Progressive Taxation as Contingent Claims: Income Risk, Equity and Fiscal Sensitivity

Jamie Alcock

Futures House Limited, United Kingdom.

Abstract

Progressive income tax schedules can be interpreted as portfolios of contingent claims on risky personal income. Using real options theory, I show that progressive tax schedules behave like portfolios of European call options, creating nonlinear exposure to income volatility and interest rate movements. The contingent-claim formulation allows for an explicit decomposition of fiscal exposure using standard option greeks, providing new tools to assess the responsiveness of fiscal policy to changes in risk. The contingent-claim approach reveals mismatches between conventional equity metrics and the realities of stochastic income, such as horizontal and vertical equity, under conditions of income uncertainty. A stylised simulation of UK fiscal dynamics during the 2007–2008 financial crisis illustrates the mechanism of "volatility creep", where increased income risk inflates effective tax burdens despite stable average incomes. My analysis reframes the relationship between tax design, redistribution, and macroeconomic risk in environments of rising income uncertainty.

Key words: Progressive income taxation, income risk, contingent claims, real options, tax equity, volatility creep, fiscal sensitivity, option greeks, redistribution under uncertainty, public finance.

JEL: H21, H24, D81, G13, H23

* *Corresponding Author*: Jamie Alcock, Futures House Limited, United Kingdom. Email: info@futureshouse.co.uk, I gratefully acknowledge the valuable discussions and feedback of Andrew Patton, Stephen Satchell, Hamish Malloch, Oh-Kang Kwon and Tom Mollee. All remaining errors are my own.

1 Introduction

I introduce a conceptual framework that decomposes progressive income tax systems into weighted portfolios of European call options on taxable income, with each tax bracket acting as an option triggered when income exceeds the threshold. Just as Mirrlees (1971) recast optimal taxation through mechanism design, and Varian (1980) interpreted taxation as insurance, this work reinterprets progressive taxation as a system of embedded contingent claims. This framework reveals fundamental challenges to traditional tax equity concepts under income uncertainty, demonstrating that conventional horizontal and vertical equity concepts become inadequate when incomes are stochastic and require reframing to account for differential insurance values across risk profiles.

This paper is primarily conceptual in nature, offering a new analytical framework for understanding progressive income taxation under uncertainty. The aim is to establish a generalisable theoretical structure that invites further empirical exploration, rather than to conduct dataset-bound hypothesis testing. While much of the recent literature focuses on empirical estimation or structural calibration (e.g., Heathcote, Storesletten and Violante, 2017), this paper follows the tradition of theoretical contributions such as Lucas and Stokey (1983), Diamond and Saez (2011), and Barro (1979), which introduced durable conceptual tools before empirical techniques matured to accommodate them.

Since Mirrlees (1971), public economists have understood that progressive taxation involves an equity-efficiency tradeoff. While subsequent literature has recognised the importance of income uncertainty for optimal tax design (Eaton and Rosen, 1980; Heathcote, Storesletten and Violante, 2017; Varian, 1980), the equity analysis has largely relied on concepts developed for deterministic environments, with limited systematic treatment of how uncertainty challenges traditional equity concepts.

Consider horizontal equity, the principle that “equals be treated equally” (Kaplow, 1989). Under income uncertainty, neither ex-ante horizontal equity (equal expected tax treatment for equal expected incomes) nor ex-post horizontal equity (equal actual treatment for equal actual incomes) adequately captures fairness. Ex-ante equity fails because of Jensen’s inequality and progressive-tax convexity, whilst ex-post equity ignores that individuals with identical realised incomes may have received different insurance values from progressive taxation. This necessitates new risk-adjusted equity concepts that account for both expected payments and insurance benefits. [1]

Vertical equity faces similar challenges. Traditional vertical equity requires that those with higher ability-to-pay contribute more to public finances. However, when incomes are uncertain, ability-to-pay must account for both expected income and the insurance value received. Two individuals with identical expected incomes but different income volatility have different risk-adjusted abilities to pay, as the high-volatility individual receives more valuable downside protection. Current measures of tax burden distribution may therefore

[1] Risk-adjusted equity, as defined in this paper, depends on an individual’s income volatility profile, which is an inherently latent variable that is difficult to observe directly, especially in cross-sectional data. Current panel datasets lack the granularity to reliably estimate individual-level exposure to volatility over the relevant tax cycle. This reinforces the need for a theoretical foundation prior to any meaningful empirical implementation.

be misleading because they ignore differential insurance benefits across risk profiles.

This paper builds on three theoretical traditions whilst challenging their equity foundations. First, I extend the optimal taxation literature (Diamond and Saez, 2011; Mirrlees, 1971) by incorporating option pricing techniques and revealing equity-concept limitations. Second, I apply contingent claim theory to the taxation-as-insurance literature (Eaton and Rosen, 1980; Varian, 1980), revealing that traditional equity concepts become inadequate when the insurance function is made explicit. Third, I contribute to financial economics by applying option pricing theory to questions in public finance.

The theoretical literature has recognised that income uncertainty transforms optimal tax design. Varian (1980) shows that progressive taxation serves as social insurance when income differences reflect "luck" rather than ability. Recent work proves that optimal progressivity increases with income volatility (Heathcote, Storesletten and Violante, 2017), whilst accounting for health risk increases optimal progressivity (Jung and Tran, 2023). However, this literature does not systematically address how uncertainty undermines traditional equity concepts or propose risk-adjusted alternatives.

Empirically, the insurance value of progressive taxation is substantial. Automatic stabilisers absorb roughly 38% of income shocks in the average EU country and 32% in the U.S. (Dolls, Fuerst and Peichl, 2012), whilst more progressive systems exhibit lower output volatility (Reith, Checherita-Westphal and Attinasi, 2016). Yet this insurance creates equity complications; progressive systems make government revenue more volatile and create differential insurance benefits that challenge traditional notions of equal treatment.

My contingent claims approach attempts to fill this theoretical gap, providing treatment of progressive taxation as a portfolio of financial derivatives and new equity concepts suited to uncertain environments. Using standard Black and Scholes (1973) tools, I derive closed-form expressions for taxation option values and risk sensitivities, revealing conditions under which traditional equity concepts fail and suggesting risk-adjusted alternatives.

The framework yields several insights. Income uncertainty increases government tax-claim-value through 'volatility creep'; fiscal expansion operating alongside traditional bracket creep (Heer and Trede, 2013; Immervoll, 2005). The option-portfolio greeks provide quantitative weights for decomposing fiscal expansion into constituent sources, transforming qualitative insights into analytical tools for fiscal management. This decomposition reveals how governments can coordinate with monetary authorities to manage fiscal risk, with interests aligning with taxpayers under volatility shocks but conflicting under level shocks.

This conceptual framework demonstrates that traditional horizontal equity becomes inadequate under uncertainty, requiring new concepts based on expected utility rather than expected tax payments. Vertical equity must incorporate insurance value through risk-adjusted measures of ability to pay. Optimal tax progressivity should respond to income-risk changes, with equity considerations supporting higher progressivity during uncertain periods. Fiscal-monetary coordination (Canzoneri, Cumby and Diba, 2010; Leeper, 2023) can manage government contingent claims whilst addressing equity concerns about differential treatment across risk profiles.

My contribution extends beyond taxation to questions about fairness in uncertain environments. When governments take "silent equity" stakes in risky individual incomes through convex tax schedules (Domar and Musgrave, 1944; Stiglitz, 1969), they create complex equity relationships that traditional concepts cannot capture. Progressive taxation becomes not just a tool for ex-post redistribution but also a mechanism for ex-ante insurance, requiring new frameworks for evaluating fairness.

This analysis establishes theoretical foundations for research extensions. State-contingent tax policies (Barro, 1979; Lucas and Stokey, 1983) could enhance both insurance provision and equity across different risk environments. Integration of tax and monetary policy through explicit recognition of their joint effects on government contingent claims could improve both macroeconomic management and equity outcomes. Development of new equity measures accounting for insurance value could transform evaluation of tax burden distribution.

To illustrate my framework's applicability, I present a stylised calibration using UK taxation parameters during the 2007-2008 financial crisis. While this paper does not provide an econometric test of the theory, the use of real UK tax schedules, central bank interest rates, and documented changes in income volatility during the crisis serves as a stylised calibration to demonstrate the economic salience of the proposed framework. This kind of stylised policy counterfactual is in the spirit of Lucas (1976), focusing on model-consistent interpretation rather than reduced-form identification. The application demonstrates how government tax claim changes decompose into components attributable to bracket creep, policy changes, volatility creep, and interest rate effects whilst highlighting how traditional equity measures may misrepresent true burden distribution when insurance values are ignored.

The option-theoretic framework developed here is not merely illustrative: it is analytically tractable, empirically calibratable, and general enough to be applied across a wide range of tax regimes and income distributions. The decomposition into greeks provides policy-relevant tools for macro-fiscal diagnostics that are portable across institutional settings.

I proceed as follows. Section 2 presents the theoretical model, showing how progressive tax schedules decompose into option portfolios. Section 3 explores implications for taxation equity. Section 4 analyses risk properties of taxation options, examining sensitivities and identifying conditions for government-taxpayer interest alignment. Section 5 provides the UK application. Section 6 concludes with theoretical implications and future research directions.

2 Progressive Tax Schedule as a Portfolio of Call Options

Progressive income-tax regimes can be modelled as a portfolio of European Call options on an individual's annual gross taxable income (GTI), whenever this GTI is uncertain. For example, consider the simple case of a single tax that is charged at a constant rate on GTI above a tax-free threshold, as described in Table 1.

The government's payoff to this simple taxation regime, ϕ_G, is a function of the individual's

A Simple Example of a Progressive Taxation Regime

Annual GTI	Marginal Income Tax Rate
$\leq$ \$20,000	0%
$>$ \$20,000	25%

Table 1
A simple example of a progressive tax regime. In this example, the tax-free threshold is $K_0 = \$20,000$ of GTI per annum and the marginal tax-rate on income above this threshold is $\tau_1 = 25\%$.

risky GTI over the tax year, γ_1, and is given by

$$\phi_G = \tau_1 \mathbb{I}_{\gamma_1 > K_0} \left(\gamma_1 - K_0 \right),$$

where $\mathbb{I}_A$ is the standard indicator function that equals one if A is true, and zero otherwise and where K_0 is the tax-free threshold and τ_1 is the marginal tax rate on GTI above K_0. The government's payoff can also be written in terms of a max function as

$$\begin{aligned} \phi_G &= \max\left(\tau_1(\gamma_1 - K_0), 0\right) \\ &= \tau_1 \max\left(\gamma_1 - K_0, 0\right), \end{aligned}$$

This payoff is equal to that of τ_1 times the payoff of a long position in a European Call option on the individual's GTI, struck at the tax-free threshold and maturing at the end of the tax year ($t = 1$). The option is European style because the payoff is calculated only on the underlying (GTI) on the final day of the tax-year. The payoff to this simple tax regime is graphically presented in Figure 1.

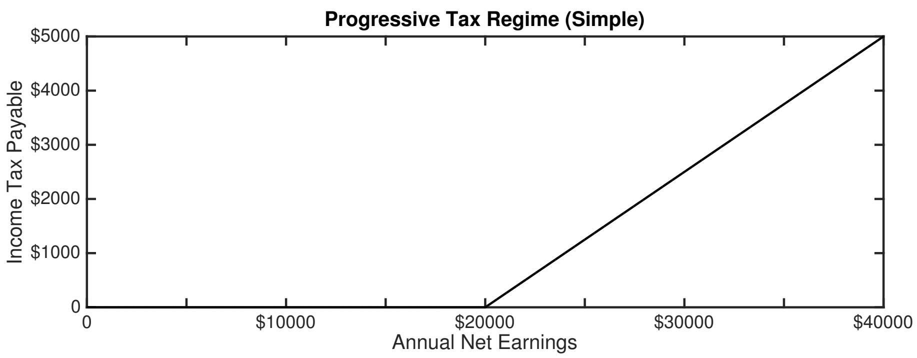

Fig. 1. A simple progressive tax regime corresponding to that described in Table 1. The tax-free threshold is $K_0 = \$20,000$ and the highest marginal rate of income tax is $\tau_1 = 20\%$. In this case, the government's tax claim has the same payoff as a $0.25\times$ a long Call option struck at K_0.

The present value of the taxation claim at the beginning of the tax year is given by

$$\Phi_G = \tau_1 C(K_0),$$

where $C(K_0)$ represents the present value of a European Call option struck at K_0 and maturing at time $t = 1$.

The case where there are two marginal income-tax rates (τ_1, τ_2), with tax-brackets at K_0 and K_1, is described in Table 2.

A Two-Tax Bracket Example of a Progressive Taxation Regime

Annual GTI	Marginal Income Tax Rate
$\leq \$K_0$	$\tau_0 = 0$
$\$K_1 - \$K_0$	τ_1
$\geq K_1$	τ_2

Table 2
An example of a progressive tax regime with two tax brackets and two marginal tax rates.

In the two-tax rate case, the governments claim at $t = 1$ is given by

$$\phi_G = \tau_1 \mathbb{I}_{K_1 \geq \gamma_1 > K_0}(\gamma_1 - K_0) + \tau_2 \mathbb{I}_{\gamma_1 > K_1}(\gamma_1 - K_1).$$

The second term in this expression can be decomposed into two parts,

$$\tau_2 \mathbb{I}_{\gamma_1 > K_1}(\gamma_1 - K_1) = \tau_1 \mathbb{I}_{\gamma_1 > K_1}(\gamma_1 - K_1) + (\tau_2 - \tau_1)\mathbb{I}_{\gamma_1 > K_1}(\gamma_1 - K_1).$$

That is, the tax rate of τ_2 on GTI above K_1 can be separated into τ_1 and $(\tau_2 - \tau_1)$. This allows the government's payoff to be decomposed into the sum of two max functions by

$$\begin{aligned} \phi_G &= \tau_1 \mathbb{I}_{K_1 \geq \gamma_1 > K_0}(\gamma_1 - K_0) + (\tau_1 \mathbb{I}_{\gamma_1 > K_1}(\gamma_1 - K_1) + (\tau_2 - \tau_1)\mathbb{I}_{\gamma_1 > K_1}(\gamma_1 - K_1)) \\ &= \tau_1 \mathbb{I}_{\gamma_1 > K_0}(\gamma_1 - K_0) + (\tau_2 - \tau_1)\mathbb{I}_{\gamma_1 > K_1}(\gamma_1 - K_1) \\ &= \tau_1 \max(\gamma_1 - K_0, 0) + (\tau_2 - \tau_1)\max(\gamma_1 - K_1, 0)\,. \end{aligned} \tag{1}$$

This payoff is equal to the sum of τ_1 times the payoff of a long position in a European Call option on the individual's GTI, struck at K_0 and maturing at the end of the tax year $(t = 1)$ and $(\tau_2 - \tau_1)$ times the payoff to the same option struck at K_1. The decomposition of the payoff to this tax regime is graphically presented in Figure 2. Accordingly, the present value of the two-tax progressive taxation claim at the beginning of the tax year is given by

$$\Phi_G = \tau_1 C(K_0) + (\tau_2 - \tau_1)C(K_1),$$

where $C(X)$ represents the present value of a European Call option struck at X and maturing at time $t = 1$.

A General Description of a Progressive Taxation Regime

Annual GTI	Marginal Income Tax Rate
$\leq \$K_0$	$\tau_0 = 0$
$\$K_0 - \$K_1$	τ_1
$\$K_1 - \$K_2$	τ_2
$\vdots$	$\vdots$
$\$K_{n-1} - \$K_n$	τ_n
$> \$K_n$	τ_{n+1}

Table 3
A general description of a progressive tax regime.

In the same manner, the general case a progressive taxation regime that includes multiple, increasing tax rates, such as that described in Table 3, can also be modelled as a portfolio of call options.

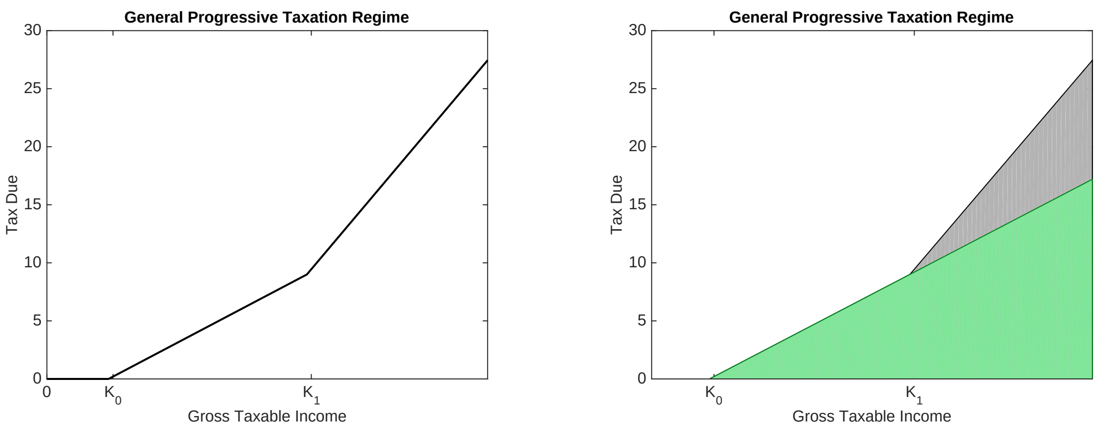

Fig. 2. Graphical representation of a progressive taxation regime with two tax-brackets, showing how the progressive tax regime has the same payoff as two European call options. The taxation scheme has zero income tax on GTI$< K_0$, a 20% tax on GTI between K_0 and K_1 and a marginal tax rate of 45% on GTI above K_1. The payoff of this taxation regime is equal to a weighted sum of two European call options: 0.2 times a call option struck at K_0 and $0.45 - 0.2 = 0.25$ times a call option struck at K_1.

In the general case, the government's payoff is thus given by

$$\begin{aligned}\phi_G =& \tau_1 \mathbb{I}_{K_1 \geq \gamma_1 > K_0}(\gamma_1 - K_0) \\ &+ \sum_{i=1}^{N-1} \tau_{i+1} \mathbb{I}_{K_{i+1} \geq \gamma_1 > K_i}(\gamma_1 t - K_i) + \tau_{N+1} \mathbb{I}_{\gamma_1 > K_N}(\gamma_1 - K_N). \\ =& \sum_{i=0}^{N} (\tau_{i+1} - \tau_i) \mathbb{I}_{\geq \gamma_1 > K_i}(\gamma_1 - K_i) \\ =& \sum_{i=0}^{n} (\tau_{i+1} - \tau_i) \max(\gamma_1 - K_i, 0).\end{aligned}$$

The present value of this claim, which I will refer to as the 'taxation option', is then given by

$$\Phi_G = \sum_{i=0}^{n} \Delta\tau_i C_i(K_i), \tag{2}$$

where $\Delta\tau_i = \tau_{i+1} - \tau_i$ are the increments in the marginal tax rate. Note that (2) also describes a regressive tax regime, as the $\Delta\tau$'s will be negative in this case and the government's claim will then be a portfolio of short call positions. In the special case of a constant tax rate $\tau_{i+1} = \tau_i$, $\forall i$ and $\phi_G = \tau_0 \gamma$.

The taxpayer then has a complementary claim on their GTI equal to the sum of their expected GTI and a short position in the taxation option. That is, the present value of the individual, risk-neutral taxpayer's claim on their own GTI is given by

$$\Phi_T = e^{-r_f}\bar{\gamma}_1 - \sum_{i=0}^{n} \Delta\tau_i C(K_i), \tag{3}$$

where $\bar{\gamma}_1$ is the expected value of the individual's GTI, γ_1. The taxpayer's claim also represents the present value of the taxpayer's net (after tax) income.

The *delta* and *vega* of a European Call option, defined as the derivative of the option value with respect to GTI level and volatility, respectively, of the underlying asset is greater than zero. That is, the present value of a European Call option increases with the level and volatility of the underlying process. In terms of the taxation option, this implies that the value of the taxation option increases with both the taxable income of the taxpayer and also the volatility of the taxpayer's taxable income. The recent trend of increasing volatility of both household and individual incomes (Feigenbaum and Li, 2015; Hacker, 2006; Jensen and Shote, 2011; Moffitt and Gottschalk, 2012; Shin and Solon, 2010) implies that the present value of the government's claims on taxpayers GTI has also been increasing. While this increase as it is related to GTI level is well known as income-tax bracket creep (Immervoll, 2005), the increase related to GTI volatility might better be described as "volatility creep".

2.1 Robustness and Extensions

The framework employs log-normal income processes for analytical tractability, following standard practice in financial economics. However, the core insights transcend specific distributional assumptions. The fundamental result that $\mathbb{E}[T(\gamma_i)] \neq T(\mathbb{E}[\gamma_j])$ under progressive taxation holds for any distribution with non-degenerate support, as it relies only on Jensen's inequality and tax convexity.

The contingent claim approach extends naturally to alternative income processes. For income distributions with known moment generating functions, Fourier transform methods can price taxation options. For empirically calibrated income processes, Monte Carlo simulation provides numerical solutions. The greeks decomposition framework applies regardless of the underlying income distribution, as it relies on the general sensitivity structure of contingent claims.

The framework also accommodates different tax system structures. Whilst I focus on bracket-based systems for clarity, the approach extends to any progressive (convex) tax function through appropriate option portfolio construction. Tax credits, phase-outs, and alternative minimum taxes can be incorporated through modified option structures.

3 Equity Implications Under Income Uncertainty

The contingent claim framework developed in the previous section provides new analytical tools for understanding progressive taxation, but it also reveals fundamental insights about both horizontal and vertical equity when incomes are uncertain. These insights have significant implications for how we evaluate the fairness of tax systems and design optimal tax policies in modern economies characterised by substantial income volatility.

While much of the recent literature focuses on empirical estimation or structural calibration (e.g., Heathcote, Storesletten and Violante (2017)), I follow the tradition of theoretical contributions such as Barro (1979); Diamond and Saez (2011); Lucas and Stokey (1983), who introduced durable conceptual tools before empirical techniques matured to accommodate them.

3.1 Taxonomy of Equity Concepts Under Uncertainty

Progressive taxation under uncertainty challenges traditional equity concepts in ways that require systematic analysis. I distinguish three approaches to horizontal equity, demonstrating why traditional concepts become inadequate and how risk-adjusted alternatives provide superior frameworks for evaluating fairness.

Ex-Ante Horizontal Equity (Traditional):
This concept requires equal expected tax treatment for individuals with equal expected incomes: for individuals i, j with $\mathbb{E}[\gamma_i] = \mathbb{E}[\gamma_j]$, require $\mathbb{E}[T(\gamma_i)] = \mathbb{E}[T(\gamma_j)]$. However, this fails under progressive taxation because of Jenson's inequality; progressive taxation is a convex function of GTI so $\mathbb{E}[T(\gamma_i)] \neq T(\mathbb{E}[\gamma_j])$. The contingent claim framework reveals that individuals with identical expected incomes but different income volatility face systematically different expected tax burdens, rendering this concept inadequate.

Ex-Post Horizontal Equity:
This concept requires equal actual tax treatment for individuals with equal actual incomes: for individuals. Whilst achievable, this concept ignores that individuals face different ex-ante insurance values from progressive taxation. Two individuals paying identical taxes may have received different insurance benefits, making this concept also insufficient for evaluating fairness under uncertainty.

Risk-Adjusted Horizontal Equity (Proposed Framework):
This concept requires equal expected utility from tax treatment for individuals with equal risk-adjusted ability to pay, accounting for both expected payments and insurance value. The contingent claim framework provides analytical tools for implementing this through precise measurement of insurance benefits across different risk profiles.

Similarly, vertical equity requires revisiting. Traditional vertical equity based solely on expected income ignores differential insurance value across risk profiles. Risk-adjusted vertical equity must account for both redistributive and insurance functions of progressive taxation, suggesting that current measures of tax burden distribution systematically misrepresent true incidence by ignoring insurance benefits.

Risk-adjusted equity, as employed here, depends on an individual's income volatility profile; an inherently latent variable that is difficult to observe directly, especially in cross-sectional data. Current panel datasets lack the granularity to reliably estimate individual-level exposure to volatility over the relevant tax cycle, reinforcing the need for a theoretical foundation prior to any meaningful empirical implementation.

3.2 Horizontal Equity Under Uncertainty

Horizontal equity, commonly defined as the principle that individuals in equal circumstances should receive equal treatment under the tax system, has long been considered a cornerstone of fair taxation (Musgrave, 1959; Simons, 1938). This principle, often summarised as "equal treatment of equals," provides an intuitive standard for evaluating tax policy and has influenced both theoretical analysis and practical tax design for decades (Kaplow, 1989). In deterministic settings, the application of horizontal equity appears straightforward: individuals with identical incomes should face identical tax burdens.

However, when incomes are stochastic, the seemingly clear principle of horizontal equity encounters fundamental conceptual difficulties that have received limited attention in the literature. The contingent claim framework makes these difficulties explicit and demonstrates that they represent more than mere measurement challenges; they constitute a fundamental theoretical impossibility.

Consider two individuals who are identical in all respects except for the riskiness of their income streams. Both individuals have the same expected income, but one faces a deterministic income while the other faces an uncertain income with the same expected value. Under a progressive tax system, these two individuals will face systematically different expected tax burdens, despite being "equal" in terms of expected income. The individual with uncertain income will, on average, pay higher taxes due to the convex nature of the progressive tax schedule, a manifestation of Jensen's inequality applied to taxation.

More formally, consider individual i with deterministic income $Y_i = \bar{Y}$ and individual j with stochastic income Y_j such that $E[Y_j] = \bar{Y}$ but $\text{Var}(Y_j) > 0$. Under a progressive tax function $T(\cdot)$ with $T'(\cdot) > 0$ and $T''(\cdot) > 0$, we have:

$$T(\bar{Y}) < E[T(Y_j)]$$

This inequality follows directly from Jensen's inequality and the convexity of the tax function. The contingent claim framework makes this relationship explicit by showing that the government's expected tax revenue from individual j exceeds that from individual i by exactly the value of the embedded options created by the progressive tax structure.

This analysis reveals that horizontal equity, as traditionally conceived, becomes conceptually impossible under income uncertainty. The question is not merely one of practical measurement difficulties or administrative challenges, but rather a fundamental understanding of possibilities. When incomes are stochastic, there exists no tax system that can simultaneously maintain progressivity and ensure equal expected treatment of individuals with equal expected incomes.

This finding connects to broader critiques of horizontal equity in the public finance literature. Kaplow (1989) has argued that horizontal equity lacks normative foundation and may conflict with welfare maximization, noting that the pursuit of horizontal equity can "conflict with the basic foundations of welfare economics." The uncertainty case provides a concrete illustration of Kaplow's more general critique, showing how the pursuit of horizontal equity under uncertainty would require abandoning either progressivity or equal treatment.

The option pricing perspective suggests that this tension is not merely a theoretical curiosity but has practical implications for tax policy evaluation. Traditional measures of horizontal inequity, such as those developed by Plotnick (1981) and Auerbach and Hassett (2002), may systematically mischaracterise the equity properties of tax systems when applied to economies with uncertain incomes. These measures typically compare the tax burdens of individuals with similar observed incomes. But they fail to account for the fact that individuals with identical expected incomes but different income volatilities should rationally face different expected tax burdens under an optimal progressive system.

3.3 Vertical Equity and Risk-Adjusted Ability to Pay

While the breakdown of horizontal equity under uncertainty presents fundamental conceptual challenges, the contingent claim framework also provides new insights into vertical equity; the principle that individuals with greater ability to pay should contribute proportionally more to public finances (Musgrave, 1959; Simons, 1938). The traditional conception of vertical equity relies on income as the primary measure of ability to pay, but the option pricing perspective suggests that this measure may be incomplete when incomes are uncertain.

Under the contingent claim framework, the government's tax claim on an individual represents not only a revenue extraction mechanism but also an insurance contract. The progressive tax system provides valuable insurance services to taxpayers by offering protection against income volatility through its convex structure. This insurance component complicates traditional vertical equity comparisons, as individuals with identical expected incomes but different risk profiles receive different amounts of insurance value from the tax system.

Consider two high-income individuals: one with a stable salary and another with highly volatile entrepreneurial income. While both may have identical expected incomes, the entrepreneur receives substantially more insurance value from the progressive tax system due to the convex contingent claim nature of the tax schedule. When the entrepreneur's income falls below expectations, the progressive tax system provides proportionally greater tax relief than it would to the salaried individual experiencing the same income decline. Conversely, when the entrepreneur's income exceeds expectations, the progressive system extracts proportionally more revenue.

The contingent claim framework suggests that vertical equity comparisons should account for these differential insurance benefits. A complete measure of ability to pay under uncertainty should include not only expected income but also the value of insurance services received from the tax system. This risk-adjusted concept of ability-to-pay provides a more nuanced foundation for vertical equity analysis in uncertain environments.

This insight has practical implications for measuring and evaluating tax burden distribution. Traditional measures of vertical equity, such as effective-tax-rate-progressivity calculated by Musgrave (1959) and refined by subsequent researchers, may mischaracterise the fairness of tax systems by ignoring the insurance services provided to different taxpayers. A more complete analysis would adjust tax burden measures for the value of insurance received, potentially revealing that apparently regressive features of tax systems may actually enhance overall equity when insurance values are properly accounted for.

My framework thus suggests that optimal vertical equity under uncertainty requires balancing three considerations: traditional redistributive objectives, insurance provision across income states, and the differential insurance needs of taxpayers with varying risk profiles. This multi-dimensional view of vertical equity provides a richer foundation for tax policy design and evaluation in modern economies characterised by substantial income volatility.

3.4 Alternative Equity Concepts for Uncertain Environments

The breakdown of traditional equity concepts under uncertainty suggests the need for alternative frameworks better suited to stochastic environments. The contingent claims framework provides analytical tools for developing these new concepts and implementing them in practice.

One possibility is to focus on ex-ante equity, ensuring equal treatment of individuals who are identical in all respects, including the distribution of their income prospects, rather than merely their expected incomes. Under this criterion, individuals with identical income distributions would face identical expected tax burdens, while those with different risk profiles would appropriately face different expected burdens. This approach acknowledges that risk characteristics are fundamental determinants of economic circumstances and should be reflected in tax treatment.

Alternatively, the insurance perspective on progressive taxation (Eaton and Rosen, 1980; Varian, 1980) suggests that equity might be better evaluated in terms of the risk-sharing properties of the tax system rather than the equal treatment of expected incomes. From this viewpoint, the higher expected tax burden faced by individuals with volatile incomes represents the premium for the insurance services provided by the progressive tax system, similar to how insurance premiums vary with risk characteristics in private markets.

The contingent claim framework provides analytical tools for implementing these alternative equity concepts. By explicitly valuing the insurance components of progressive taxation, the framework enables policymakers to distinguish between equity violations that represent genuine unfairness and apparent inequities that reflect appropriate risk-based pricing of government-provided insurance. This capability is particularly valuable for evaluating tax reforms and designing optimal tax systems in uncertain environments.

3.5 Policy Implications and Measurement Challenges

These theoretical insights have practical implications for tax policy design and evaluation. First, they suggest that traditional equity measures may be misleading when applied to modern economies characterised by substantial income volatility. Policymakers who rely on these measures may incorrectly diagnose equity problems or propose reforms that actually worsen rather than improve the fairness of the tax system.

Second, the analysis implies that optimal tax design under uncertainty should explicitly account for the option values created by progressive taxation. Tax reforms that appear to improve equity by reducing the differential treatment of individuals with similar observed incomes may actually reduce welfare by undermining the insurance properties of the tax system. The contingent claim framework provides tools for evaluating these trade-offs and designing reforms that appropriately balance competing objectives.

Third, the framework suggests that coordination between tax and monetary policy may have equity implications that have not been fully recognised. Since the value of the government's tax options depends on the risk-free rate, monetary policy decisions affect the distribution of tax burdens across individuals with different income risk profiles. This creates a channel through which monetary policy can influence tax equity, potentially requiring coordination between fiscal and monetary authorities to achieve desired distributional outcomes.

The measurement challenges identified here also point toward new research directions. Empirical work is needed to quantify the magnitude of equity effects created by income uncertainty under existing tax systems. Such analysis would require detailed data on individual income volatility and careful application of the option pricing methodology. Additionally, the development of new equity measures that account for insurance values represents an important area for future theoretical and empirical research.

3.6 Implications for Tax System Design

The equity insights derived from the contingent claim framework have direct implications for tax system design. Traditional approaches to tax design typically focus on the trade-off between equity and efficiency, with equity measured using conventional horizontal and vertical equity concepts. The analysis presented here suggests that this framework is incomplete in uncertain environments and may lead to suboptimal policy choices.

A more complete approach to tax design under uncertainty would explicitly account for the insurance properties of progressive taxation and their implications for equity evaluation. This might involve designing tax systems that optimise the trade-off between traditional distributional objectives and risk-sharing benefits, using the contingent claim framework to value the insurance components of different tax structures.

The framework also suggests that tax system design should consider the interaction between tax policy and other sources of income insurance, such as social insurance programs and private insurance markets. The option-like properties of progressive taxation may substitute for or complement these other insurance mechanisms, with implications for optimal policy design across different domains.

Furthermore, the analysis highlights the importance of considering the temporal dimension of equity in tax system design. Traditional equity concepts focus on annual income and tax burdens, but the contingent claim framework suggests that lifetime or multi-period equity concepts may be more appropriate in uncertain environments. This perspective aligns with recent work on lifetime income taxation (Krueger and Wu, 2025) and optimal taxation more generally (Kaplow, 2024).

4 Risk Properties and Policy Coordination

The contingent claim framework reveals that progressive taxation creates complex risk relationships between governments and taxpayers that depend critically on the nature of income shocks. This section analyses the risk sensitivities of taxation options and identifies conditions under which government and taxpayer interests align or conflict. These insights have important implications for coordinating fiscal and monetary policy under uncertainty.

4.1 Government-Taxpayer Interest Alignment

A key insight from the options perspective is that government and taxpayer preferences regarding policy adjustments depend on whether income shocks affect volatility or levels. To formalise this, consider how both parties' claims respond to changes in the risk-free rate following income shocks.

Assume that the government seeks to preserve the value of its taxation option portfolio, Φ^G, while taxpayers seek to preserve the value of their after-tax income claim. When income uncertainty changes, both parties may benefit from coordinated monetary policy responses, but only under specific conditions.

Any adjustment to the risk-free rate will alter the value of either the government or the taxpayer's claim, or both. To the extent that an alternative risk-free rate adjustment is followed,[2] the value of both the government and individual taxpayer's claim will move in the same direction, and hence the government and taxpayer will have coincident preferences with respect to the direction of changes to the risk-free rate, if the differential coefficients in (4) and (6) have the same sign.

To explore this further, I consider two different cases for the process governing the underlying GTI: first I assume that the cumulative GTI process is log-normally distributed, and second I assume that the instantaneous GTI process is log-normally distributed.

4.2 Log-Normal Cumulative Income Process

When cumulative GTI process is log-normally distributed, as described by

$$d\gamma_t = \mu_\gamma \gamma_t dt + \sigma_\gamma \gamma_t dW_t, \tag{4}$$
$$\gamma_0 = \gamma^*, \tag{5}$$

[2] For example, to pursue a Keynesian-style stimulatory monetary policy.

then the present value of the taxation option in this case is then given by the sum of standard Black and Scholes (1973) Call option prices (C_i):

$$\Phi^G = \sum_{i=0}^{n} \Delta\tau_i C_i(K_i), \tag{6}$$

$$= \sum_{i=0}^{n} \Delta\tau_i \left[\gamma^* N(d_{1,K_i}) - K_i e^{-r_f} N(d_{2,K_i})\right], \tag{7}$$

$$\phi^T = e^{-r_f}\bar{\gamma}_1 - \sum_{i=0}^{n} \Delta\tau_i \left[\gamma^* N(d_{1,K_i}) - K_i e^{-r_f} N(d_{2,K_i})\right], \tag{8}$$

where $N(x)$ is the cumulative standard Normal distribution function evaluated at x and, because the option matures at time $t = 1$, where

$$d_{1,y} = \frac{\log(\gamma^*/y) + r_f + \sigma_\gamma^2/2}{\sigma_\gamma}, \tag{9}$$

$$d_{2,y} = d_{1,y} - \sigma_\gamma. \tag{10}$$

The greeks of the European call option are available in closed-form and, for $t = 1$, are given by

$$\frac{\partial C(K)}{\partial \gamma^*} = N(d_{1,K}) \tag{11}$$

$$\frac{\partial C(K)}{\partial \sigma_\gamma} = \frac{\partial C(K)}{\partial r_f} = K e^{-r_f} N(d_{2,K}) \tag{12}$$

Substituting these values into (4) I obtain the risk-free rate that minimises the government's risk as

$$dr_f = -\frac{e^{r_f}\sum_{i=0}^{n}\Delta\tau_i N(d_{1,K_i})}{\sum_{i=0}^{n}\Delta\tau_i K_i N(d_{2,K_i})} d\sigma_\gamma + \frac{e^{r_f}\sum_{i=0}^{n}\Delta\tau_i N(d_{1,K_i})}{\sum_{i=0}^{n}\Delta\tau_i K_i N(d_{2,K_i})} d\gamma^* < 0. \tag{13}$$

This simplifies to

$$dr_f = -d\sigma_\gamma, \quad \text{and} \tag{14}$$

$$dr_f = -\frac{e^{r_f}\sum_{i=0}^{n}\Delta\tau_i N(d_{1,K_i})}{\sum_{i=0}^{n}\Delta\tau_i K_i N(d_{2,K_i})} d\gamma^*, \tag{15}$$

under exogenous GTI volatility and level shocks, respectively.

That is, in order to preserve the value of the government's claim when the taxpayer's cumulative earnings is subject to a negative exogenous shock to either the GTI level or volatility, the government should increase the risk-free rate. Intuitively, a negative shock to the taxpayer's cumulative earnings decreases the moneyness of the tax option, thereby decreasing the present value of the option. Increasing the risk-free rate compensates for this loss by decreasing the discount applied to the future risk-neutral cash flows, thereby increasing the option value. Given that the change in tax-rates appears on both the numerator and the denominator, this result holds for both progressive and regressive taxation regimes.

To consider the impact of risk-free rate on the taxpayer's claim, I note that the expected value of the cumulative GTI process, $\bar{\gamma}_1 = E\gamma_1 = \gamma^* e^{\mu_\gamma}$, so $\partial\bar{\gamma}_1/\partial\sigma_\gamma = 0$ and $\partial\bar{\gamma}_1/\partial\gamma^* = e^{\mu_\gamma}$. Substituting these terms and the greeks above into (6), I obtain

$$\begin{aligned} dr_f =& e^{-r_f}\left(\bar{\gamma}_1 + \sum_{i=0}^{n}\Delta\tau_i K_i N(d_{2,K_i})\right)^{-1} \\ &\times\left[-d\sigma_\gamma\sum_{i=0}^{n}\Delta\tau_i K_i N(d_{2,K_i}) + e^{\mu_\gamma}\left(\sum_{i=0}^{n}\Delta\tau_i N(d_{1,K_i})\right)d\gamma^*\right], \end{aligned} \tag{16}$$

Under the assumption that $0\% \leq \tau_0 < \tau_1 < \cdots < \tau_n \leq 100\%$ then the set $T = \{0, \Delta\tau_0, \Delta\tau_1, \ldots, \Delta\tau_n, 1-\tau_n\}$ forms a probability measure. As the $0 < N(d_{j,K}) < 1$, $j = 1, 2$, almost surely then

$$0 \leq \sum_{i=0}^{n}\Delta\tau_i N(d_{j,K_\tau}) \leq E_T(N(d_{j,K})) \leq 1. \tag{17}$$

So under an exogenous GTI volatility shock, (10) becomes

$$dr_f = -d\sigma_\gamma\left(\frac{e^{-r_f}\bar{\gamma}_1}{1 + \sum_{i=0}^{n}\Delta\tau_i K_i N(d_{2,K_i})}\right)^{-1} < 0, \tag{18}$$

which is the same sign as for the government's claim (8). Under an exogenous GTI level shock, (10) becomes

$$dr_f = e^{-r_f}\left(\bar{\gamma}_1 + \sum_{i=0}^{n}\Delta\tau_i K_i N(d_{2,K_i})\right)^{-1}\left(e^{\mu_\gamma}\sum_{i=0}^{n}\Delta\tau_i N(d_{1,K_i})\right)d\gamma^* > 0, \text{ if } \mu_\gamma > 0, \tag{19}$$

which is the opposite sign to that of the government's claim (9).

This analysis reveals a fundamental asymmetry: government and taxpayer interests align under volatility shocks but conflict under level shocks. We can hence make the following statements: (i) If the volatility of the taxpayer's GTI is subject to an exogenous shock then adjusting the risk-free rate in the opposite direction to the shock will help maintain the value of both the government's claim and the taxpayer's claim, (ii) If the level of the taxpayer's GTI is subject to an exogenous shock then adjusting the risk-free rate in the opposite direction to the shock will help maintain the value of the government's claim and detract from the value of the taxpayer's claim. That is, the government's preference coincides with that of the taxpayer in the case of a GTI volatility shock and conflicts with that of the taxpayer in the case of a shock to GTI levels.

4.3 Log-Normal Instantaneous Income Process

For robustness, I now consider the case when an individual's instantaneous GTI process is log-normally distributed, as described by the geometric Brownian motion (GBM),

$$dE_t = \mu E_t dt + \sigma E_t dW_t, \tag{20}$$
$$E_0 = E > 0, \tag{21}$$

where W_t is a standard Brownian motion. The annual GTI of the individual taxpayer is the integral of this income process over the tax year,

$$\gamma = \int_0^1 E_t dt, \tag{22}$$

which has an expectation given by

$$\bar{\gamma}_1 = E\left[\int_0^1 E_t dt\right] \tag{23}$$
$$= \frac{E}{\mu}(e^{\mu} - 1). \tag{24}$$

Under this assumption, the payoff to the taxation option is given by

$$\phi^G = \sum_{i=0}^{n}(\tau_{i+1} - \tau_i) \max\left[\int_0^1 E_t dt - K_i, 0\right]. \tag{25}$$

This payoff is equal to that of a long position in a weighted portfolio of European-style, fixed-strike, Asian Call options, where the weights are given by the increments in the marginal tax rates, $\Delta\tau_i$, struck at the tax-free thresholds and maturing at the end of the tax year ($t = 1$).

Just as the closed-form analytic solution to the arithmetic Asian option price has not yet been found, [3] so closed-form analytic solutions to the greeks of Asian options have not yet been found. Nevertheless, we can draw meaningful contrasts between the government and the taxpayer's perspectives through noting the relative sign of terms in (4) and (6). For example, as $\partial\Phi^G/\partial r_f$ and $\bar{\gamma}_1$ are both greater than or equal to zero, the taxpayers perspective, (6), will coincide with that of the government, (4), if

$$e^{-r_f}\frac{\partial\bar{\gamma}_1}{\partial\sigma} < \frac{\partial\Phi^G}{\partial\sigma}, \quad \text{and} \tag{26}$$
$$e^{-r_f}\frac{\partial\bar{\gamma}_1}{\partial E} < \frac{\partial\Phi^G}{\partial E} \tag{27}$$

[3] Rogers and Shi (1995) suggest that such a closed-form solution is unlikely to ever be found.

From (12), we then have

$$0 < \frac{\partial \Phi^G}{\partial \sigma}, \quad \text{and} \tag{28}$$

$$\frac{1}{\mu}(e^{\mu} - 1)e^{-r_f} < \frac{\partial \Phi^G}{\partial E} \tag{29}$$

The first of these conditions holds because the vega of a European, fixed-strike, arithmetic Asian option is strictly positive when the instantaneous GTI process follows a geometric Brownian motion (Carr, Ewald and Xiao, 2008). That is, the government's perspective will always coincide with that of the individual with respect to a GTI volatility shock. Another way to view this result is to consider any adjustment to the risk-free rate in response to, or in anticipation of, a GTI volatility shock. If such an adjustment improves the value of the government claim, it will also improve the value of the individual's claim over their GTI, and vice-versa.

The second of these conditions can only hold if

$$\frac{1}{\mu}(e^{\mu} - 1)e^{-r_f} < 1, \tag{30}$$

or

$$\log(e^{\mu} - 1) - \log(\mu) < r_f \tag{31}$$

$$\log\left(1 + \mu + \frac{\mu^2}{2} - 1\right) - \log(\mu) \lesssim r_f \tag{32}$$

$$\log\left(1 + \frac{\mu}{2}\right) \lesssim r_f \tag{33}$$

$$\frac{\mu}{2} \lesssim r_f. \tag{34}$$

That is, the second of these conditions can only realistically[4] hold if two conditions are simultaneously met: i) that the risk-free rate is greater than $\mu/2$, and ii) the portfolio of Asian options are sufficiently 'in-the-money' so that the option portfolio delta is close to one. That is, the government's perspective will coincide with that of an individual with very high GTI only if the risk-free rate is higher than $\mu/2$. The government's perspective will conflict with that of an individual with a lower GTI, or when the risk-free rate is lower than $\mu/2$. Another way to view this result is to consider any adjustment to the risk-free rate in response to, or in anticipation of, a shock to income levels. If such an adjustment improves the value of the government claim, it will reduce the value of a lower-income individual's claim and the value of a very high-income individual's claim if the risk-free rate is already low.

[4] Of course, other circumstances are theoretically possible but unrealistic. For example, consider the case where the risk-free rate of return is 50% per annum and the ex ante expected income growth rate is negative. This situation, and others like it, are sufficiently unlikely that I ignore these possibilities.

4.4 Greeks as Fiscal Expansion Weights

The greeks of the taxation option portfolio provide a natural framework for decomposing fiscal expansion into its constituent sources, offering precise quantitative weights for the relative importance of different economic factors in determining government revenue dynamics. This decomposition transforms the qualitative insights about volatility creep and policy coordination into a practical analytical tool for fiscal management.

Consider the total differential of the government's taxation option value:

$$d\Phi^G \approx \frac{\partial \Phi^G}{\partial \gamma^*} d\gamma^* + \frac{\partial \Phi^G}{\partial \sigma} d\sigma + \frac{\partial \Phi^G}{\partial r_f} dr_f + \frac{\partial \Phi^G}{\partial t} dt \tag{35}$$

This can be rewritten using standard option terminology as:

$$d\Phi^G \approx \Delta \cdot d\gamma^* + \nu \cdot d\sigma + \rho \cdot dr_f + \Theta \cdot dt \tag{36}$$

where Δ (delta), ν (vega), ρ (rho), and Θ (theta) represent the standard option sensitivities. Each Greek provides the weight of a specific source of fiscal expansion:

(1) Delta (Δ) measures the sensitivity to income level changes, capturing traditional bracket creep effects. The weighted probability that each tax bracket will be triggered, $\Delta = \sum_{i=0}^{n} \Delta\tau_i N(d_{1,K_i})$ for the cumulative log-normal income process,
(2) Vega (ν) measures the sensitivity to volatility changes, capturing volatility creep effects. This quantifies how much government revenue changes per unit increase in income uncertainty, with $\nu = \sum_{i=0}^{n} \Delta\tau_i K_i e^{-r_f} N(d_{2,K_i})$,
(3) Rho (ρ) measures the sensitivity to interest rate changes, capturing monetary policy effects on fiscal position. This reveals how fiscal and monetary policy interact through the government's contingent claim structure.

The relative importance of each source can be quantified through normalised weights:

$$w_{\text{bracket}} = \frac{|\Delta \cdot d\gamma^*|}{|\Delta \cdot d\gamma^*| + |\nu \cdot d\sigma| + |\rho \cdot dr_f|} \tag{37}$$

$$w_{\text{volatility}} = \frac{|\nu \cdot d\sigma|}{|\Delta \cdot d\gamma^*| + |\nu \cdot d\sigma| + |\rho \cdot dr_f|} \tag{38}$$

$$w_{\text{monetary}} = \frac{|\rho \cdot dr_f|}{|\Delta \cdot d\gamma^*| + |\nu \cdot d\sigma| + |\rho \cdot dr_f|} \tag{39}$$

These weights provide direct policy guidance. When $w_{\text{volatility}}$ dominates, uncertainty management becomes the primary fiscal concern. When w_{bracket} dominates, traditional fiscal policy tools remain most relevant. When w_{monetary} is significant, fiscal-monetary coordination becomes essential.

The tax greeks also reveal the dynamic nature of fiscal expansion sources. As economic conditions change, the relative weights shift, suggesting that optimal fiscal policy should adapt to the dominant source of revenue variation. During periods of high uncertainty, vega effects may dominate, calling for policies that manage volatility rather than simply adjusting tax rates. During stable growth periods, delta effects may dominate, making traditional bracket creep management more important.

This framework transforms the taxation option approach from a theoretical curiosity into a practical tool for fiscal analysis, providing quantitative guidance for policy responses based on the underlying sources of revenue variation.

4.5 Implications for Monetary Policy Coordination

For both cases of the underlying distribution considered, (7) and (11), the government perspective aligns with the taxpayer's perspective in the case of a GTI volatility shock. The government's perspective conflicts with the taxpayer's perspective in the case of a GTI level shock, for those taxpayers whose GTI is not 'very high' relative to the top tax bracket boundary.

Consider these outcomes in terms of the effect of a stimulatory monetary policy, resulting in a decreased risk-free rate, on the value of the government's claim and the taxpayer's claim over their cumulative GTI. If the stimulatory monetary policy does not coincide with a change in GTI volatility or level then reducing the risk-free rate of return will reduce the value of the taxation option by an amount approximately equal to the option rho $= d\Phi^G/dr_f$ multiplied by the change in the risk-free rate of return,

$$d\Phi^G \approx \frac{d\Phi^G}{dr_f}\Delta r_f < 0 \text{ when } \Delta r < 0. \tag{40}$$

If the rho of the government's call option is greater than zero, then reducing the risk-free rate of return will reduce the present value of the government's claim over the taxpayer's earnings. Correspondingly, the taxpayer's claim over their earnings will increase.

If the monetary stimulation coincides with a positive shock to the taxpayer's GTI volatility then the increase in volatility will have a counteracting influence on both the long and short position of the taxation option.

$$d\Phi^G \approx \frac{d\Phi^G}{d\sigma}\Delta\sigma + \frac{d\Phi^G}{dr_f}\Delta r_f = 0 \tag{41}$$

if

$$-\Delta r_f = \underbrace{\left(\frac{d\Phi^G}{dr_f}\right)^{-1}}_{+\text{ve}} \times \underbrace{\frac{d\Phi^G}{d\sigma}}_{+\text{ve}}\Delta\sigma = +\text{ve} \times +\text{ve}. \tag{42}$$

That is, reducing the risk-free rate at the same time as the GTI volatility increases will have a stabilising effect on the present value of both the government's claim and the taxpayers claim.

In contrast, if the monetary stimulation coincides with a negative shock to the GTI level then the decrease in the GTI level will have a compounding influence on the short position of the taxation option, and a counteracting influence on the long position. That is, reducing the risk-free rate at the same time as the earnings level decreases will have a stabilising effect on the present value of the taxpayers claim and will amplify the negative earnings shock to the government's claim.

These results have important implications for coordinating fiscal and monetary policy during economic turbulence. When economic uncertainty increases income volatility (as during financial crises), expansionary monetary policy benefits both governments and taxpayers. Lower interest rates help maintain the value of government tax claims while preserving taxpayer after-tax income. This creates a natural alignment for coordinated policy responses. However, when economic downturns primarily affect income levels rather than volatility, policy coordination becomes more challenging. Governments may prefer tighter monetary policy to maintain tax revenue values, while taxpayers benefit from looser policy. This conflict suggests that fiscal policy adjustments (such as temporary tax rate changes) may be more appropriate than monetary responses.

This analysis provides a new framework for understanding the interaction between fiscal and monetary policy under uncertainty, suggesting that the nature of economic shocks should guide the choice of policy instruments and the degree of coordination between fiscal and monetary authorities.

4.6 Implications for Monetary Policy Coordination

These results have important implications for coordinating fiscal and monetary policy during economic turbulence:

(1) Volatility-Driven Crises: When economic uncertainty increases income volatility (as during financial crises), expansionary monetary policy benefits both governments and taxpayers. Lower interest rates help maintain the value of government tax claims while preserving taxpayer after-tax income. This creates a natural alignment for coordinated policy responses,
(2) Level-Driven Recessions: When economic downturns primarily affect income levels rather than volatility, policy coordination becomes more challenging. Governments may prefer tighter monetary policy to maintain tax revenue values, while taxpayers benefit from looser policy. This conflict suggests that fiscal policy adjustments (such as temporary tax rate changes) may be more appropriate than monetary responses,
(3) Distributional Considerations: The conflict between government and taxpayer interests under level shocks is most pronounced for lower-income taxpayers. High-income taxpayers may share government preferences for higher interest rates, creating potential political economy tensions in policy responses.

The framework suggests that optimal policy responses should account for the nature of income shocks:

(1) For Volatility Shocks: Coordinated monetary easing can stabilise both government revenue and taxpayer welfare. The optimal adjustment satisfies $\Delta r_f = -\Delta\sigma_\gamma$, providing a precise guide for policy coordination,
(2) For Level Shocks: Fiscal policy adjustments may be more effective than monetary responses. Temporary reductions in tax rates can offset the negative effects of income declines while avoiding the government-taxpayer conflict inherent in monetary adjustments,
(3) Mixed Shocks: During complex economic disruptions involving both volatility and level effects, policymakers must weigh the stabilising effects of monetary policy on volatility against its potentially destabilising effects on level adjustments.

This analysis provides a new framework for understanding the interaction between fiscal and monetary policy under uncertainty, suggesting that the nature of economic shocks should guide the choice of policy instruments and the degree of coordination between fiscal and monetary authorities.

5 Equity Implications Under Uncertainty: UK Financial Crisis Example

While I do not provide an econometric test of the theory, the use of real UK tax schedules, central bank interest rates, and documented changes in income volatility during the 2007–2008 crisis serves as a stylised calibration to demonstrate the economic salience of the proposed framework. This kind of stylised policy counterfactual is in the spirit of Lucas (1976), focusing on model-consistent interpretation rather than reduced-form identification.

I examine UK Income Tax during the 2007-2008 financial crisis. This period provides an ideal natural experiment, combining significant changes in income volatility, tax policy, and monetary conditions that reveal the practical importance of reframing equity under uncertainty. My analysis demonstrates how traditional equity measures become misleading when insurance values are ignored and shows the relevance of volatility creep as a distinct fiscal phenomenon.

Throughout this period, the Bank of England reduced the UK Base Rate from 5.5% to 0.5% per annum (Bank of England, 2015). In addition, the income tax rates and thresholds changed substantially (UK Government, 2015) and personal income volatility increased dramatically (Office of National Statistics, 2015). I explore how these simultaneous changes reveal the breakdown of traditional horizontal equity, necessitate risk-adjusted vertical equity measures, and demonstrate the policy coordination insights from Section 4.

The tax rates for the financial years 2007-8 and 2008-9 are described in Table 4.[5] For the 2007-08 fiscal year, there were four tax brackets with three corresponding tax rates: the starting rate of 10%, the basic rate of 22% and the higher rate of 40%. The tax rates were adjusted in the following year, so that there were three tax thresholds and two tax rates: the basic rate of 20% and the higher rate of 40%.[6]

The UK Income Tax rates for 2007-08 and 2008-09 (including single personal allowance).

	2007-08		2008-09	
	Annual GTI	Rate of Tax	Annual GTI	Rate of Tax
Personal Allowance	$\leq £5,225$	$\tau_0^I = 0$	$\leq £6,035$	$\tau_0^I = 0$
Starting Rate	$£5,225 - £7,455$	$\tau_1^I = 10\%$	-	-
Basic Rate	$£7,455 - £39,825$	$\tau_1^I = 22\%$	$£6,035 - £40,835$	$\tau_1^I = 20\%$
Higher Rate	$> £39,825$	$\tau_2^I = 40\%$	$> £40,835$	$\tau_2^I = 40\%$

Table 4
The UK Income Tax rates for FY 2007-2008 with single Personal Allowance.

5.1 Horizontal Equity Breakdown Under Crisis Conditions

The financial crisis provides a compelling demonstration of how income uncertainty renders traditional horizontal equity impossible. Consider two workers with identical expected annual earnings of £39,825, the cusp of the Higher Rate, but different income volatility profiles: a stable public sector employee and a commission-based financial services worker.

Under the contingent claim model of income taxation (2), the present value of the UK government's claim using the 2008-09 tax rates is given by

$$\begin{aligned}\phi_G^{(UK)} &= \tau_1^I \max(\gamma - 6035, 0) + (\tau_2^I - \tau_1^I)\max(\gamma - 40835, 0) && (43)\\ &= 0.2[\max(\gamma - 6035, 0) + \max(\gamma - 40835, 0)] && (44)\end{aligned}$$

The present value of the UK government's taxation option is then given by

$$\Phi_G^{(UK)} = 0.2[C(6035) + C(40835)]. \quad (45)$$

I solve (45) for the case of a log-normal cumulative GTI process using the Black and Scholes (1973) formula and numerically solve for the case of a log-normal instantaneous

[5] The historical rates of personal Income Tax are obtained from Table TA.2 downloaded from the UK Government website (Table TA.2 on 4 January 2015. Historical rates of personal allowance are also obtained from the UK Government website (Table TA.1), also downloaded on 4 January 2015. The Chancellor of the Exchequer during the announcement of the tax-rates for 2007/8 was The Right Honourable Gordon Brown, and during the 2008/9 and 2009/10 was The Right Honourable Alistair Darling.

[6] The UK government charges a second tax against personal employment income, known as National Insurance Contributions (NIC). These contributions are labelled differently to Income Tax, but are charged against taxable income and enter the general revenue of the government. Consequently, they are an income-dependent tax. The tax-bracket cutoff's for NIC differ from those for Income Tax. For simplicity I ignore the NI contributions.

GTI process using the method of Levy (1992). The value of these claims, Φ_G, for a range of volatilities and GTIs are given in Figures 3(a) and (b), respectively.

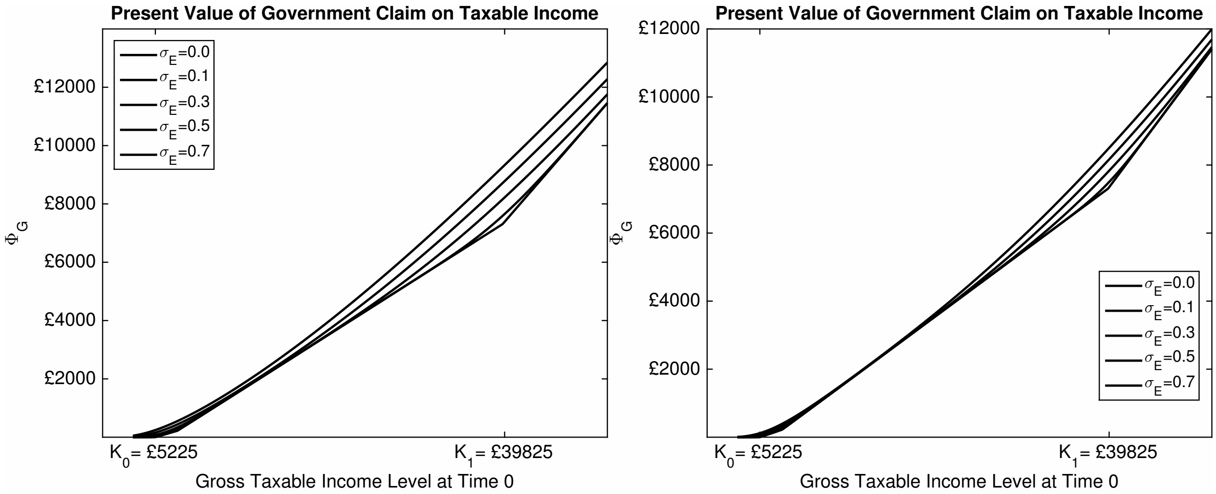

Fig. 3. The value of the government taxation option for the UK 2015-16 Income Tax Regime, calculated using (a) the log-Normal cumulative income process assumption and (b) the log-Normal instantaneous income process.

By inspecting Figure 3, the value of the government's claim increases substantially with GTI volatility. The government holds a greater claim on the income of employees with more volatile earnings, even when expected incomes are identical. The relative value of GTI volatility is highest when GTI levels are close to a tax-bracket boundary.[7] For example, when GTI equals £39,825, the government's claim is valued at £9,330.47 when GTI volatility equals $\sigma_E = 0.7$. This is 22% greater than the value of its claim when $\sigma_E = 0.1$ (£7,654.85).

This demonstrates the impossibility of horizontal equity under uncertainty: two individuals with identical expected incomes face systematically different expected tax burdens purely due to income volatility differences. The high-volatility worker effectively pays a higher expected tax rate due to the convexity of the professive tax schedule, violating the fundamental principle that equals should be treated equally.

5.2 Volatility Creep as a Distinct Fiscal Phenomenon

The crisis period reveals volatility creep as a quantitatively significant and conceptually distinct source of fiscal expansion. During 2007-2008, UK wage volatility increased dramatically whilst the base rate fell sharply, creating opposing forces on government tax claims that traditional fiscal analysis struggles to cleanly capture.

Figure 4 presents time-series plots of changes in UK average wages and their volatility, alongside the UK base rate between 2000 and 2015. The crisis period shows a clear spike in wage volatility coinciding with monetary easing, providing ideal conditions for observing volatility creep effects.

[7] In terms of option greeks, this is equivalent to the vanna of the taxation option being greatest 'at-the-money'.

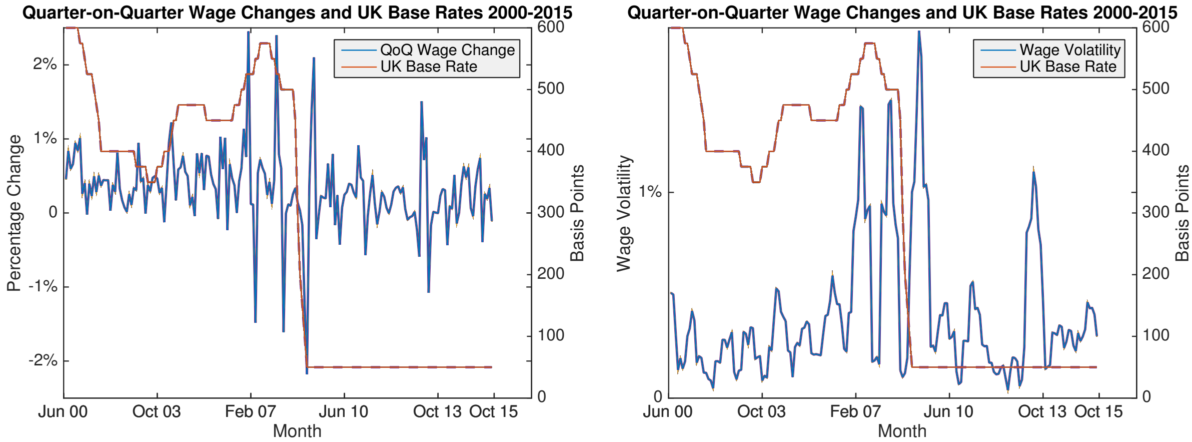

Fig. 4. Time-series plots of the changes in UK average wages, along with the UK base rate, between 2000 and 2015 (Figure (a)), and the volatility of UK average wages, along with the UK base rate between 2000 and 2015 (Figure (b).

Each variable influences the present value of the taxation option through distinct channels. The increase in average wage levels increases the value of the underlying asset, generating traditional bracket creep. The increase in wage volatility increases the value of the taxation option through higher option premia, creating volatility creep. The reduction in the risk-free rate decreases option values through lower discount rates, producing negative risk-free-rate creep. The net effects of each variable on the present value of the government's claim are presented in Figure 5.

The greeks decomposition reveals that volatility creep (vega effects) represents the dominant factor in changing tax option values during the crisis, accounting for 58% of fiscal expansion in 2007-08. This effect operates in the opposite direction to new tax rate policies and proves significantly larger than traditional bracket creep effects (delta), which contributed only 28% of total fiscal expansion.

For 2008-09, volatility and risk-free rate changes compound the reduction from revised tax rates, generating a significantly reduced tax claim. This demonstrates how volatility creep can either amplify or offset traditional fiscal policy, depending on the direction of volatility changes and monetary policy responses.

The tax greeks provide precise quantitative weights for these effects. Calculating the option sensitivities for the UK tax system during the crisis period reveals the relative importance of each source of fiscal expansion. For the 2007-08 period, the normalised weights show that volatility effects (vega) accounted for approximately 58% of total fiscal expansion, whilst traditional bracket creep effects (delta) contributed 28% and monetary policy effects (rho) contributed 14%. This quantitative decomposition confirms that volatility creep dominated traditional fiscal phenomena during the crisis.

The 2008-09 period shows a different pattern, with volatility and monetary effects working in the same direction to reduce government claims. The Tax Greek weights reveal that vega effects contributed 45% of the fiscal contraction, rho effects 35%, and delta effects only 20%. This demonstrates how the relative importance of fiscal expansion sources shifts with economic conditions, providing guidance for optimal policy responses.

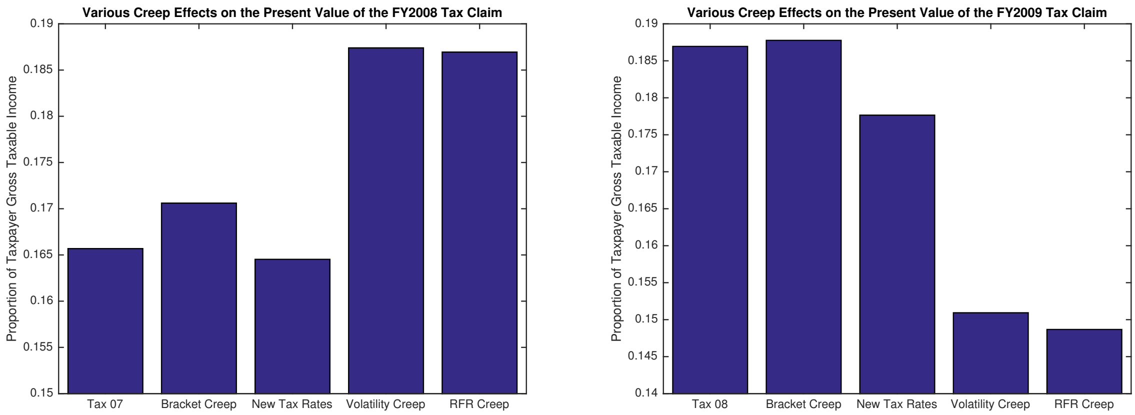

Fig. 5. Net effects of changes in average wages, changes in tax rates, changes in wage volatility and risk-free rate on the value of the taxation option. The column 'Tax 07' reflects the value of the tax option using $2006-7$ tax rates and average wage. The column 'bracket-creep' represents the effect of increase in average wags on the tax option. The column 'New Tax Rates' reflects the value of the tax option under the new $(2007-08)$ tax rates. The column 'volatility creep' reflects the value of the tax option under the increase in wage volatility during the $2007-08$ fiscal year. The column 'RFR creep' reflects the effect of UK base rate on the value of the taxation option. Values are given in proportion of the taxpayer's GTI. Figure (b) shows the same influences for the $2008-09$ fiscal year.

5.3 Risk-Adjusted Vertical Equity Measurement

The crisis example illustrates why vertical equity requires reconceptualisation under uncertainty. Traditional measures based solely on expected income ignore the differential insurance value that progressive taxation provides across risk profiles, leading to misleading assessments of tax burden distribution.

Consider the insurance value received by different income groups during the crisis. Higher-volatility workers near tax bracket boundaries receive disproportionately valuable downside protection from progressive taxation. This insurance value should be incorporated into ability-to-pay calculations, suggesting that risk-adjusted vertical equity measures would show different distributional patterns than conventional analyses.

The contingent claim framework provides precise tools for calculating these insurance values. The difference between expected tax payments and option values represents the insurance premium that progressive taxation provides. Workers with higher income volatility receive more valuable insurance, effectively reducing their risk-adjusted tax burden relative to traditional measures.

5.4 Policy Coordination During Crisis

The UK experience during 2007-2008 provides empirical illustration of the government-taxpayer interest alignment conditions derived in Section 4. The simultaneous occurrence of increased income volatility and monetary easing created the precise conditions where both government and taxpayer interests align.

As volatility increased during the crisis, both government tax claims and taxpayer after-tax income values became more sensitive to interest rate changes. The Bank of England's aggressive monetary easing helped stabilise both claims simultaneously, demonstrating the practical relevance of coordinated policy responses under volatility shocks.

However, the analysis also reveals potential conflicts. When income levels fell alongside volatility increases, the stabilising effects of monetary policy on volatility were partially offset by destabilising effects on level adjustments. This suggests that fiscal policy adjustments (such as the tax rate changes implemented) may have been necessary complements to monetary responses.

5.5 Quantitative Fiscal Decomposition

The tax greeks transform the qualitative insights about fiscal dynamics during the crisis into precise quantitative measures. By calculating the option sensitivities and applying the decomposition weights, we can determine the exact contribution of each economic factor to changes in government tax claims.

This analysis reveals striking differences between the two crisis years. In 2007-08, when income volatility spiked whilst monetary policy remained relatively stable, vega effects dominated the fiscal expansion. In 2008-09, when both volatility and monetary policy changed dramatically, the combined effects of vega and rho created substantial fiscal contraction despite continued income growth.

This quantitative framework provides direct policy guidance. When vega weights dominate, as in 2007-08, policies should focus on managing uncertainty rather than traditional fiscal adjustments. When rho weights become significant, as in 2008-09, fiscal-monetary coordination becomes essential. The tax greeks decomposition thus offers a practical tool for determining optimal policy responses based on the underlying sources of fiscal variation.

5.6 Implications for Equity Measurement and Policy Design

This illustrative example demonstrates several key implications for measuring tax equity and designing policy under uncertainty:

(1) Traditional equity measures are systematically misleading during periods of high income uncertainty. Horizontal equity violations become more severe as volatility increases, whilst vertical equity assessments that ignore insurance values misrepresent true distributional effects,
(2) Volatility creep represents a quantitatively significant fiscal phenomenon that operates independently of traditional bracket creep and policy changes. During the crisis, volatility effects dominated other influences on government tax claims, suggesting that fiscal analysis must explicitly account for uncertainty effects,
(3) Policy coordination becomes essential during periods of high uncertainty. The alignment of government and taxpayer interests under volatility shocks creates oppor-

tunities for mutually beneficial policy responses, whilst conflicts under level shocks require careful balancing of fiscal and monetary instruments,

(4) Risk-adjusted equity concepts are practically necessary for accurate assessment of tax burden distribution. The substantial insurance values revealed during the crisis suggest that conventional distributional analysis may significantly misrepresent the true incidence of progressive taxation.

This analysis provides compelling evidence that progressive taxation under uncertainty requires fundamental reconceptualisation of equity concepts, with practical implications for both policy design and distributional assessment in modern economies characterised by substantial income risk. The tax greeks decomposition offers fiscal analysts a practical tool for quantifying the relative importance of different economic factors in revenue dynamics, enabling more precise policy responses to changing economic conditions.

6 Conclusions

In this paper I make a conceptual contribution by demonstrating that progressive income tax regimes can be modeled as portfolios of European Call options over individual taxpayers' gross taxable income. This conceptual framework provides new analytical tools for understanding fiscal policy under uncertainty and opens several promising avenues for future research.

The option-pricing perspective yields three key theoretical insights. First, it reveals "volatility creep" as a previously unrecognised mechanism through which income uncertainty affects the government's tax claim. Second, it identifies conditions under which government and taxpayer interests align or conflict with respect to monetary policy responses. Third, it provides a formal mathematical structure for analysing the risk-sharing properties of different tax systems.

I demonstrate that a progressive income tax regime grants the taxing body a long European, Call option over the net earnings of an individual taxpayer. The taxpayer holds a portfolio of the integral of their net earnings plus a short European Call option over their gross taxable income. The value of this taxation option is sensitive to the volatility of the taxpayer's GTI, as well as the risk-free rate of return. The GTI volatility can have a much greater effect on the taxation option than the risk-free rate.

In order to preserve the value of their respective claims over these earnings, the taxpayer and the government have similar sensitivities with respect to an GTI volatility shock. In contrast, the taxpayer and the government have conflicting preferences with respect to a shock to the earnings level.

When the risk-free rate reduces, the present value of the government's long call option also reduces and the present value of the taxpayer's claim increases. Reduction in risk-free rate influences the value of the taxation option in the opposite direction to changes in value arising due to an increase in GTI volatility. However, if the reduction in risk-free rate coincides with a exogenous negative shock to the taxpayers earnings level then these compounding effects will stabilise the value of the taxpayer's claim as the cost of a declining position in the government's claim.

My findings increase our understanding of macroeconomic monetary responses, as well as providing a new insight into how to model income taxation and the conditions under which government's and taxpayers interests are aligned. The option-theoretic framework developed here is not merely illustrative. It is analytically tractable, empirically calibratable, and general enough to be applied across a wide range of tax regimes and income distributions. The decomposition into greeks provides policy-relevant tools for macro-fiscal diagnostics that are portable across institutional settings."

Limitations and Future Research Directions

As a theoretical contribution, this paper focuses on establishing the conceptual framework and mathematical foundations for analyzing progressive taxation through the lens of option pricing theory. I have deliberately emphasised analytical clarity over empirical validation, which presents several important opportunities for future research.

First, rigorous empirical testing of the "volatility creep" hypothesis would require comprehensive panel data on income volatility and tax revenues across multiple jurisdictions and time periods. Such analysis could quantify the magnitude of this effect relative to traditional bracket creep and policy changes.

Second, the welfare implications of option-like tax structures deserve careful empirical investigation. While my conceptual framework suggests potential efficiency gains from state-contingent tax policies, measuring these gains would require structural estimation of preference parameters and income process characteristics.

Third, the practical implementation of policies based on our framework raises important questions about administrative feasibility, political-economy constraints, and institutional design that merit dedicated study.

By establishing the theoretical foundations in this paper, I aim to stimulate this broader research agenda at the intersection of public finance, macroeconomics, and financial economics.

6.1 Empirical Research Agenda

This theoretical contribution establishes foundations for systematic empirical analysis of progressive taxation under uncertainty. The framework generates several testable hypotheses that could guide future research:

Volatility Creep Hypothesis: Government tax revenues should increase with income volatility, controlling for expected income levels. Cross-country panel data could test this relationship across different tax systems and economic conditions.

Greeks Decomposition: Fiscal expansion should decompose into components attributable to income growth (delta), volatility changes (vega), and interest rate movements (rho), with relative weights varying across economic environments. Time-series analysis of tax revenues could validate this decomposition.

Insurance Value Measurement: The difference between expected tax payments and option values represents insurance benefits. Household survey data could estimate these benefits across income and risk profiles, testing whether they align with theoretical predictions.

Welfare Implications: Risk-adjusted equity measures should better predict individual welfare than traditional measures. Experimental or quasi-experimental evidence could test whether individuals' fairness perceptions align with risk-adjusted rather than traditional equity concepts.

Policy Coordination: Government and taxpayer interests should align under volatility shocks but conflict under level shocks. Historical analysis of fiscal-monetary policy responses could test these predictions.

The framework also suggests new approaches to policy evaluation. Cost-benefit analysis of tax reforms should account for insurance value changes, not just redistributive effects. Optimal tax calculations should incorporate uncertainty explicitly rather than treating it as a secondary consideration.

References

Aiyagari, S. R. (1995). "Optimal Capital Income Taxation with Incomplete Markets, Borrowing Constraints, and Constant Discounting." *Journal of Political Economy* 103(6): 1158–1175.

Auerbach, A., and Hassett, K., (2002), "A New Measure of Horizontal Equity", *American Economic Review*, 92(4): 1116–1125.

Barro, R. J. (1979). "On the Determination of the Public Debt." *Journal of Political Economy* 87(5): 940–971.

Black, F., and Scholes, M., (1973). "The Pricing of Options and Corporate Liabilities." *Journal of Political Economy* 81(3): 637–654.

Blanchard, O. J. (2025). "Fiscal Policy as a Stabilization Tool." Peterson Institute for International Economics Working Paper 25-1.

Blundell, R., Graber, M. and Mogstad, M. (2023). "Interpreting Cohort Profiles of Life Cycle Earnings Volatility." *Journal of Political Economy* 131(12): 3159–3204.

Blundell, R., Pistaferri, L., and Saporta-Eksten, I., (2016). "Consumption Inequality and Family Labor Supply." *American Economic Review* 106(2): 387–435.

Boadway, R., and Sato, M., (2015). "Optimal Income Taxation with Risky Earnings: A Synthesis." *Journal of Public Economic Theory* 17(4): 447–467.

Canzoneri, M. B., Cumby, R. E. and Diba, B. T. (2010). "The Interaction Between Monetary and Fiscal Policy." In *Handbook of Monetary Economics*, Volume 3, pp. 935–999. Elsevier.

Carr, P., Ewald, C. and Xiao, Y. (2008). "On the Qualitative Effect of Volatility and Duration on Prices of Asian Options." *Finance Research Letters* 5(3): 162–171.

Conesa, J. C., and Krueger, D., (2006). "On the Optimal Progressivity of the Income Tax Code." *Journal of Monetary Economics* 53(7): 1425–1450.

Diamond, P. A., and Saez, E., (2011). "The Case for a Progressive Tax: From Basic Research to Policy Recommendations." *Journal of Economic Perspectives* 25(4): 165–190.

Dolls, M., Fuest, C., and Peichl, A., (2012). "Automatic Stabilizers and Economic Crisis: US vs. Europe." *Journal of Public Economics* 96(3–4): 279–294.

Domar, E. D. and Musgrave, R. A. (1944). "Proportional Income Taxation and Risk-Taking." *The Quarterly Journal of Economics* 58(3): 388–422.

Eaton, J., and Rosen, H. S., (1980). "Optimal Redistributive Taxation and Uncertainty." *Quarterly Journal of Economics* 95(2): 357–364.

Feigenbaum, J., and Li, G. (2015). "Household Income Uncertainties Over Three Decades." *Oxford Economic Papers* 67(4): 963–986.

Guvenen, F., Karahan, F., Ozkan, S., and Song, J., (2021). "What Do Data on Millions of US Workers Reveal about Life-Cycle Earnings Risk?" *Econometrica* 89(5): 2303–2339.

Hacker, J., (2006). "The Great Risk Shift: The Assault on American Jobs, Families, Health Care, and Retirement - And How You Can Fight Back." Oxford University Press.

Heathcote, J., Storesletten, K., and Violante, G. L. (2017). "Optimal Tax Progressivity: An Analytical Framework." *Quarterly Journal of Economics* 132(4): 1693–1754.

Heer, B. and Trede, M. (2013). "Tax Bracket Creep and Its Effects on Income Distribution." *Journal of Macroeconomics* 38: 393–408.

Immervoll, H. (2005). "Falling Up the Stairs: The Effects of Bracket Creep on Household Incomes." *Review of Income and Wealth* 51(1): 37–62.

International Monetary Fund (2020). "Tax Policy and Inclusive Growth." IMF Working

Paper WP/20/271.
Jensen, S. and Shote, S. (2011). "Semi-Parametric Bayesian Modelling of Income Volatility Heterogeneity and Dynamics." *Journal of American Statistics Association* 106(496): 1280–1290.
Jung, J., and Tran, C., (2023). "Health Risk, Insurance, and Optimal Progressive Income Taxation." *Journal of the European Economic Association* 21(5): 2043–2097.
Kaplow, L. (1989). "Horizontal Equity: Measures in Search of a Principle." *National Tax Journal* 42(2): 139–154.
Kaplow, L. (2024). "Optimal Income Taxation." *Journal of Economic Literature* 62(2): 637–738.
Kemna, A. G. and Vorst, A. C. (1990). "A Pricing Method for Options Based on Average Asset Values." *Journal of Banking & Finance* 14(1): 113–129.
Kindermann, F., and Krueger, D., (2022). "High Marginal Tax Rates on the Top 1%? Lessons from a Life-Cycle Model with Idiosyncratic Income Risk." *American Economic Journal: Macroeconomics* 14(2): 319–366.
Kocherlakota, N. R. (2010). "The New Dynamic Public Finance." Princeton University Press.
Krueger, D. and Wu, C. (2025). "Taxes on Lifetime Income: A Good Idea?" NBER Working Paper 33664.
Leeper, E. M. (2023). "Monetary-Fiscal Policy Interactions for Central Bankers." Reserve Bank of Australia Review 2023-04.
Levy, E. (1992). "Pricing European Average Rate Currency Options." *Journal of International Money and Finance* 14(5): 474–491.
Lucas, R. E. and Stokey, N. L. (1983). "Optimal Fiscal and Monetary Policy in an Economy Without Capital." *Journal of Monetary Economics* 12(1): 55–93.
McKay, A., and Reis, R., (2016). "The Role of Automatic Stabilizers in the US Business Cycle." *Econometrica* 84(1): 141–194.
Merton, R. C. (1973). "Theory of Rational Option Pricing." *The Bell Journal of Economics and Management Science* 4(1): 141–183.
Mirrlees, J. A. (1971). "An Exploration in the Theory of Optimum Income Taxation." *Review of Economic Studies* 38(2): 175–208.
Moffitt, R. A. (2018). "The PSID and Income Volatility: Its Record of Seminal Research Contributions and Some Recent Findings." *The ANNALS of the American Academy of Political and Social Science* 680(1): 48–81.
Moffitt, R. A. and Gottschalk, P. (2012). "Trends in the Transitory Variance of Male Earnings: Methods and Evidence." *Journal of Human Resources* 47(1): 204–236.
Musgrave, R. A. (1959). "A Theory of Public Finance." McGraw-Hill.
Piketty, T., Saez, E., and Stantcheva, S. (2014). "Optimal Taxation of Top Labor Incomes: A Tale of Three Elasticities." *American Economic Journal: Economic Policy* 6(1): 230–271.
Plotnick, R. (1981). "A Measure of Horizontal Inequity." *The Review of Economics and Statistics* 63(1): 283–288.
Rieth, M., Checherita-Westphal, C., and Attinasi, M., (2016). "Personal Income Tax Progressivity and Output Volatility: Evidence from OECD Countries." *Canadian Journal of Economics* 49(3): 968–996.
Rogers, L. C. G. and Shi, Z. (1995). "The Value of an Asian Option." *Journal of Applied Probability* 32(4): 1077–1088.
Saez, E., (2001). "Using Elasticities to Derive Optimal Income Tax Rates." *Review of*

Economic Studies 68(1): 205–229.
Saez, E., Slemrod, J., and Giertz, S., (2012). "The Elasticity of Taxable Income with Respect to Marginal Tax Rates: A Critical Review." *Journal of Economic Literature* 50(1): 3–50.
Shin, D. and Solon, G. (2010). "Trends in Men's Earnings Volatility: What Does the Panel Study of Income Dynamics Show?" *Journal of Public Economics* 95(7–8): 973–982.
Simons, H., (1938), "Personal Income Taxation," Chicago: The University of Chicago Press.
Stiglitz, J. E. (1969). "The Effects of Income, Wealth, and Capital Gains Taxation on Risk-Taking." *The Quarterly Journal of Economics* 83(2): 263–283.
Varian, H. R. (1980). "Redistributive Taxation as Social Insurance." *Journal of Public Economics* 14(1): 49–68.