initial distributions, the result can be illustrated via a concrete, albeit simplified, example. For example, consider a single actor with all wealth

(1), and two possible observable distributions: (0.5, 0.5) and (0.9, 0.1). By the transfer principle, the latter distribution has strictly greater inequality. Sybil-proofness is violated: the two do not have identical inequality.

4.2 Relaxing the Desiderata

One might hope that by relaxing this principle to its weak form, a meaningful Sybil-proof metric could be constructed. However, the weak transfer principle as-is leaves the door open for metrics that cannot distinguish between distributions (as we show in Section 5), thus highlighting one merit of the strict transfer principle. To avoid that, we present in Definition 7 a mild axiom called the egalitarian zero principle, which has been featured in prior work (Cowell 2011).

Definition 7 (Egalitarian Zero Principle). *Measure \mathcal{I} satisfies the egalitarian zero principle iff for any $k \in \mathbb{N}$ and any distribution $x = (x_1, \dots, x_k)$, then $\mathcal{I}(x) = 0$ iff x is egalitarian ($\forall i_1, i_2 \in [k] : x_{i_1} = x_{i_2}$). The weak egalitarian zero principle holds iff for any egalitarian x : $\mathcal{I}(x) = 0$.*

Even in its non-weak form, the egalitarian zero axiom is a relaxed alternative to the transfer principle: a minimum is imposed on the measure, and, rather than requiring that *any* progressive order-preserving transfer would lower inequality, this is only strictly enforced for transfers that result in full equality. However, we show in Proposition 2 that this relatively lax property still results in an impossibility.

Proposition 2. *No Sybil-proof inequality measure can satisfy the egalitarian zero principle.*

We prove this by showing a non-egalitarian distribution which, for a specific Sybil manipulation, can be transformed into an egalitarian distribution. This creates a conflict between the egalitarian zero principle, which requires the two corresponding inequalities to differ, and Sybil-proofness, which necessitates all inequalities to be the same.

5 Characterizing Sybil-Proof Measures

So far, we have shown through a set of impossibilities that Sybil-proofness cannot co-exist with some of the commonly sought-after properties of the literature. We now turn to fully characterize which measures are resistant to Sybil manipulations, and the properties which they *can* satisfy. We do this by first presenting a series of results showing that Sybil-proofness in some cases also implies other properties. Then, we prove that requiring Sybil-proofness and certain other mild properties necessarily imposes a specific structure on measures. We demonstrate this by presenting a concrete Sybil-proof measure, and then generalize it into a family containing all Sybil-proof metrics which are either scale independent or population insensitive. Finally, we characterize the entire class of Sybil-proof inequality measures, derive all properties that they satisfy, and prove that they admit constructions differing from the aforementioned family.

5.1 Axioms Implied by Sybil-Proofness

We now present a set of useful results, showing the implications of imposing Sybil-proofness. E.g., in Proposition 3 we show that Sybil-proofness has a nice by-product: symmetry.

Proposition 3. *Any Sybil-proof measure is symmetric.*

Proposition 3 serves as an illuminating companion to our first main result, Theorem 1, where we show that coupling Sybil-proofness with symmetry is directly at odds with the transfer principle. In a way, our proof provides a new answer to Shakespeare’s question, “*what’s in a name?*” That is because the symmetry property, also sometimes referred to as anonymity (Dasgupta, Sen, and Starrett 1973), is directly implied by Sybil-proofness: the presence of Sybil identities makes it necessary for a measure to be agnostic to permutations. As we show, this extends further, and essentially requires measures to operate at a “coarse” level.

Next, we combine Proposition 3 and Theorem 1 to derive Proposition 4, thus proving that Sybil-resistant measures must also adhere to the weak transfer principle. Our proof shows that this is a delicate result, as one has to rule-out the possibility that progressive order-preserving transfers (per Definition 5) may *harm* inequality. To do so, we construct several Sybil manipulations where the wealth of real actors is chosen carefully as to ensure that one actor controls both identities that take part in transfers.

Proposition 4. *Any Sybil-proof inequality measure satisfies the weak transfer principle.*

We proceed with Proposition 5, where we highlight the interplay between Sybil-proofness, scale independence and population insensitivity. In particular, we show that invariance under population duplication, the condition at the heart of Definition 3, can be viewed as a Sybil manipulation which is combined with some scaling of the economy’s wealth.

Proposition 5. *Any scale independent Sybil-proof metric is population insensitive.*

This result is obtained by performing a Sybil manipulation where each identity splits its wealth equally across two identities, and then scaling the resulting distribution by 2.

5.2 Aggregation Invariance

We prove an analogous result to Proposition 5, i.e., coupling Sybil-proofness with the population insensitivity property implies scale independence (see Corollary 1). However, this requires stronger technical heavy-lifting and additional groundwork, that we now perform. Fortunately, this very same groundwork results in several tools which are of immense use through the remainder of the paper.

We continue by presenting Definition 8, and showing in Theorem 2 that this axiom is equivalent to Sybil-proofness. Intuitively, this axiom implies that a measure does not need to observe an economy’s entire wealth distribution; instead, it can observe a “summarized” distribution which is shorter by 1, if the wealth of the omitted index of the original distribution is spread over the summarized distribution’s indices.

Definition 8 (Aggregation Invariance). *Measure \mathcal{I} is aggregation invariant iff for any $x = (x_1, \dots, x_k) \in \mathbb{R}_{\geq 0}^k$ with $k \in \mathbb{N}_{\geq 2}$, and any aggregation matrix $A \in \mathbb{R}_{\geq 0}^{(k-1) \times k}$ such that $\sum_{i \in [k-1]} (Ax)_i = \sum_{j \in [k]} x_j$, then: $\mathcal{I}(x) = \mathcal{I}(Ax)$.*

Theorem 2. *\mathcal{I} is aggregation invariant iff it is Sybil-proof.*

We prove the first direction (Sybil-proofness \Rightarrow aggregation-invariance) by assuming some wealth distribution and aggregation matrix, and constructing a counterfactual distribution where a single actor initially controls all wealth. This is followed by presenting two Sybil manipulations: one ending in the assumed distribution, and another that arrives at the result of applying the aggregation matrix to the assumed distribution. We show the second direction by letting some hidden and observable wealth distributions, and inductively constructing a sequence of aggregation matrices that take both distributions to a counterfactual “initial” distribution where again only a single actor is present.

We follow with one of our main results, Theorem 3, where we show that imposing population insensitivity on Sybil-proof measures must result in some constant measure.

Theorem 3. *If \mathcal{I} is a population insensitive Sybil-proof inequality metric, then it must be expressible as a constant function. That is, there is some $c \in \mathbb{R}$ such that for any distribution $x = (x_1, \dots, x_k) \in \mathbb{R}_{\geq 0}^k$ where $k \in \mathbb{N}$: $\mathcal{I}(x) = c$.*

The proof of Theorem 3 is by contradiction: given two distinct distributions that result in differing inequalities, both can be aggregated into each one’s corresponding sum via Theorem 2. Then, by repeated applications of Sybil-proofness and population insensitivity, we can show that the measure does not only admit inequality-preserving population doubling, but also wealth halving. Due to the literature’s standard continuity assumption (Shorrocks 1984), the inequality at the limit of any given starting wealth distribution must equal that of the singleton distribution with no wealth, i.e., $\mathcal{I}(0)$. This shows that, in fact, population insensitivity is quite a strong property when used in tandem with Sybil-proofness. In our full characterization of Sybil-proofness, we also consider measures which are not population insensitive, and show that indeed the broad class of Sybil-proof measures admits other types of functions.

Having assembled the needed tools, we prove the analog of Proposition 5 where the roles of scale independence and population insensitivity are reversed by applying Theorem 3 and noting that constant metrics are scale independent.

Corollary 1. *Any population insensitive Sybil-proof measure is also scale independent.*

5.3 The Family of Constant Measures

The previous results seem to point towards the possibility that large swaths of the design space for Sybil-proof measures are occupied by metrics that are expressible using constant functions. Before carrying out our full characterization of Sybil-proof metrics, we fully analyze one specific such measure (Definition 9), and then follow by considering the family of constant measures (Definition 10). We prove in Proposition 6 that one constant measure in particular can satisfy the complete desiderata (where the transfer and egalitarian zero principles are in their weak form). While the large set of properties may paint a seemingly rosy picture, the measure cannot be used to meaningfully compare the inequality of two wealth distributions, being a constant function. Our characterization of the constant measure family

plays a key technical role in later results, as, by satisfying certain mild properties, any measure collapses to this form.

Definition 9 (Baseline Measure \mathcal{I}_0). *Given any wealth distribution $x = (x_1, \dots, x_k) \in \mathbb{R}_{\geq 0}^k$ where $k \in \mathbb{N}$, the baseline measure \mathcal{I}_0 is defined as: $\mathcal{I}_0(x) \stackrel{\text{def}}{=} 0$.*

Proposition 6. *The measure \mathcal{I}_0 is scale independent, population insensitive, symmetric, Sybil-proof, and satisfies the weak egalitarian zero and weak transfer principles.*

This result can be proven by going back to the definitions of the different axioms and seeing that, due to the measure being constant, these properties hold by definition.

Having observed that \mathcal{I}_0 satisfies the desiderata, including the weak egalitarian zero and transfer principles, consider that the specific choice that the metric would always output 0 is, while helpful in satisfying the weak egalitarian zero principle, also somewhat arbitrary. Indeed, \mathcal{I}_0 can be extended into a family of constant inequality metrics, as we do in Definition 10. We prove in Corollary 2 that this family is notable for comprising all scale-independent and population insensitive Sybil-proof measures.

Definition 10 (Constant Measure Family). *The constant measure family is the set $C \stackrel{\text{def}}{=} \{\mathcal{I}_c \mid c \in \mathbb{R}\}$, where for all $k \in \mathbb{N}$ and $x = (x_1, \dots, x_k)$ then: $\forall \mathcal{I}_c \in C : \mathcal{I}_c(x) = c$.*

Corollary 2. *Any Sybil-proof measure \mathcal{I} which is either scale independent or population insensitive must be part of the constant measure family and satisfy the symmetry and weak transfer principles. Moreover, \mathcal{I} satisfies the weak egalitarian zero principle iff $\mathcal{I} = \mathcal{I}_0$.*

The proofs that each of the properties mentioned by Corollary 2 are satisfied are corollaries of Propositions 3 to 5 and Theorem 3, with the exception of the egalitarian zero principle, which is a corollary of Proposition 6.

5.4 Completing the Characterization

To break away from the degenerate structure imposed by Corollary 2, we turn back to Theorem 2. By following the technique applied in that result’s proof to its logical conclusion, one can view any Sybil-proof measure as essentially a function which, given a wealth distribution vector, collates it into a single scalar value: its total wealth. We formalize this intuition in Definition 11 and Corollary 3.

Definition 11 (Sum Dependence). *Measure \mathcal{I} is sum-dependent iff for any distributions x, y where $x = (x_1, \dots, x_{k_1}) \in \mathbb{R}_{\geq 0}^{k_1}$, $y = (y_1, \dots, y_{k_2}) \in \mathbb{R}_{\geq 0}^{k_2}$ and $k_1, k_2 \in \mathbb{N}$: $\mathcal{I}(x) = \mathcal{I}(y) \Leftrightarrow \sum_{i \in [k_1]} x_i = \sum_{j \in [k_2]} y_j$.*

Notably, measures satisfying Definition 11 treat any distribution as if originating from a collusion by the grand coalition of all actors, akin to a world where all identities belong to one actor.

Corollary 3. *A measure is Sybil-proof iff it is sum-dependent. Such measures are symmetric and satisfy the weak transfer principle, and those which are scale independent or population insensitive are constant measures.*

This is proven by applying Theorem 2 and Corollary 2.

An interesting implication of Corollary 3 is that, because Sybil-proof measures are sum-dependent, then they essentially come with collusion-resistance baked-in. That is because such measures must treat any observable distribution as if it was generated by a single actor who may arbitrarily spread out wealth over many identities. Thus, Sybil manipulations are indistinguishable, from the perspective of an inequality measure, from a perfectly colluding grand coalition comprising all actors inhabiting the economy. That is not to say that results are driven by that form of strong collusion. In fact, some of the technical challenges we faced in our proofs stem from the delicate task of optimizing our analyses to minimize the amount of actors required to carry out Sybil manipulations. In fact, Sybil manipulations by a larger amount of actors are generally performed to “set the stage” and reach a state with well-defined inequality. Upon reaching such a state, it is taken as some counterfactual initial state, which is then used to drive results.

The technique driving Corollary 3 leads to another result.

Corollary 4. *A Sybil-proof measure \mathcal{I} satisfies the weak egalitarian zero principle iff $\mathcal{I} = \mathcal{I}_0$.*

To prove the first direction (\mathcal{I} is Sybil-proof and satisfies the weak egalitarian zero principle $\Rightarrow \mathcal{I} = \mathcal{I}_0$), consider some wealth distribution and aggregate it recursively until reaching a distribution comprised of a single entry. By definition, this is an egalitarian distribution, so the resulting inequality should equal 0 per Definition 7. By Theorem 2, a Sybil-proof measure is invariant under aggregation, and so the initial inequality should also equal 0. The other direction (\mathcal{I} is Sybil-proof and satisfies the weak egalitarian zero principle $\Leftarrow \mathcal{I} = \mathcal{I}_0$) is shown by Proposition 6.

6 Discussion

In this work, we take the perspective of an on-looker, e.g., a tax auditor, attempting to assess the inequality in a given economy. The on-looker has access to the wealth reports created by the population inhabiting the economy. These reports, while faithfully presenting the magnitude of the population’s underlying wealth, may be distorted due to actors spreading wealth across multiple Sybil identities. That is, the difficulty lies not in observing the amount of wealth, but in assigning it to the correct entities, as the linking between observable identities and “real” actors is hidden.

We have fully characterized all Sybil-proof measures. Our analysis reveals a fundamental tension between the traditional axiomatic foundations for inequality measures and their robustness to pseudonymity, which manifests in both digital and traditional settings. For example, this tension is not alleviated by relaxing strict properties like the transfer principle (perhaps embodying the essence of inequality measures) or replacing them with mild alternatives such as the egalitarian zero principle. The robustness of our results emphasize the challenges of devising Sybil-proof measures. Possible interesting directions for future theoretical work include considering other relaxations, e.g., robustness

to a bounded number of Sybils or providing approximate inequality guarantees in the presence of Sybils. We note that empirical studies highlight the general difficulty of assessing the parameters required for such measures to succeed in practice (Victor 2020; Messias, Yaish, and Livshits 2023).

We now highlight the generality of our of results.

6.1 Common Measures

We now apply our results to commonly-used measures.

Putting the Gini Back in the Bottle The GC is widely used (Patty and Penn 2019), and has been called the “default” choice (Neves Costa and Pérez-Duarte 2019) and the “most popular measure” (Ferreira 2020) for studying inequality. Notably, this measure was found to be more robust than others on data that may contain errors (Cowell and Victoria-Feser 1996). However, as we show in Corollary 5, it is not Sybil-proof. To see why, we first state one of the canonical formulations of the GC in Definition 12.

Definition 12 (Gini coefficient (GC)). *Given wealth distribution $x = (x_1, \dots, x_k)$ with $k \in \mathbb{N}$, the GC is defined as:*

$$\mathcal{I}_{GC}(x) \stackrel{\text{def}}{=} \frac{\sum_{i \in [k]} \sum_{j \in [k]} |x_i - x_j|}{2k \sum_{i \in [k]} x_i}.$$

Corollary 5. *The GC is not Sybil-proof.*

As can be gleaned from Definition 12, when applied to a strictly positive egalitarian distribution, the GC equals zero and thus immediately satisfies the weak egalitarian zero principle. This positions the GC squarely within the realm of Corollary 4. However, as the GC is not a constant measure (besides directly testing this using Definition 12, one can also observe Fig. 1), it cannot be Sybil-proof.

Generalized Entropy Measures The GE family of measures received attention by the foundational literature due to its convenient properties. Chief among them is decomposability, which we state in Definition 13 (following the definition of (Shorrocks 1984)). Intuitively, this property confers a measure the ability to estimate the inequality of a big group by considering the inequality of its subgroups and the subgroups’ means and population sizes.

Definition 13 (Decomposability). *Metric \mathcal{I} is decomposable iff there is a function D where for any $x = (x_1, \dots, x_{k_1}) \in \mathbb{R}_{\geq 0}^{k_1}$, $y = (y_1, \dots, y_{k_2}) \in \mathbb{R}_{\geq 0}^{k_2}$, and letting $\mu(x) = \frac{\sum_{i \in [k_1]} x_i}{k_1}$ and $\mu(y) = \frac{\sum_{j \in [k_2]} y_j}{k_2}$, then:*

$$\mathcal{I}(x \sqcup y) = D(\mathcal{I}(x), \mu(x), k_1, \mathcal{I}(y), \mu(y), k_2).$$

Results such as those of (Shorrocks 1984) show that the GC is not decomposable, and that any scale independent decomposable measure belongs to the GE family. Adapting the statement of (Shorrocks 1984), this is shown by Theorem 4.

Theorem 4 (GE Family (Shorrocks 1984)). *\mathcal{I} is scale independent and decomposable iff $\forall x = (x_1, \dots, x_k)$ there is a*

$c \in \mathbb{R}$ and a continuous function $F(\mathcal{I}, k)$ strictly increasing in its first parameter with $F(0, k) = 0$ such that:

$$F(\mathcal{I}(x), k) \stackrel{\text{def}}{=} \begin{cases} \frac{1}{kc(c-1)} \sum_{i \in [k]} \left(\left(\frac{x_i}{\mu(x)} \right)^c - 1 \right), & \text{if } c \neq 0, 1 \\ \frac{1}{k} \sum_{i \in [k]} \frac{x_i}{\mu(x)} \ln \left(\frac{x_i}{\mu(x)} \right), & \text{if } c = 1 \\ \frac{1}{k} \sum_{i \in [k]} \ln \left(\frac{\mu(x)}{x_i} \right), & \text{if } c = 0 \end{cases}$$

\mathcal{I} is also population invariant iff F is independent of k .

The literature shows that this characterization and its transformations admit a long list of measures, including the CV, the AM, and the HH, TL, and TT indices (Cowell 2011). However, we prove that this family is not Sybil-proof.

Corollary 6. *The GE family is not Sybil-proof.*

One can verify that none of these measures is constant, yet, due to their scale independence, we obtain from Corollary 3 that they cannot be Sybil-proof.

6.2 Sybils in Traditional and Digital Economies

Well-known strategies used to obscure wealth in conventional economies and digital ones serve as real-world analogs to the Sybil manipulations that we consider. We now discuss the implications of our results, in light of previous work studying both types of economies.

Traditional Economies The difficulty of assigning wealth to its owner is well-documented in traditional economies: individuals may utilize complex legal structures, such as shell corporations and irrevocable trusts, to legally distance themselves from assets (Auerbach and Siegel 2000). Such methods serve the same function as Sybil identities, obscuring the origins of observable wealth from onlookers.

Digital Economies In the digital world, identities may be easily hidden, and, in some cases, obscurity can even be the default modus operandi. For example, on (bitcoin.org 2025b), a website originally created by Bitcoin’s creator (bitcoin.org 2025a), an explicit directive is given:

“To protect your privacy, you should use a new Bitcoin address each time you receive a new payment. Additionally, you can use multiple wallets for different purposes. Doing so allows you to isolate each of your transactions in such a way that it is not possible to associate them all together. People who send you money cannot see what other Bitcoin addresses you own and what you do with them. This is probably the most important advice you should keep in mind.”

That need not even be said for actors who require the utmost obscurity. A prominent example is given by so-called airdrop farmers, specialized actors who may create many Sybil identities to maximize their profits from rewards issued by blockchain-based platforms (Halaburda, Livshits, and Yaish 2025). Platforms tend to give out per-capita rewards in an effort to create or expand their user-bases, and so, airdrop farmers attempt to ensure their different identities cannot be linked to each other. Some rewards are of *governance* tokens that enable voting on a platform’s direction, with several works noting that such designs put platforms at risk (Feichtinger et al. 2024a; Dotan et al. 2023).

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