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The Fair Wage Hypothesis and Disinflation Costs: A DSGE approach

A hipótese *Fair Wage* e o Custo da Desinflação: Uma abordagem DSGE

Lucas Daniel Duarte
Supervisor: Marcio Issao Nakane

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Prof. Dr. Carlos Gilberto Carlotti Júnior
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LUCAS DANIEL DUARTE

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Orientador: Prof. Dr. Marcio Issao Nakane

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Lucas Daniel Duarte

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Work presented as a requirement for the degree of Master in Economics from the Institute of Economic Research at the University of São Paulo (IPE-USP).

Marcio Issao Nakane
University of São Paulo

André Lunardelli
Instituto Casa Branca

Eurilton Alves Araujo Junior
Banco Central do Brasil

Roseli da Silva
University of São Paulo

São Paulo
2025

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"Education never ends, Watson.
It is a series of lessons,
with the greatest for the
last."
- Sir Arthur Conan Doyle

Abstract

This paper seeks to examine the role of the fair wage hypothesis of the gift-exchange framework in improving the New Keynesian DSGE model performance in explaining disinflation costs. In simulated disinflations of different sizes, we compare the sacrifice ratio generated by two models - one with the behavioral fair wage hypothesis and one without. We find that the model with the behavioral hypothesis generates higher sacrifice ratio than the standard model, aligned with empirical literature estimates. After decomposing the sacrifice ratio into two effects, we argue that without the behavioral assumption, the model fails in generating plausible sacrifice ratios, showing the importance of the fair wage hypothesis in explaining disinflation costs in New Keynesian DSGE models.

Key-words: Fair Wage; Disinflation; Sacrifice Ratio; Behavioral New Keynesian DSGE; Monetary Policy.

Resumo

Este trabalho visa examinar o papel da hipótese comportamental *fair wage* do tipo *gift-exchange* em melhorar a capacidade de um modelo DSGE Novo Keynesiano em explicar o custo de desinflações. Em simulações de desinflações de diferentes tamanhos, compara-se as taxas de sacrifício geradas por dois modelos - um com a hipótese comportamental de *fair wage* e outro sem. Encontra-se que o modelo com a hipótese comportamental tem um desempenho melhor ao gerar taxas de sacríficio maiores, alinhadas com estimativas da literatura empírica. A partir da decomposição da taxa de sacríficio em dois efeitos, argumentamos que sem a hipótese comportamental, o modelo falha em gerar taxas de sacrifício empiricamente plausíveis, denotando a importância dessa hipótese para explicar o custo de desinflações em modelos DSGE Novo Keynesianos.

Palavras-chave: Fair Wage; Desinflações; Taxa de sacríficio; Modelo Novo Keynesiano DSGE comportamental; Política Monetária.

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1 Introduction

It is widely known that monetary policy often tries to induce a recession to keep inflation in check. This relation - a fall in output below its natural level to force a fall in inflation - is called sacrifice ratio and is often used to summarize the disinflation cost. There is a extensive empirical literature on the determinants of the sacrifice ratio. One of the most important works in this field is Ball (1994a), which developed a simple way to calculate the sacrifice ratio for different disinflation episodes across countries, finding that the most significant determinant in the size of the sacrifice ratio is the disinflation speed - faster disinflations would generate lower sacrifice ratios.

After Ball's work, literature sought to identify several other variables that could influence the sacrifice ratio size, such as the role played by central bank independence (CBI) (Jordan (1997), Diana and Sidiropoulos (2004)), the degree of openness of the economy (Temple (2002), Daniels et al. (2005), Badinger (2009), Daniels and VanHoose (2013)), the impact of adopting inflation targeting (IT) regimes (Gonçalves and Carvalho (2009), Brito (2010), Roux and Hofstetter (2014) and Huang et al. (2019)), effects of political regimes (Caporale and Caporale (2008) and Caporale (2011)), wage-setter coordination (Bowdler and Nunziata (2010)), differences between OECD and non-OECD countries (Mazumder (2014)) and the disinflation experiences of Latin American and the Caribbean countries (Hofstetter (2008)) and the possibility of monetary policy long-lived effects (Zhang (2005)), with various mixed and often ambiguous results. Magkonis and Zekente (2020) uses a Bayesian Model Averaging (BMA) to evaluate several models used in the literature, finding that the most robust determinants of the sacrifice ratio are the disinflation speed, duration, the presence of central bank independence and the degree of capital openness.

However, theoretical models have lacked behind in explaining such disinflation costs and often are at odds with the empirical evidence. Works such as that of Taylor (1983), proposes that gradual disinflations can occur without any costs, and Ball (1994b), showing that even in the staggered-price setting, disinflations can be expansionary. In order to reconciliate model predictions with empirical observations, subsequent works made assumptions about either the monetary policy credibility (Ball (1995), Erceg and Levin (2003) and Goodfriend and King (2005)) or about information (Mankiw and Reis (2002)).

Another approach was to introduce several *ad hoc* elements to improve the model's fit to macroeconomic data, such as Christiano et al. (2005) and Smets and Wouters (2007). This class of models was used by Ascari and Ropele (2012a) to study disinflation costs, reaching favorable conclusions - that is, the nominal and real frictions present in the model were sufficient to generate plausible sacrifice ratios, without the need for additional assumptions. This conclusion, however, was questioned by Lunardelli and Nakane (2019), which argued that Ascari and Ropele (2012a) incurred in a measurement error in calculating the sacrifice ratios, meaning that a medium scale DSGE New Keynesian model still can't generate plausible sacrifice ratios.

This work seeks to contribute to this literature by proposing that the Fair Wage hypothesis - in the gift exchange framework idea first proposed by Akerlof (1982) - in a medium scale DSGE New Keynesian model can improve the model's ability to generate empirical plausible sacrifice ratio's in a disinflation shock. This approach has at least two advantages - the first is that the assumptions that workers react to unfair treatments has important microeconomic evidence. Using telephone surveys, Kahneman et al. (1986) finds nominal wage cuts are generally considered unfair, providing a explanation to downward nominal wage rigidity (Dickens et al. (2007)); Krueger and Mas (2004) finds that company announcements considered unfair were responsible for a fall in the quality of Bridgestone/Firestone tires; Dube et al. (2019) finds that unfair rises in wages to similar peers were responsible for the decision to quit; Fehr et al. (2009) also finds evidence that changes in wages affect's worker effort. The second advantage is that the model does not require any additional assumption about the credibility, formation of expectations or information.

Using the model proposed by Croix et al. (2010) - which differs from past works by using a more general effort function specification - we study disinflation shocks and the theoretical sacrifice ratio the model generates, reaching favorable conclusions - model estimates for the sacrifice ratio ranges from 2.11 to 3.9, depending on the disinflation sizes, compared to the 0.94 - 0.95 estimates in the benchmark model. Decomposing this into two effects - one coming from the Fair Wage Hypothesis and the remaining from Other Nominal Frictions, we clearly see that, without the Fair Wage, the model fails to generate higher sacrifice ratios, achieving estimates from 1.08 to 1.37. For comparison, empirical estimates used by Mazumder (2014) average 1.95 for a large sample of OECD countries.

The model also has other desirable attributes following the disinflation shock, such as a reduced real marginal cost reaction to falls in output, a higher variation in employment in relation to real wages.

This work also relates to a large literature that uses behavioral economics assumptions to improve the standard DSGE New Keynesian model performance, summarized by Driscoll and Holden (2014). The use of the gift-exchange hypothesis in DSGE models goes back to Danthine and Donaldson (1990), which often inspired subsequent works, such as Collard and Croix (2000), Danthine and Kurmann (2004) and Danthine and Kurmann (2010). More closely related to this work is Lunardelli (2014) and Lunardelli and Nakane

(2024). The former built upon Driscoll and Holden (2004) to argue that workers need a reason to accept readjustments below the reference level, provided by a deep recession. Modifying the Shapiro and Stiglitz (1984) model, he simulates a disinflation with sacrifice ratio's close to that of Volcker's episode. The latter uses the same model as Ascari and Ropele's, but with a negative term in the household utility associated with receiving a adjustment lower than the reference, and the authors also concluded that fairness improved the model's performance in terms of sacrifice ratio.

The remainder of the work is structured as follows. Section 2 provides a more profound literature review; Section 3 derives the model proposed by Croix et al. (2010) in its full non-linear form, discussing the role played by the effort function; Section 4 shows the main results, discussion and robustness exercises, with Section 5 concluding.

2 Literature Review

In this section, we present the literature review on sacrifice ratios, the New Keynesian DSGE model and its problems, as well the behavioral modifications alternatives to it.

2.1 Disinflation Costs, the Sacrifice Ratio and its determinants

According to Romer and Romer (1989), there were several moments when the Federal Reserve (FED) sought to induce a recession to reduce inflation in the postwar United States. For example, in October 1979, FED committed to a contractionary monetary policy that was followed by one of the most profound recession in the United States in the postwar period in the twentieth century.

A common way to refer to such disinflation costs is the so called sacrifice ratio (SR) - the ratio of the total output loss to the change in trend inflation. One of the most important works in measuring the SR and its determinants is Ball (1994a), for two reasons. The first, it is one of the earliest works to develop a simple method to calculate the SR that can be applied to different episodes almost mechanically.

This method consists in i) defining trend inflation in t as a centered, nine quarter moving average of actual inflation, from $t-4$ through $t+4$ and ii) identifying what he calls "peaks" and "troughs": moments where trend inflation is above or below than in the previous four quarters and the following four quarters. A disinflation episode is any period that starts at a peak inflation and ends with a trough at least two points lower than the peak. Then, he makes three assumptions for the output behavior - output is equal to its natural level at the inflation peak; it returns to the natural level after four quarters after the end of a disinflation episode and finally, that output grows log-linearly between these two points.

The second reason Ball's work is important is because he applied that method to all OECD countries with reliable data (quarterly or annual) and looked for different variables that can explain the size of the SR, finding that faster disinflations and a lower wage rigidity has lower output losses.

He also investigates other possible determinants of the SR, such as the initial inflation level, the disinflation size, defined as the percent change in inflation from the peak to the trough, the role played by income policies and how open the economy is (share of imports in total spending). However, for each of these variables, he finds no conclusive results, ranging from insignificant estimates or not so robust results.

After Ball's work, literature sought to identify other possible variables that could explain the SR, such the as central bank independence (CBI), the role of inflation targeting (IT) policies, ideology and democracy and - again - the degree of openness of the economy.

For example, Jordan (1997) finds, counterintuitively, that central bank independence (CBI) tends to increase the sacrifice ratio during disinflation periods. Interestingly, the author argues that this result comes from the initial level of inflation, since it is a proxy for CBI. In that sense, countries with CBI tend to haver a lower inflation ratio and at lower inflation ratios, the cost of diminishing said inflation even further is increased. He also finds that the size of the disinflation is a important and significant variable, with positive effects on the SR.

However, Diana and Sidiropoulos (2004) finds empirical evidence that countries with CBI may have a "credibility bonus" via lower inflation persistence and therefore a faster disinflation speed, reducing, not increasing, the sacrifice ratio, contrary to prior empirical evidences.

When it comes to the openness of the economy, Temple (2002) finds a weak and negative correlation with the SR, even after controlling for outliers and different measures for the SR. Yet, Daniels et al. (2005) brings a different reasoning: countries with imperfectly competitive goods market and potential higher nominal wage rigidity due to inflation reductions generated by a higher degree of openness and or central bank independence brings the theoretical prediction that SR should be positively associated with more openness. Then, using Temple's dataset expanded with a measure of CBI, finds empirical support for their argument - a more open economy has a higher sacrifice ratio. Daniels and VanHoose (2013) brings evidence that a greater extent of exchange-rate pass through increases the sacrifice ratio.

Badinger (2009), on the other hand, argues that there is a shortcoming of this finding: by not taking into consideration how openness affects inflation and focusing solely on its effects on the output-inflation tradeoff is not informative: depending on the model being used, the effect on the tradeoff can be associated with higher or a lower inflation. He also argues for the role played by financial openness (actual openness, not only trade openness) and of more recent data, since important structural changes may have happened in the 1990s, such as strengthened relation between openness and inflation. The author has two main findings: first, a higher degree of openness to trade and financial flows decreases inflation rates and increases the output-inflation tradeoff. Secondly, when considering only the OECD subsamples, as did previous studies, he finds no robust relation between openness and inflation.

Another important discussion when it comes to the determinants of the sacrifice ratio comes from the role played by inflation targeting (IT) regimes. After using data from 61 disinflations in OECD economies, Gonçalves and Carvalho (2009) argues that the adoption of IT regimes did, in fact, reduce disinflation costs, even after controlling for self-selection. However, Brito (2010) argues directly against the results obtained by Gonçalves and Carvalho (2009), by reviewing their methodology and, after controlling for i) a more precise treatment group and ii) common time-varying conditions, the results effectively disappear.

Nevertheless, Roux and Hofstetter (2014) brings back the role played by IT regimes by finding that IT matters only in a longer disinflation, showing that fast disinflations and IT may be substitute alternatives in order to reduce the sacrifice ratio in a disinflation episode. Importantly, they take into consideration the time-varying effects used by Brito (2010), which does not change their main conclusions. Huang et al. (2019) brings novel evidence when considering a larger database with more countries and by using endogenous switching regression (ESR) instead of propensity score matching (PSM), as commonly used in the literature, finding that the adoption of IT is associated with significantly lower sacrifice ratios, both in developing and developed subsamples, even after several robustness checks.

The effects of political regimes in the size of SR was studied by Caporale and Caporale (2008), finding consistently that right-wing governments tend to have lower sacrifice ratios because of a credibility bonus from anti-inflation reputation. The presence of a higher degree of wage-setter coordination also tends to reduce the sacrifice ratio, since this may eliminate worker concerns about relative wage changes and allowing for a disinflation to proceed at a lower cost, as argued by Bowdler and Nunziata (2010).

When focusing specifically on Latin America and the Caribbean (LAC) countries, Hofstetter (2008) shows that there is no free lunch: disinflation from the 1970s and 1980s were achieved at the cost of large sacrifice ratios, independent of the inflation peak. Caporale (2011) also shows that the political regime matters - right-wing (vs left-wing) or democratic (vs autocratic) government have less costly disinflation.

Considering that there may be important differences between OECD and non-OECD countries, Mazumder (2014) showed that for OECD economies, the speed of disinflation is the most important determinant. However, for non-OECD economies, lower sacrifice ratio has been associated with the presence of CBI, higher degree of commercial opening and higher debt-to-GDP ratio. The latter is specially important for middle income economies.

A important contribution made by Zhang (2005) was correcting the calculation of sacrifice ratios made by Ball's standard method. The author argues that a disinflationary monetary policy may have long-lived effects on output, increasing the SR of a episode. His method was also used a several subsequent papers.

Another two important variables are used in some of these works, with mixed results on the sacrifice ratio - the initial inflation level and the disinflation size. The use of these variables in empirical studies is motivated by Ball et al. (1988), which argues that, in New Keynesian models, the reason nominal shocks have real effects is the presence of nominal frictions that prevents prices to quickly adjust. In higher inflation settings, firms would have to adjust prices more frequently, diminishing the presence of nominal frictions and allowing a faster adjustment of prices in the face of nominal shocks, lowering the real effects of said shock.

For instance, Ball (1994a) found that, for quarterly data, the disinflation size and the initial inflation tends to reduce the sacrifice ratio, but for annual data, both variables are not significant and have positive signs, meaning they tend to increase the sacrifice ratio. Daniels et al. (2005) finds that the initial inflation and disinflation size coefficients have a positive and negative sign, respectively. On the other hand, Mazumder (2014), finds that the disinflation is is highly significant with negative effects on the sacrifice ratio. When it comes to the initial inflation size, he finds non-significant parameters.

Works such as that of Jordan (1997) and Caporale and Caporale (2008) found opposite evidence, suggesting that the disinflation size matters and tends to increase the sacrifice ratio.

Lastly, but not least, Magkonis and Zekente (2020) takes on the degree of uncertainty showed by different model selections in previous studies by using a Bayesian Model Averaging (BMA) in order to determine the most robust sacrifice ratio determinants. The authors found that the variables that matters the most are the disinflation's length (positive) and speed (negative), the CBI (negative) and capital openness (positive).

All other variables, such as initial inflation, the disinflation size, the adoption of IT regimes, debt-to-GDP ratio, trade openness, presence of employment protection and others have mixed effects.

Despite the overwhelming evidence that disinflations are costly, many economic models cannot explain such costs. Earlier works, such as that of Taylor (1983), argues that it is possible for a gradual disinflation to occur without any costs. Ball (1994b) shows that in a model with staggered-price setting, disinflation can actually be expansionary - that is, followed by a boom rather than a recession.

In an attempt to reconciliate the staggered-price model with empirical observations, Ball (1995) introduces a form of imperfect credibility to the central banker's behavior - with a known probability, he will not keep his promise to decrease money growth - finding that, in the presence of both the staggered-price setting and imperfect credibility, disinflations are costly.

Following this work, Erceg and Levin (2003) and Goodfriend and King (2005) also used some form of imperfect credibility to explain the costs of the Volcker Disinflation episode. Mankiw (2001), on the other hand, argues that this problem cannot be so easily solved. Since monetary shocks have a delayed and gradual effect on inflation, there is a credible announced disinflation every time there is a contractionary shock - but without the boom the model predicts. He also argues that modifications in the formation of expectations, namely, using adaptive rather than rational expectations, is also not a satisfactory solution: it lacks microeconomic foundations.

In a subsequent work, Mankiw and Reis (2002) proposes a modification to the standard sticky-price model: assuming there are costs to acquiring information or costs to re-optimize, information about macroeconomic conditions diffuses slowly in the economy - a sticky-information, as they called. Their model was able to generate contractionary disinflations, delayed effects of monetary policy on inflation and a positive correlation between inflation and output level. A similar approach was made by Calvo et al. (2007) by assuming that the optimizing firm jointly chooses the initial price level and a rate to update the chosen price level - a 'firm-specific inflation rate', with the advantage of a more tractable model. Their model was also capable of generating output losses in a fully credible disinflation. Arslan (2008) also concludes that sticky-information model have a more consistent dynamic response to a cost-push shock, depending of the shock persistence.

So, in order to explain disinflation costs, the literature on New Keynesian models used either some form of imperfect credibility or information to explain disinflation costs. Another possible approach is to amend the standard New Keynesian staggered-pricing model with *ad hoc* assumptions to improve the model's fit to important macroeconomic data, a tradition exemplified by Christiano et al. (2005) and Smets and Wouters (2007).

A important step in understanding disinflation costs in this tradition was made by Ascari and Ropele (2012a). By using a non-linearized medium-scaled New Keynesian model, they sought to investigate whether the numerous real and nominal rigidities in their model were capable to generate plausible sacrifice ratios in a credible disinflation, without the need for additional assumptions. They argued that the model did, in fact, quantitatively replicate plausible sacrifice ratios, with this finding being sensible to the price and wages degree of indexation to past inflation and Calvo probabilities parameter values.

In subsequent works, they also found that disinflations entails overall welfare gains, which is unaffected by the monetary policy rule (money supply vs. interest rate) (Ascari and Ropele (2012b) and Ascari and Ropele (2013)).

The matter seemed resolved until Lunardelli and Nakane (2019), which argues that AR's work incurred in a important measurement error, finding SR which were 4 times lower than reported. Furthermore, the model used by Ascari and Ropele (2012a) falls under the critique of Chari et al. (2009): by lacking microeconomic evidence to justify the added shocks and their implications, the model becomes unreliable for policy analysis. For instance, the markup shock in Smets and Wouters (2007) arises from changes in the elasticity of substitution between different types of labor - which in turn implies a high level of substitution between different types of labor, such as carpenters and neurosurgeons, once again opening the issue of New Keynesian models not being able to quantitatively replicate empirical sacrifice ratios without additional assumptions.

Lastly, there is a alternative approach which does not use any additional assumptions about the formation of expectations, information or credibility with substantial microeconomic evidence: the role of fairness concerns in the labor market.

2.2 Fairness and the Labor Market

Fairness in the labor market - in the sense that workers care about being treated in a just way - is often used to explain several departures from the standard competitive model with empirical evidences. What is considered just, however, usually depends on the comparison between the current situation and a reference point[1], usually set by social norms, expectations or personal aspirations (Tversky and Kahneman (1981)).

Akerlof (1982) was one of the first works that used the idea of reference points and norms to better understand labor contracts and explain wages above the market clearing level, a framework which the author called and formalized as partial gift exchange.

In it, workers receive a gift from the firm - a wage - and reciprocate - the exchange - in terms of effort. Here, there are two ideas that are linked together. The first one is that workers must decide upon the fairness of the wage they are receiving. For this, each worker has a reference set, which may consist of wages paid to workers in other firms and unemployment rates. After deciding upon the fairness of the wage, they must decide upon the level of effort they will supply. There is also a reference point for this effort, which depends on the work rules, the incentive system of the firm (variable wages depending upon output level) and the utility of co-workers in the work group, i.e., the minimum effort level required by the firm.

With this framework in mind, the author argues that is not necessarily true that firms will always pay the market-clearing wage. Firms may choose to pay a higher wage to incentivize workers to supply a higher effort level or to have reputation gains - by only paying the minimum necessary to keep its workers, firms may lose reputation and have

[1] Kahneman and Tversky (1979) - one of the early works in the field known today as behavioral economics - showed several empirical evidences that contradicts the predictions of expected utility theory. One of those evidences is that in many different situations, economic agents may decide what is perceived as a gain or a loss based on a reference point.

more difficulties in finding qualified workers.

To better understand how wages may affect worker effort, Fehr et al. (2009) summarize both lab and field experiments on the topic, finding that higher wages indeed lead to a increase in worker effort. For instance, Krueger and Mas (2004) examines the effect of several company announcements on the quality of manufactured Bridgestone/Firestone tires. Some of the company announcements include lowering wages for new hires by 30%, increasing shift times from 8 to 12 hours - decisions that were considered unfair by the workers. Since the manufacturing of tires is a complex one, the fall in tire quality produced was interpreted as a fall in worker effort. The effect of a unfair treatment may also affect the decision to quit, as shown by Dube et al. (2019). Following increases in the federal minimum wage in 1996 and 1997, an American firm adopted a discontinuous rule to update its workers wage, generating arbitrary differences in wages to workers who were very similar - a unfair treatment. The authors showed that this was responsible for the unfair treated workers decision to quit, and this effect was guided by comparisons with higher paid peers.

By using telephone surveys to elicit community standards of fairness for wage and price setting, Kahneman et al. (1986) found the idea of dual entitlement - transactors have a entitlement to their reference transaction and firms are entitled to their reference profit, with several important implications.

For instance, the fairness of a wage adjustment is determined based on a comparison with a reference point. If the wage adjustment happens to a firm employees, said reference point is his current wage - in other words, the employee has a entitlement to his current wage. In this sense, wage cuts are almost always considered unfair. However, for new hires, the reference point is not a former employee wage, but the current market wage - new hires do not have a entitlement to former employee's wage.

When it comes to wage adjustments, a real fall of 7% is perceived as fair if it comes from a 5% increase in nominal wage in a 12% inflation setting. However, if the same real adjustment comes from a 7% decrease in nominal wages with 0% inflation, it is considered unfair. A consequence of this behavior is that wages will be insensitive to excess supply - providing, therefore, a behavioral explanation for wage stickiness[2].

Fairness may also explain inflation persistence. Bhaskar (1990) builds a model where the main hypothesis is that workers resent being paid less than other workers in the same sector - in other words, have fairness concerns. The model then implies that unions will set wages taking into consideration what it expects other unions to do, in order to avoid relative wages changes between sectors. Then, Driscoll and Holden (2004) suggests that, if unions expect other unions to behave as they did in the past in relation

[2]See, for instance, Dickens et al. (2007) for evidence on downward nominal wage rigidity.

to wage growth rate, inflation persistence arises as a self fulfilling prophecy, rationalizing adaptive expectations.

Building upon the ideas of Akerlof (1982) and Kahneman et al. (1986), Akerlof and Yellen (1990) built a model with the fair wage-effort hypothesis to explain unemployment. This hypothesis relates the effort level with the fair wage - which is considered to be a weighted average between the wage received by other workers in the firm and the Walrasian market clearing wage, implying that changes in current market conditions also affect the formation of reference points. With two types of workers - a low and high pay - and perfectly competitive firms, their model predicts the existence of involuntary unemployment.

In dynamic equilibrium models, the first work to implement the fair wage-effort hypothesis in a DSGE setting was Danthine and Donaldson (1990). Using a function that relates effort to the current wage - reference wage (which is defined as a mean between the current wage and self-employment income) ratio, they find that the model did not account for the wage-employment puzzle. In a later work, Collard and Croix (2000) amends their model by allowing reference wage to also depend on past wages - either on personal past wages (personal norm) or society's past wage (social norm), arguing that this helps explain the high variability of employment and low variability of wages.

Further exploring the matter, Danthine and Kurmann (2004) introduces the fair wage hypothesis to a New Keynesian DSGE setting by generalizing Collard and Croix (2000) effort function, allowing for effort to be independently affected either by personal current and past wages, labor market tightness and aggregate average wage, improving the model dynamics in i) making employment more procyclical than wages, with near zero correlation between both and ii) amplifying the propagation of real and monetary shocks. Rent-sharing and wage entitlements effects also help DSGE models exogenous shocks dynamics fit better the data (Danthine and Kurmann (2010)). Fair wage considerations also improved search and match models dynamics (Wesselbaum (2013) and Kuang and Wang (2017)).

Interestingly, there are few works that relate fairness concerns and disinflations costs. One of them is Lunardelli (2014), which argues, following Driscoll and Holden (2004), that workers need a reason to accept readjustments below the reference level - past inflation. Modifying the Shapiro and Stiglitz (1984) model with a reciprocity related term, he is able to simulate a disinflation with a SR close to that of Volcker's episode. Another important work is this directions is Lunardelli and Nakane (2024). By modifying the model used by Ascari and Ropele (2012a) with a negative utility term associated with receiving a wage adjustment lower than the reference, the authors concluded that fairness and ambiguity improved the model capacity to explain the size of empirical observed sacrifice ratios.

Importantly, the use of behavioral economics findings to help explain several puzzles in macroeconomic literature is not limited to fairness in the labor market - it also includes the hyperbolic discounting, bounded rationality, heterogeneous expectations and others[3] .

3 The Model

In this section, we develop the New Keynesian DSGE model with fair wages, following Croix et al. (2010). We'll use the model in its non-linear form in order to study how the model performs in a disinflation simulation, since a disinflation is, by definition, a change in the model steady-state inflation rate.

The original model used by these authors has physical capital, a monetary policy with a Taylor rule, habit formation on consumption, costs on physical capital adjustment and variable degree of capital utilization. It also uses nominal price and wage stickiness a la Calvo and a indexation rule for non-optimized prices and wages, based on a weighted average of past and trend inflation.

However, the model used in this work has three main differences. First, we are using the same monetary policy rule as Ascari and Ropele (2012a); second, we removed all exogenous shocks; third, we are using the same functional forms for capital adjustment costs and variable degree of capital utilization as Schmitt-Grohé and Uribe (2005).

3.1 Households

The effort level supplied by workers has effects in terms of utility. In fair wage models, it is common for utility to be negatively affected by the quadratic distance between the effort supplied by the household j, $e_t(j)$ and the effort considered to be fair by the same household, $e_t^*(j)$: $(e_t(j) - e_t^*(j))^2$

The fair effort is a function of the real wage of the household $w_t(j)$, of labor market tightness and of the aggregate wage in the economy w_t, given by:

$$e_t^*(j) = \phi_1 \frac{w_t(j)^\psi - \phi_2 \left(\frac{1}{1-N_t}\right)^\psi - \phi_3 w_t^\psi - (\phi_0 - \phi_2 - \phi_3)}{\psi} \tag{1}$$

Where the parameters follow the restrictions: $\phi_0 \in \mathbb{R}, \phi_1 > 0, \phi_2 > 0, \phi_3 \in$

[3]See Driscoll and Holden (2014), Afsar et al. (2024), Jump and Levine (2019), Meggiorini (2023) and Miura (2023) for a more detailed discussion.

$[0,1), \psi \in [0,1)$

In this generalized effort function, N_t is the aggregate employment rate, ϕ_0 and ϕ_1 are used to scale the steady state values of employment and effort to values determined exogenously (or simply scale parameters).

The ϕ_3 parameter indicates the worker sensitivity to the reference or fair wage. In this specification, that wage is the wage they would earn, on average, in the rest of the economy [4]. The ϕ_2 parameter is the worker sensitivity to changes in external conditions, represented by changes in the employment rate in the economy. Lastly, ψ describes the substitutability between the different elements of the effort function.

This means that if there is an improvement in external conditions, for example, a higher aggregate employment, firms would have to offer higher wages to keep effort constant. For larger values of ψ, the higher wages would have to rise.

Family utility has the following form:

$$U_t(j) = \left(\frac{(C_t(j) - hC_{t-1})^{1-\sigma_c}}{1-\sigma_c} - n_t(j)\left[e_t(j) - e_t^*(j)\right]^2 \right) \tag{2}$$

Where σ_c is the inverse of the elasticity of intertemporal substitution, $n_t(j)$ is the fraction of the household family members employed.

Family income has three sources: labor income plus the net cash inflows from the state-contigent securities $\Lambda_t(j)$, the net return on capital stock associated with the cost of variations in the degree of capital utilization and the dividends derived from intermediate firms acting on imperfect competitive markets[5].

The function form of the variable degree of capital utilization follows Schmitt-Grohé and Uribe (2005):

$$\Psi(u_t(j)) = \gamma_1(u_t(j) - 1) + \frac{\gamma_2}{2}(u_t(j) - 1)^2 \tag{3}$$

Therefore, the family income is given by:

$$\mathcal{Y}_t(j) = (w_t(j)n_t(j) + \Lambda_t(j)) + K_{t-1}(j)(r_t^k u_t(j) - \Psi(u_t(j))) + Div_t(j) \tag{4}$$

The state-contigent securities allow households to be insured against specific labor income variations derived from unemployment, so that the first term in the total income

[4] However, in alternative specifications, the fair wage could be the workers own past wage, following Collard and Croix (2000), for example.

[5] The firm behavior is described in the subsection below.

is equal to aggregate labor income and the marginal utility of wealth is identical across households.

The household can buy one period domestic bonds B_t with a nominal rate of return R_t. Household income can also be used for consumption and investment purposes. In that sense, households are restricted by the following budget constraint:

$$R_t \frac{B_t(j)}{P_t} = \frac{B_{t-1}}{P_t} + \mathcal{Y}_t(j) - C_t(j) - I_t(j) \tag{5}$$

Households will choose the optimal path for consumption, bonds holding and effort, as well as the capital stock, investment and the degree of capital utilization in order to maximize their intertemporal objective function subject to the budget constraint and the capital accumulation law given by:

$$K_{t+1} = K_t(1-\tau) + \left[1 - \frac{\delta}{2}\left(\frac{I_t}{I_{t-1}} - 1\right)^2\right] I_t \tag{6}$$

Notice that this equation is also the same used by Schmitt-Grohé and Uribe (2005).

The first order conditions for consumption, effort and bonds holding are:

$$(C_t(j) - hC_{t-1}(j))^{-\sigma_c} - h\beta E_t(C_{t+1}(j) - hC_t(j))^{-\sigma_c} = \lambda_t \tag{7}$$

$$e_t(j) = \phi_1 \frac{w_t(j)^{\psi} - \phi_2\left(\frac{1}{1-N_t}\right)^{\psi} - \phi_3 w_t^{\psi} - (\phi_0 - \phi_2 - \phi_3)}{\psi} \tag{8}$$

$$E_t\beta\left[\frac{\lambda_{t+1}}{\lambda_t}\frac{P_t}{P_{t+1}}R_t\right] = 1 \tag{9}$$

Equation (7) extends the usual first order condition by taking into consideration habit formation, equation (8) indicates the optimal effort as a function of the real wage and aggregate employment rate. Lastly, equation (9) reveals that the marginal benefit of acquiring bonds in terms of consumption in the future must be equal to the marginal cost in terms of consumption of buying them.

The first order conditions for capital, investment and the degree of capital utilization are:

$$Q_t = \beta E_t\left[\frac{\lambda_{t+1}}{\lambda_t}[r^k_{t+1}u_{t+1} - \gamma_1(u_{t+1}-1) - \gamma_2/2(u_{t+1}-1)^2 + Q_{t+1}(1-\tau)]\right] \tag{10}$$

$$Q_t\left(1-\frac{\delta}{2}\left(\frac{I_t}{I_{t-1}}-1\right)^2\right)=1+Q_t\frac{I_t}{I_{t-1}}\delta\left(\frac{I_t}{I_{t-1}}-1\right)-\beta E_t\left[\frac{\lambda_{t+1}}{\lambda_t}Q_{t+1}\left(\frac{I_{t+1}}{I_t}\right)^2\delta\left(\frac{I_{t+1}}{I_t}-1\right)\right] \tag{11}$$

$$r_t^k=\gamma_1+\gamma_2(u_t-1) \tag{12}$$

Equation (10) reveals that the optimal path for capital depends on the expectations on future earnings, taking into consideration expectations on the degree of capital utilization and also on depreciation. Equation (11) shows that the optimal level of investment depends largely on the costs associated with varying the capital stock and, last but not least, equation (12) indicates that the household will equate the marginal benefit of increasing capital utilization (r_t^k) with the marginal cost of said increase ($\gamma_1+\gamma_2(u_t-1)$).

3.2 Firms

Also following Croix et al. (2010), there are 3 production sectors. The intermediate producers operate in a competitive market, hiring capital and labor and managing effort through their wage policy, which is assumed to be sticky. They sell their homogeneous products to the intermediate retail firms, which in turn transform them one-to-one into a differentiated product, incurring in a fixed cost. These retail firms operate on a monopolistic market and, therefore, choose prices, which is also assumed to be sticky. Lastly, the final output firms buy the differentiated product from intermediate retail firms and use it as a input in the production of a homogeneous good serving for consumption and investment purposes. These firms operate on a competitive market.

3.2.1 Final Output Firms

The final homogeneous good is made by firms operating on a competitive market, combining the differentiated inputs from the intermediate retail firms into a homogeneous good, used for consumption and investment purposes. The production function of these firms is given by:

$$Y_t=\left[\int_0^1(y_t(i))^\theta di\right]^{\frac{1}{\theta}} \tag{13}$$

Where the elasticity of substitution between the different intermediate goods is $1/(1-\theta)$, with $\theta\in(0,1)$. In that way, the parameter θ represents a competitiveness index. The demand for the final good and the aggregate price are:

$$y_t(i) = \left(\frac{p_t(i)}{P_t}\right)^{\frac{1}{\theta-1}} Y_t \tag{14}$$

$$P_t = \left[\int_0^1 p_t(i)^{\frac{\theta}{\theta-1}} di\right]^{\frac{\theta-1}{\theta}} \tag{15}$$

3.2.2 Intermediate Retail Firms

The intermediate retail firms $h \in [0,1]$ act on a monopolistic market with sticky prices. They buy the homogeneous good from the intermediate producers at a price Z_t and transform them into a differentiated good one-to-one, incurring in a fixed cost Φ, facing the demand given by (14). Current real profits are given by:

$$\Pi_t(i) = (\widetilde{p}_t(h) - z_t) \cdot y_t(h) - z_t \Phi \tag{16}$$

Where $\widetilde{p}_t(i) \equiv p_t(h)/P_t$ and $z_t \equiv Z_t/P_t$, which indicate the relative price and the real marginal cost, respectively. Given that prices are assumed to be sticky a la Calvo, at each period t, a fraction of $1-\xi_p$ sets a new price $p_t^*(h)$, which will prevail for t periods with a probability of ξ_p^t. The fraction of firms that do not set optimal prices, index it to a weighted average of past and trend inflation:

$$p_t(i) = p_{t-1}(i)\pi_{t-1}^{\gamma_p}\overline{\pi}^{1-\gamma_p}$$

In this way, each firm maximizes the flow of real expected profits, discounted by the stochastic factor $\rho_{t+s} = \frac{\lambda_{t+s}}{\lambda_t}$. Its objective function, therefore, is:

$$E_t \sum_{s=0}^{\infty} (\beta\xi_p)^s \frac{\lambda_{t+s}}{\lambda_t} \left[\left(\widetilde{p_t^*} \frac{P_t \prod_{l=0}^{s-1} \pi_{t+l}^{\gamma_p}\overline{\pi}^{1-\gamma_p}}{P_{t+s}} - z_{t+s}\right)\left(\widetilde{p_t^*} \frac{P_t \prod_{l=0}^{s-1} \pi_{t+l}^{\gamma_p}\overline{\pi}^{1-\gamma_p}}{P_{t+s}}\right)^{\frac{1}{\theta-1}} Y_{t+s}\right] \tag{17}$$

Where $\widetilde{p_t^*} \equiv p_t^*/P_t$ represents the optimal relative price. Since all firms face the same marginal cost, they all choose the same optimal relative price.

We can define two auxiliary variables X_t^1 and X_t^2, which in their recursive form are given by:

$$X_t^1 = z_t Y_t \widetilde{p_t^*}^{1/(\theta-1)-1} + \beta\xi_p E_t \frac{\lambda_{t+1}}{\lambda_t} \left(\frac{\widetilde{p_t^*}}{\widetilde{p_{t+1}^*}}\right)^{1/(\theta-1)-1} \left(\frac{\pi_t^{\gamma_p}\overline{\pi}^{1-\gamma_p}}{\pi_{t+1}}\right)^{1/(\theta-1)} X_{t+1}^1 \tag{18}$$

$$X_t^2 = Y_t \widetilde{p_t^*}^{1/(\theta-1)} + \beta\xi_p E_t \frac{\lambda_{t+1}}{\lambda_t} \left(\frac{\widetilde{p_t^*}}{\widetilde{p_{t+1}^*}}\right)^{1/(\theta-1)} \left(\frac{\pi_t^{\gamma_p}\overline{\pi}^{1-\gamma_p}}{\pi_{t+1}}\right)^{\theta/(\theta-1)} X_{t+1}^2 \tag{19}$$

Therefore, we can enunciate the first order condition in relation to p_t^* as:

$$\theta X_t^2 = X_t^1 \tag{20}$$

The aggregate price law of motion can finally be declared as:

$$1 = \xi_p \pi_t^{\frac{\theta}{1-\theta}} (\pi_{t-1}^{\gamma_p}\overline{\pi}^{1-\gamma_p})^{\frac{\theta}{\theta-1}} + (1-\xi_p)(\widetilde{p_t^*})^{\frac{\theta}{\theta-1}} \tag{21}$$

3.2.3 Intermediate Producers

The intermediate producers operate on a competitive market, hiring labor and capital and managing effort through their wage policy, assumed to be sticky. The production function of these firms is:

$$q_t(i) = (e_t(i)n_t(i))^\alpha \kappa_t(i)^{1-\alpha} \tag{22}$$

Since they operate on a competitive market, real profits are straightforward given by:

$$z_t q_t(i) - w_t(i)n_t(i) - r_t^k \kappa_t(i) \tag{23}$$

Solving the maximization problem these firms face, we find the first order conditions for $n_t(i)$ and $\kappa_t(i)$:

$$\frac{w_t(i)}{e_t(i)} = z_t\alpha \left[\frac{\kappa_t(i)}{e_t(i)n_t(i)}\right]^{1-\alpha} \tag{24}$$

$$r_t^k = z_t(1-\alpha)\left[\frac{\kappa_t(i)}{e_t(i)n_t(i)}\right]^{-\alpha} \tag{25}$$

From these equations, we can find the real marginal cost:

$$z_t = \left(\frac{w_t}{e_t}\right)^\alpha (r_t^k)^{1-\alpha}\alpha^{-\alpha}(1-\alpha)^{-(1-\alpha)} \tag{26}$$

Notice that, since they operate on a competitive market, real marginal costs are the same for all firms and therefore, the wage-effort ratio is also the same for all firms.

As it is common in New Keynesian Fair Wage models, firms also choose which nominal wage to pay for labor. In our case, this decision is assumed to be sticky a la Calvo. A fraction $1-\xi_w$ of firms choose the optimal nominal wage, which will prevail for t periods with a probability ξ_w^t. The fraction of firms that do not choose optimal wages, index it to a weighted average of past and trend inflation:

$$W_t(i) = W_{t-1}(i)\pi_{t-1}^{\gamma_w}\bar{\pi}^{1-\gamma_w}$$

In this sense, these firms also maximize the discounted flow of expected real profits, but they face the additional effort restriction. Hence, its objective function is:

$$\mathbb{E}_t \sum_{s=0}^{\infty}(\beta\xi_w)^s \frac{\lambda_{t+s}}{\lambda_t}\frac{1}{P_{t+s}}\left[Z_{t+s}q_{t+s}(i) - W_t^*(i)n_{t+s}(i)\cdot\prod_{j=0}^{s-1}\pi_{t+j}^{\gamma_w}\cdot\bar{\pi}^{1-\gamma_w} - P_t r_t^k \kappa_t(i)\right] \tag{27}$$

Subject to:

$$e_{t+s}(i) = \frac{\phi_1}{\psi}\left[\left(\frac{W_t^*(i)}{P_t}\prod_{l=0}^{s-1}\pi_{t+l}^{\gamma_w}\cdot\bar{\pi}^{1-\gamma_w}\right)^{\psi} - \phi_2\left(\frac{1}{1-N_{t+s}}\right)^{\psi} - \phi_3 w_{t+s}^{\psi} - (\phi_0-\phi_2-\phi_3)\right] \tag{28}$$

Notice that the effort restriction also depends on the expected wage s periods ahead of the optimal decision.

In order to solve this problem, we also define two auxiliary variables, f_t^1 and f_t^2, given by, in its recursive form:

$$f_t^1 = z_t\frac{q_t}{e_t}(w_t^*)^{\psi} + \beta\xi_w\left(\frac{w_t^*}{w_{t+1}^*}\right)^{\psi}\frac{\lambda_{t+1}}{\lambda_t}(\pi_t^{\gamma_w}\cdot\bar{\pi}^{1-\gamma_w})^{\psi}f_{t+1}^1 \tag{29}$$

$$f_t^2 = w_t N_t + \beta\xi_w\left(\frac{w_t^*}{w_{t+1}^*}\right)\frac{\lambda_{t+1}}{\lambda_t}\frac{(\pi_t^{\gamma_w}\cdot\bar{\pi}^{1-\gamma_w})}{\pi_{t+1}}f_{t+1}^2 \tag{30}$$

Finally, the first order condition for this problem can be enunciated as:

$$\alpha\phi_1 f_t^1 = f_t^2 \tag{31}$$

We can also find the wage law of motion, defined as:

$$w_t = \xi_w w_{t-1} \frac{(\pi_{t-1}^{\gamma_w} \cdot \bar{\pi}^{1-\gamma_w})}{\pi_t} + (1 - \xi_w) w_t^* \tag{32}$$

3.2.4 Aggregate Conditions

We can define the aggregate quantity of labor and effectively used capital:

$$N_t = \int_0^1 n_t(i) di$$

$$\kappa_t = \int_0^1 \kappa_t(i) di$$

Applying these definitions in equations (24) and (25), we obtain the aggregate employment rate, effectively used capital and the production function as:

$$\frac{w_t}{e_t} = z_t \alpha \left[\frac{\kappa_t}{e_t N_t} \right]^{1-\alpha} \tag{33}$$

$$r_t^k = z_t (1 - \alpha) \left[\frac{\kappa_t}{e_t N_t} \right]^{-\alpha} \tag{34}$$

$$s_t Y_t = (e_t N_t)^{\alpha} (\kappa_t)^{1-\alpha} - \Phi \tag{35}$$

Where $s_t \equiv \int_0^1 \left(\frac{p_t(i)}{P_t} \right)^{\frac{1}{\theta - 1}} di$, representing the price dispersion between firms in period t. Its law of movement is given by:

$$s_t = (1 - \xi_p) \widetilde{p_t^*}^{\frac{1}{\theta - 1}} + \xi_p \left(\frac{\pi_{t-1}^{\gamma_p} \bar{\pi}^{1-\gamma_p}}{\pi_t} \right)^{\frac{1}{\theta - 1}} s_{t-1} \tag{36}$$

We also need to aggregate the effort function. Since the wage is the same for all workers, the aggregate function is simply given by:

$$e_t = \phi_1 \frac{w_t^{\psi} (1 - \phi_3) - \phi_2 \left(\frac{1}{1 - N_t} \right)^{\psi} - (\phi_0 - \phi_2 - \phi_3)}{\psi} \tag{37}$$

3.3 Monetary Policy

In order to define the monetary policy rule, we follow the specification given by Ascari and Ropele (2012a):

$$\frac{R_t}{\overline{R}} = \left(\frac{\pi_t}{\bar{\pi}} \right)^{\rho} \tag{38}$$

Where R_t is the nominal gross interest rate, $\overline{R}$ is the monetary policy interest rate target, π_t is the current gross inflation and $\overline{\pi}$ is the target gross inflation. The parameter ρ is the monetary authority sensibility to inflation deviation from the target.

3.4 Market Equilibrium

This economy is in equilibrium if the demand for capital by the intermediate producers is equal to the supply by the household's; if the government bonds with the return rate R_t, as defined by the monetary policy, are bought and the total supply of goods is equal to the households demand for consumption, investment, variable degree of capital utilization costs and government expenditure:

$$Y_t = C_t + G_t + I_t + \Psi(u_t)K_{t-1} \tag{39}$$

Where G_t is exogenously determined. Also, notice that the labor market is always in equilibrium, since the employment supply is inelastic in the Fair Wage model. Therefore, the equilibrium path for:

$$\{C_t, I_t, G_t, Y_t, K_t, N_t, R_t, e_t, q_t, \kappa_t, s_t, r_t^k, w_t, w_t^*, z_t, u_t, \lambda_t, \widetilde{p_t^*}, X_t^1, X_t^2, f_t^1, f_t^2, \pi_t\}$$

Is fully determined by equations (6), (7)-(12) (in aggregate forms), (20), (18),(19),(21), (26), (29), (30), (31), (32), (33), (34), (35), (36), (38), (39) and by $\kappa_t = u_t K_{t-1}$, $G_t \equiv \overline{G}$.

3.5 Calibration

To simulate disinflations, we choose to use the same calibration as Croix et al. (2010), Schmitt-Grohé and Uribe (2005) and Ascari and Ropele (2012a), shown in table (11). Also, notice that we are using $\phi_3 = 0.785$, instead of $\phi_3^{Croix} = 0.795$, the value used in Croix et al. (2010). This is because when using the latter, the model does not satisfies Blanchard-Kahn conditions - so the closest value we could use is $\phi_3 = 0.785$. Other parameters, such as the share of labor α and the discount factor β are fixed as standard values.

It is important to discuss the role of ϕ_0 and ϕ_1 as scale parameters. In models with the fair wage-effort hypothesis, by eliminating labor in the utility function, there is no intertemporal labor substitution - instead, households supply inelastically a unit of time, of which a fraction is used by the firm. Following this argument, the determination of the steady-state unemployment rate is exogenous - authors usually use the average unemployment over the estimation period. Is this sense, choosing any values for ϕ_0 and

ϕ_1 effectively means you are choosing a value for N and e, which will be shown in the numerical solution for the steady-state. In our case, we also follow Croix et al. (2010) by choosing $N = 0.95$ and $e = 1$. For the model to be consistent, we must take into consideration the effect of steady-state inflation and the effort function parameters in equations (65) and (64), shown in the Appendix. Since steady-state inflation changes from the beginning to the end of the disinflation, we always choose ϕ_0 and ϕ_1 to maintain $N = 0.95$ and $e = 1$ - which means we are assuming that monetary policy shocks does not change employment and, therefore, output steady-state's value.

4 Disinflation Costs - DSGE approach

In order to simulate a disinflation, we need to change the steady state inflation of this economy, with the model in its full non-linear form, focusing on the perfect foresight case[6]. We'll simulate a disinflation from $\pi_{high} = [4\%, 6\%, 8\%]$ to $\pi_{low} = 2\%$ for the Fair Wage (Croix) model developed here and the New Keynesian Ascari and Ropele (2012a) (AR) benchmark model. For the latter, we made two modifications: we are using a CRRA utility function, instead of logarithmic one and we are using the same calibration presented by Croix et al. (2010), both of them displayed in table (11). We also present only simulations from $\pi_{high} = 4\%$ to $\pi_{low} = 2\%$, with all other simulations in the appendix. All variable dynamics presented in this work are in percentage deviation from the steady-state..

4.1 Main Results

The usual way to calculate the sacrifice ratio in terms of output loss for a fall of one percentage point in annual inflation was defined by Ball (1994a) as:

$$SR = -\frac{\left[\sum_{t=0}^{T=\bar{t}} (y_t - y_{ss})\right]/4}{\pi_{high}^{annual} - \pi_{low}^{annual}} \tag{40}$$

Where the period 0 is the starting point for the disinflation shock, and $\bar{t}$ is the period where output is stabilized - according to Ball (1994a), this would be around 4 quarters after inflation reaches its new steady state value.

However, in our simulation, the Fair Wage model output (and also other variables) presents a oscillatory dynamics[7] around the steady state following the disinflation shock, and this alters the way we calculate the sacrifice ratio.

[6]All simulations were made in MatLab/Dynare software, with codes available upon request.

[7]This feature is closely related to how workers react to changes in external conditions, ϕ_2, as explained in the section below.

For the main results presented here, we are using the full simulation period to calculate the disinflation costs, that is, where $\bar{t} = 100$, for both models. We also applied the definition given by Ball (1994a), shown in table (2). A important thing to notice is that no matter the way we calculate the SR, the Fair Wage model is able to generate higher sacrifice ratios than the benchmark model. Also, the Fair Wage SR changes little for the different methods of calculation.

When compared to the empirical estimates of SR made by Ball (1994a) and Mazumder (2014), the Fair Wage model outperforms the Benchmark model, suggesting that Fair Wage considerations may be a important feature to explain disinflation costs.

Table 1: Sacrifice Ratio

Disinflation Size		Sacrifice Ratios		
π^*_{high}	π^*_{low}	Fair Wage	Benchmark	Benchmark*
4%	2%	2.11	0.95	0.57
6%	2%	2.61	0.95	0.47
8%	2%	3.93	0.94	0.46

Notes: This table shows the calculated sacrifice ratios for the Fair Wage, Benchmark and Benchmark* models. For the Fair Wage and the Benchmark models, we are using the calibration displayed in table (11). The Benchmark* model uses the original AR calibration, which was the same as Christiano et al. (2005).

Table 2: Sacrifice Ratio - Alternative Calculations

Disinflation Size		Sacrifice Ratios	
π^*_{high}	π^*_{low}	Fair Wage	Benchmark
4%	2%	2.32	1.22
6%	2%	2.77	1.22
8%	2%	3.90	1.21

Notes: This table shows the sacrifice ratios if we use the same definition as Ball (1994), that is, we sum output deviations for 4 quarters after inflation reaches the new steady state value. For the Fair Wage Model, that happens at $t = [27, 29, 31]$ for $\pi_{high} = [4\%, 6\%, 8\%]$, respectively. For the benchmark model, that happens at $t = 22$.

Tables (1) and (2) also draws attention to two important features. The first one indicates that calibration matters - a lot. Using the original calibration of Ascari and Ropele (2012a) and correcting for measurement errors, the benchmark model has a lower sacrifice ratio than the same model with a different calibration period[8]. This means that

[8]Christiano et al. (2005) used quarterly data for real GDP, real consumption, GDP deflator, real investment, real wage and labor productivity from 1965 to 1995. Croix et al. (2010) also used quarterly data for real GDP, consumption, investment, real wages, GDP deflator, short term interest rate and employment, but from 1974-2005.

Table 3: Empirical Sacrifice Ratios

	Mazumder (2014)	Ball (1994a)	
	Sacrifice Ratio	Sacrifice Ratio	
	Annual	Quarterly	Annual
Average	1.95	1.44	0.77
Median	1.51	1.28	0.58
Max	9.07	3.56	3.92
Min	-1.01	-0.01	-0.86
Standard Deviation	2.22	0.93	1.04

Note: This table displays summary statistics for the sacrifice ratios calculated by Ball (1994a) (tables 5.1 and 5.2) and Mazumder (2014) (tables A1 and A2).

the original New Keynesian Model is able to generate higher sacrifice ratios depending on the calibration, but our calculations suggests that these estimates are still within the lower range of the empirical calculations.

The second feature is that, for the Fair Wage model, the disinflation sizes matter for the SR. A popular argument, presented by Ball et al. (1988), argues that in New Keynesian models, nominal shocks have real effects due to the presence of nominal frictions that prevents prices to adjust quickly. In this way, in the presence of a higher steady state inflation, firms would have to adjust prices more quickly - which effectively means a lower nominal friction, implying in a lower real effect in face of a nominal shock. The authors found empirical evidence supporting this prediction of New Keynesian models.

In our scenario, this would translate to a lower disinflation cost when inflation is higher - exactly the opposite of the Fair Wage model prediction. If nominal rigidities matter less when inflation is at $\pi_{high} = 8\%$ than at $\pi_{high} = 4\%$, then in the face of a nominal shock such as, say, a rise in nominal interest rates, the real effects would be lower - a smaller contraction of output - meaning a lower sacrifice ratio.

However, in the empirical literature of sacrifice ratio, this effect is ambiguous. Ball (1994a), for example, found that bigger disinflation's actually lower the sacrifice ratio, supported by other empirical papers, such as Daniels et al. (2005) and Mazumder (2014).

Other papers found the opposite - Jordan (1997) and Caporale and Caporale (2008) - and in the face of such uncertainty, Magkonis and Zekente (2020) uses a BMA approach to estimate the most important drivers of the sacrifice ratio, finding that the size of the disinflation - or the change in trend inflation - has positive effects on the sacrifice ratio in 3 out of 6 different specifications, but with a weak effect, since its posterior inclusion probability (PIP) is always lower than 0.5.

In the face of this ambiguity, it is interesting that the Fair Wage model can generate this effect. In table (9), this effect is consistent with almost all of the robustness exercises, breaking down only for more extreme values of the parameters, which increases the non-linearity of the model. However, does this mean that Ball et al. (1988) argument is not valid? Maybe there is another way to interpret their argument - given a disinflation size, the sacrifice ratio will be lower if the initial starting inflation is higher.

Consider, for example, a disinflation size of $\Delta\pi = 2\%$, but in two different scenarios: one where the $\pi^1_{high} = 8\%$ and another with $\pi^2_{high} = 4\%$. Following Ball et al. (1988) argument, disinflation costs will be lower in the second scenario. Unfortunately, the Fair Wage model does not reproduce this feature, generating SR that are close for both settings, both in terms of output at the trough and in periods below the steady state level, as table (4) shows.

Table 4: Fair Wage model Sacrifice Ratios for $\Delta\pi = 2\%$

π^*_{high}	π^*_{low}	Sacrifice Ratio	Output at the trough	Periods below SS
8%	6%	2.21	-1.12	23
4%	2%	2.11	-1.11	23

Note: This table shows the sacrifice ratio for the Fair Wage model considering two disinflations with the same size, but with different starting points. It also shows output at its trough (expressed in terms of percentage deviation from its steady state level) and the number of periods where output stays below its steady state level.

In order to better understand how the Fair Wage model generates a higher sacrifice ratio, it is important to understand the model dynamics (figure (1)). Following the rise in interest rates by the monetary policy and, consequently, a contraction of aggregate demand, firms decide to adjust production accordingly, reducing both effectively used capital and labor demand. At this point, workers perceive a worsening in external conditions, increasing effort a little (since the reaction to external conditions is small: $\phi_2 = 0.004$). Since firms know that workers react more in terms of effort to changes in wage than to changes in employment conditions, they can reduce its losses by increasing nominal wages, but allowing for the wage-effort ratio to fall, which leads to a fall in real marginal costs also[9].

Since marginal costs fall, but fall less in relation to the AR benchmark model, the price adjustment made by firms is also smaller, increasing inflation persistence and prolonging the output adjustment, with further reductions in employment demand, which creates a greater recession and therefore, increases the sacrifice ratio in a disinflation. Table (5) shows exactly that - the Fair Wage model has a lower trough for output than the benchmark model. Higher disinflations reduce output even further.

In the Fair Wage model, notice that the main adjustment in the labor market comes from a rise in unemployment (or a fall in the employment rates), whereas in the

[9]Microeconomic evidence presented by Dickens et al. (2007) shows that firms avoid cutting wages.

AR benchmark model the main adjustment comes from a fall in real wages, as figure (1) shows. This feature is important because, as shown by Danthine and Donaldson (1990), US business cycles show that employment volatility is higher than that of wages - the so called wage-employment variability puzzle - is better captured by the Fair Wage model.

Table 5: Output at the trough

		Output at the trough	
π^*_{high}	π^*_{low}	Fair Wage	Benchmark
4%	2%	-1.11	-0.55
6%	2%	-2.49	-1.09
8%	2%	-4.82	-1.62

Note: This table shows the output trough (expressed in terms of percentage deviation from its steady state level) both for the Fair Wage and the Benchmark AR models for all disinflations.

Another important question is how much of the sacrifice ratio is explained by the Fair Wage hypothesis and not other nominal frictions present in the model. To better understand this, we can proceed in two different ways. Table (6) presents output standard deviation. If we assume that the Fair Wage model is a better representation for the real world, then the increase variability in relation to the benchmark model must explain the higher sacrifice ratio. Following this argument, since the benchmark model accounts for 46% of the output variability in the disinflation from $\pi_{high} = 4\%$ to $\pi_{high} = 2\%$ - the nominal frictions present in that model also accounts for 46% of the sacrifice ratio in the fair wage model, since they are essentially the same, as shown in table (7). As expected, the Fair Wage hypothesis account for more of the sacrifice ratio as the disinflation size grows.

Table 6: Output Standard Deviation

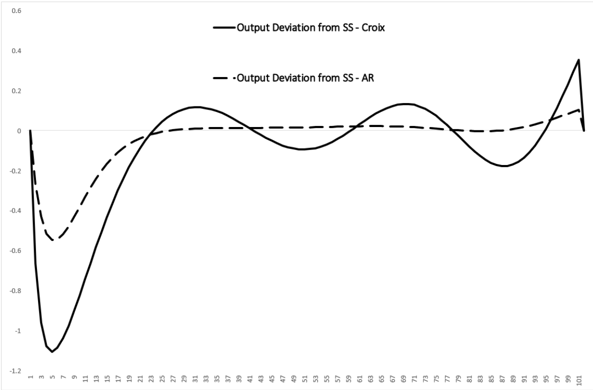
π^*_{high}	π^*_{low}	Fair Wage	Benchmark	Percentage
4%	2%	0.317	0.147	46%
6%	2%	0.739	0.293	40%
8%	2%	1.507	0.436	29%

Note: This table shows the output standard deviation (calculated on its percentage deviation from the steady state level) throughout the disinflation for the Fair Wage and the Benchmark models. The percentage column displays the Benchmark - Fair Wage output standard deviation ratio.

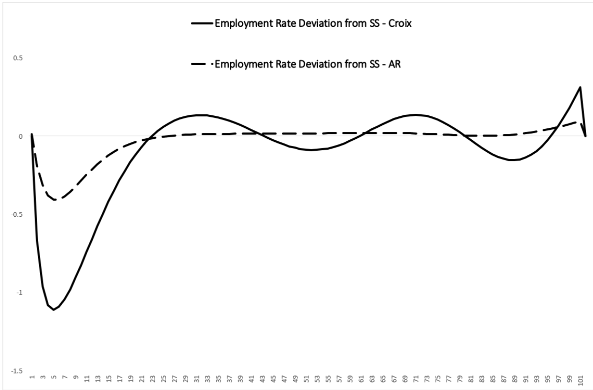
Another possible approach is by modifying the effort function parameters in order to eliminate its influence on the model dynamics and the sacrifice ratio. Notice that when $\psi \to 0$ and $\phi_0 = 1$, the effort function is given by:

$$e_t = \phi_1((1 - \phi_3)\ln(w_t) - \phi_2 \ln(N_t))$$

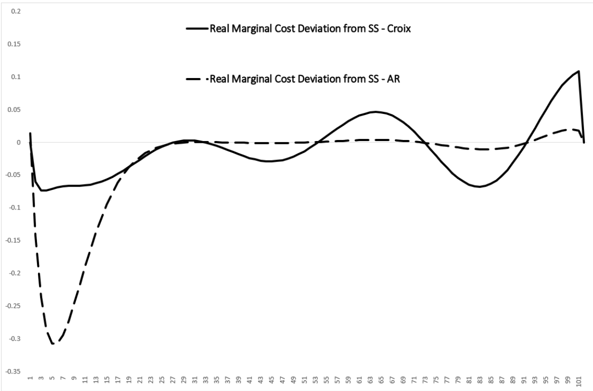
Figure 1: Model Dynamics - Fair Wage Croix vs AR Benchmark



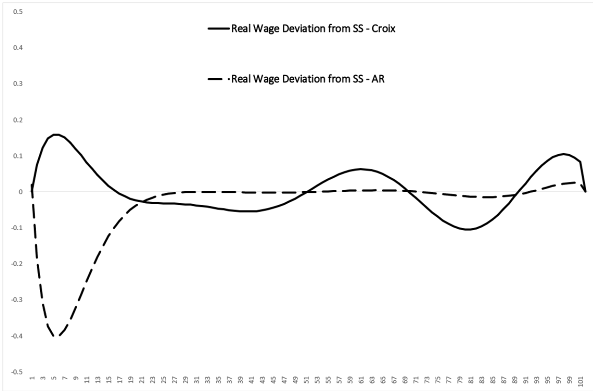
(a) Output deviation



(b) Employment deviation



(c) Marginal Cost deviation



(d) Real Wage deviation

Notes: The figure displays the dynamics for output, employment, real marginal cost and real wage in terms of deviation from its steady state value, during the disinflation, where $\pi^*_{high} = 4\%$ and $\pi^*_{low} = 2\%$. The solid line corresponds to the Croix Fair Wage model, while the dashed line corresponds to the benchmark AR model.

Then, if we increase $\phi_1, \phi_3 \rightarrow 1$, we would eliminate the effect of the reference wage on effort, allowing it to be a relation depending more heavily on the employment rate, N_t. This would allow firms to cut wages on the disinflation shock without affecting effort, reducing the need for a higher adjustment on employment rates and allowing the disinflation to proceed more quickly. The model cycle, therefore, would depend more on the nominal frictions present in the price and wage setting decisions than on the fair wage hypothesis.

Simulating the model with this in mind, we find that the sacrifice ratio actually falls - and the size of this fall would come only from the change in the parameters of the effort function, as shown in table (8). Figure (2) also shows output dynamics, which is very similar to the AR benchmark model - the differences come, of course, from different values of the other model parameters. This reinforces the idea that using this approach basically eliminates the influence of the effort function in the output dynamics and the sacrifice ratio. Both of the approaches show that the Fair Wage hypothesis is fundamental

Table 7: Sacrifice Ratio Decomposition - Standard deviation approach

		Sacrifice Ratios		
π^*_{old}	π^*_{new}	Fair Wage Hypothesis	Other Nominal Frictions	Total
4%	2%	1.13	1.08	2.21
6%	2%	1.58	1.10	2.67
8%	2%	2.79	1.13	3.92

Note: This table shows the sacrifice ratio decomposition into the Fair Wage Hypothesis and the Other Nominal Frictions effects in the standard deviation approach. Other Nominal Frictions column is the output standard deviation percentage (table (7) explained by the Benchmark model multiplied by the total sacrifice ratio in the Fair Wage model, shown in the Total Column. Fair Wage Hypothesis sacrifice ratio is found by the difference between the columns Total and Other Nominal Frictions.

to increase the sacrifice ratio in the New Keynesian model, and that its relevance also increases with the disinflation size.

Table 8: Sacrifice Ratio Decomposition - Effort function approach

		Sacrifice Ratios		
π^*_{old}	π^*_{new}	Fair Wage Hypothesis	Other Nominal Frictions	Total
4%	2%	0.78	1.33	2.11
6%	2%	1.26	1.35	2.61
8%	2%	2.56	1.37	3.93

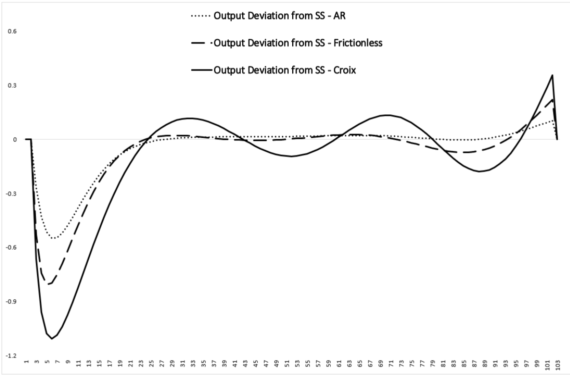
Note: This table shows the sacrifice ratio decomposition into the Fair Wage Hypothesis and Other Nominal Frictions effects in the Effort function approach. Other Nominal Frictions sacrifice ratio was found by simulating the model with $\psi = 0.001$, $\phi_2 = 0.01$ and $\phi_3 = 0.99$. Fair Wage Hypothesis is found by the difference between the columns Total and Other Nominal Frictions.

4.2 Robustness

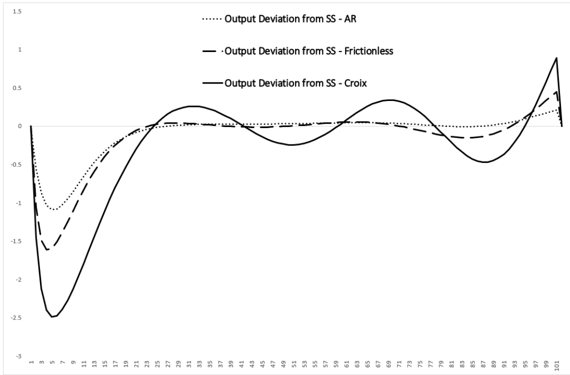
In order to better understand how the effort function parameter values affect these dynamics, we also made simulations with different values for ψ, ϕ_2 and ϕ_3, maintaining the ϕ_0 and ϕ_1 values to scale the steady-state values for employment and effort equal to 0.95 and 1, respectively. Whenever possible, we use the same parameter values as Wesselbaum (2013) in his robustness analysis, since i) for some values, the model does not satisfy Blanchard-Khan conditions and cannot be solved[10] and ii) his robustness calibration for ϕ_3 is already close to the one used in this work. For this case, we opted to use more extreme values both above and lower than the original calibration. It is also important to notice that, when simulating bigger disinflations, $\phi_2 = 0.003$ satisfy Blanchard-Khan conditions, but makes the model more non-linear and thus requires more periods (120 periods, opposed to the 100 used so far) to be solved. The same is also true for $\phi_3 = 0.9$, which

[10]This seems to be a problem for bigger disinflations simulations. For $\pi_{high} = 4\%$, this is not an issue.

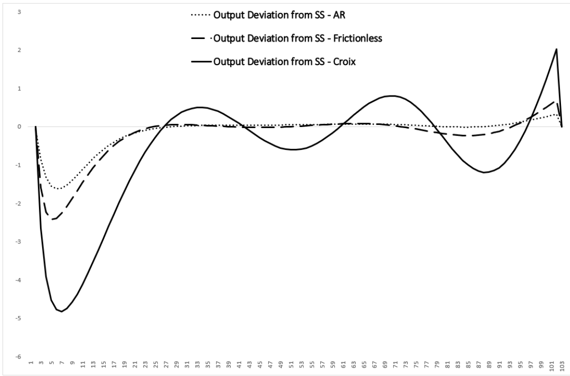
Figure 2: Output Dynamics - Fair Wage, Frictionless and AR Benchmark



(a) Output deviation - $\pi_{old} = 4\%$ to $\pi_{new} = 2\%$



(b) Output deviation - $\pi_{old} = 6\%$ to $\pi_{new} = 2\%$



(c) Output deviation - $\pi_{old} = 8\%$ to $\pi_{new} = 2\%$

Notes: The figure displays output dynamics for each disinflation, comparing the Fair Wage model, the Fair Wage model using the frictionless calibration ($\psi = 0.001$, $\phi_2 = 0.01$ and $\phi_3 = 0.99$) and the AR benchmark. The solid line corresponds to the Croix Fair Wage model, the dashed line corresponds to the frictionless calibration while the dotted line corresponds to the AR benchmark model.

required 110 periods. This also means that the results are sensible to the parametrization used - especially when using more extreme values, *ceteris paribus*.

Beginning with ψ, the degree of substitutability between the different elements of the effort function, decreasing values for ψ tends to make the effort function more linear, allowing for a smoother effort reaction to changes in wages and employment. When it comes to the output dynamics, lower values for ψ tend to increase both the output trough and the number of periods where output is below its steady state value, increasing the sacrifice ratio.

Importantly, the most significant parameter for the rise in disinflation costs in the Fair Wage model is ϕ_2. If we increase the worker's reaction to external conditions, firms no longer need to rise wages in order to increase or reduce a fall in effort - to the point where even when firms cut wages, effort still rises. In this way, sacrifice ratios fall sharply - if even when cutting wages, there is a significant rise in worker's effort because of small fall in employment rates, then marginal costs faced by the firm falls abruptly and price adjustment is fast, decreasing inflation persistence. This also eliminates the oscillatory dynamics of some variables, such as output and employment. Reducing even further the worker reaction to external conditions makes the model highly non-linear, increasing the sacrifice ratio from 2.11 to 7.10. However, for higher disinflations, the SR is lower - falling to 3.6 in $\pi_{old} = 6\%$ and rising again to 4.56 when $\pi_{old} = 8\%$. This may come from the longer periods required to solve the model.

Lastly, changing values for ϕ_3 means we are affecting mainly the effort reaction to changes in wages. In the simulation exercises, both higher or lower values for ϕ_3 do affect output dynamics following the disinflation shock, but without affecting the SR too much. For $\phi_3 = 0.9$, the SR is 2.21 - derived both from lower output trough and a slightly longer disinflation with a very similar dynamics to the benchmark calibration - whereas for $\phi_3 = 0.25$, the SR is 2.43 - that comes essentially from a longer disinflation period, despite the lower output trough.

Table 9: Sacrifice Ratio - ψ, ϕ_2 and ϕ_3

	Disinflation Size		
	4% - 2%	6% - 2%	8% - 2%
	Sacrifice Ratio	**Sacrifice Ratio**	**Sacrifice Ratio**
Croix Calibration	2.11	2.61	3.93
$\psi = 0.2$	2.31	3.06	3.15
$\psi = 0.01$	2.96	2.44	2.57
$\phi_2 = 0.01$	0.83	0.86	0.88
$\phi_2 = 0.003$	7.10	3.60*	4.56*
$\phi_3 = 0.25$	2.44	2.53	2.64
$\phi_3 = 0.9$	2.22	3.31	2.98**

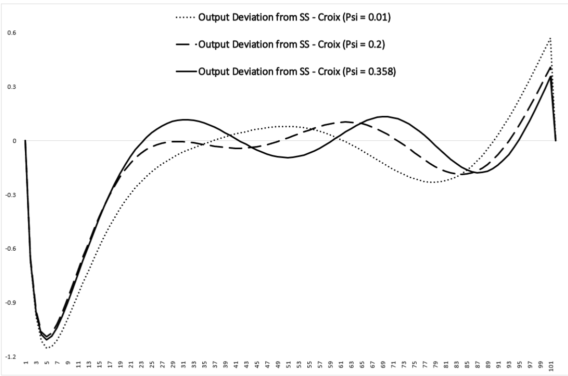
Note: The table shows the sacrifice ratio for all disinflations and for different values of effort function's parameters.
*120 periods used in the simulation.
**110 periods used in the simulation.

Table 10: Output trough - ψ, ϕ_2 and ϕ_3

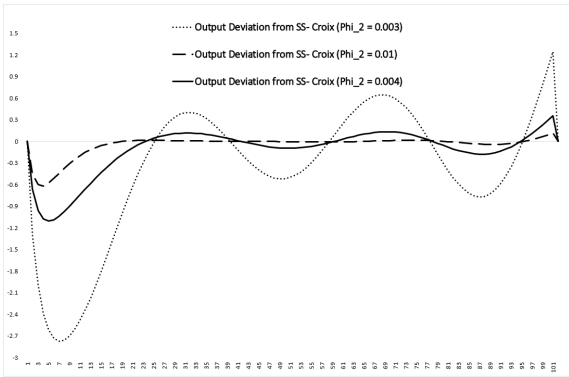
	Disinflation Size		
	4% - 2%	6% - 2%	8% - 2%
	Output trough	**Output trough**	**Output trough**
Croix Calibration	-1.11	-2.49	-4.82
$\psi = 0.2$	-1.09	-2.32	-3.50
$\psi = 0.01$	-1.15	-2.23	-3.41
$\phi_2 = 0.01$	-0.62	-1.24	-1.87
$\phi_2 = 0.003$	-2.77	-2.76*	-4.43*
$\phi_3 = 0.25$	-0.98	-1.98	-3.01
$\phi_3 = 0.9$	-1.16	-2.89	-3.92**

Note: The table shows output trough for all disinflations and for different values of effort function's parameters.
*120 periods used in the simulation.
**110 periods used in the simulation.

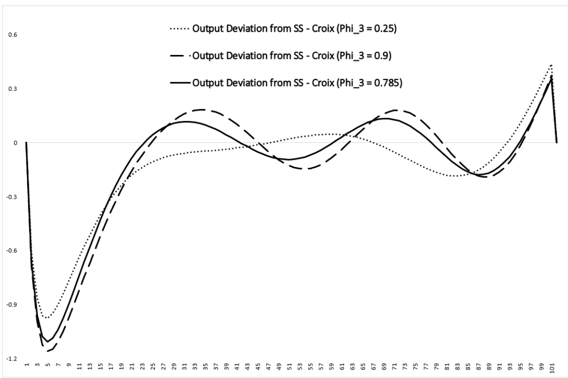
Figure 3: Output Dynamics for $\pi_{old} = 4\%$ to $\pi_{new} = 2\%$ - ψ, ϕ_2 and ϕ_3



(a) Output deviation - ψ



(b) Output deviation - ϕ_2



(c) Output deviation - ϕ_3

Notes: The figure displays the dynamics for output, for different values of ψ, ϕ_2 and ϕ_3, during the disinflation, where $\pi^*_{high} = 4\%$ and $\pi^*_{low} = 2\%$. The solid line corresponds to the Croix Original calibration, while the dashed line corresponds to $\psi = 0.2$, $\phi_2 = 0.01$ and $\phi_3 = 0.9$ and the dotted line to $\psi = 0.01$, $\phi_2 = 0.003$ and $\phi_3 = 0.25$

5 Conclusion

This work sought to investigate whether the fair wage hypothesis - modeled as a worker reaction in terms of effort to changes in the worker's own wage, the reference wage and employment rate - helps to improve a otherwise standard medium scale DSGE New Keynesian model ability's to reproduce empirical plausive disinflations costs, summarized as the sacrifice ratio - the ratio of the total output loss to the change in trend inflation.

The Fair Wage model outperforms the DSGE New Keynesian model without the fair wage hypothesis in terms of generating a higher sacrifice ratio, approximating empirical estimates of the sacrifice ratio with the model predictions, suggesting that fairness considerations may be an important driver in a disinflation. Moreover, by decomposing the simulation sacrifice ratio into two effects - Fair Wage Hypothesis and Other Nominal Frictions - we clearly see that without the Fair Wage Hypothesis, the model fails to generate higher sacrifice ratio. Another interesting feature is that the sacrifice ratio increases with disinflation size - a point with ambiguous evidence in the empirical literature.

The reason for a overall better performance of the Fair Wage Model comes from the behavior of the worker's effort and its effect on the firm real marginal cost. Following the disinflation shock, worker's effort rises, reducing the fall in marginal costs faced by the firm - which calls for a smaller optimal adjustment in prices, prolonging output adjustments and, therefore, increasing disinflations costs. Also, changes in the effort function parameters affect the sacrifice ratio, but the model is fairly robust to different calibrations, but starts to break down with more extreme values for such parameters - specially those related to the worker's reaction to employment rate and the reference wage. The model also shows some sensibility to higher disinflation sizes combined with changes in these parameters.

To the author's knowledge, this is the first attempt to use this variation of fairness in a DSGE setting to study disinflation costs and its effects on the theoretical sacrifice ratio, opening up new research opportunities. The construction of some macroeconomic measure for fairness in the labor market to use as a possible determinant for the sacrifice ratio in the empirical literature remains open. Further extensions for the Fair Wage Model, such as a more robust government sector and or a open economy would also be interesting. Another possible venue of research is the comparison between different Fair Wage models and their performance in generating plausible sacrifice ratios. For instance, comparing a model with search and match frictions to one without in a DSGE setting.

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Table

Table 11: Structural Parameters

Parameter		Benchmark	Fair Wage	Origem
Habit persistence	h	0.771	0.445	CWW (2010)
Subjective discount factor	β	0.99	0.99	CWW (2010)
Elasticity of intertemporal substitution	σ_c	1.161	1.755	CWW (2010)
Frisch elasticity of labor supply	-	1.1196	-	SGU (2005)
Degree of substitutability	ψ	-	0.358	CWW (2010)
Sensitivity to labor market tightness	ϕ_2	-	0.004	CWW (2010)
Sensitivity to alternative wage	ϕ_3	-	0.785	CWW (2010)
Price-Elasticity of demand for diff. good	θ	0.8333	0.8333	SGU (2005)
Elasticity of substitution for labor types	-	21	-	SGU (2005)
Depreciation Rate	τ	0.025	0.025	CWW (2010)
Share of Labor	α	0.76	0.76	CWW (2010)
Investment adjustment cost	δ	7.397	5.59	CWW (2010)
Capacity Utilization parameter	γ_1	0.032417	0.032417	SGU (2005)
Capacity Utilization parameter	γ_2	0.000324	0.000324	SGU (2005)
Firm Fixed Cost	Φ	0.25	0.25	-
Fraction of firms not optimizing prices	ξ_p	0.902	0.892	CWW (2010)
Fraction of firms not optimizing wages	ξ_w	0.787	0.822	CWW (2010)
Price Indexation	γ_p	0.9	0.9	-
Wage Indexation	γ_w	0.9	0.9	-
Monetary Policy	ρ	1.5	1.5	AR (2012)

Notes: This table displays the values of the structural parameters used in the main simulation for the benchmark and the fair wage model. For the parameters not presented in this work, please refer to Schmitt-Grohé and Uribe (2005) and Lunardelli and Nakane (2024).

A The Fair Wage Model Steady State

A.1 Finding the Steady State

In this appendix, we'll present the steady state equations of the fair wage model. The relevant model equations are:

$$K_{t+1} = K_t(1-\tau) + \left[1 - \frac{\delta}{2}\left(\frac{I_t}{I_{t-1}} - 1\right)^2\right] I_t \tag{41}$$

$$\lambda_t = (C_t - hC_{t-1})^{-\sigma_c} - h\beta E_t(C_{t+1} - hC_t)^{-\sigma_c} \tag{42}$$

$$e_t = \frac{\phi_1}{\psi}[w_t^{\psi}(1-\phi_3) - \phi_2\left(\frac{1}{1-N_t}\right)^{\psi} - (\phi_0 - \phi_2 - \phi_3)] \tag{43}$$

$$\lambda_t = E_t \beta R_t \left[\frac{\lambda_{t+1}}{\pi_{t+1}}\right] \tag{44}$$

$$Q_t = \beta E_t \left[\frac{\lambda_{t+1}}{\lambda_t}[r_{t+1}^k u_{t+1} - \gamma_1(u_{t+1} - 1) - \gamma_2/2(u_{t+1} - 1)^2 + Q_{t+1}(1-\tau)]\right] \tag{45}$$

$$Q_t\left(1 - \frac{\delta}{2}\left(\frac{I_t}{I_{t-1}} - 1\right)^2\right) = 1 + Q_t \frac{I_t}{I_{t-1}}\delta\left(\frac{I_t}{I_{t-1}} - 1\right) - \beta E_t\left[\frac{\lambda_{t+1}}{\lambda_t} Q_{t+1}\left(\frac{I_{t+1}}{I_t}\right)^2 \delta\left(\frac{I_{t+1}}{I_t} - 1\right)\right] \tag{46}$$

$$r_t^k = \gamma_1 + \gamma_2(u_t - 1) \tag{47}$$

$$X_t^1 = z_t Y_t \widetilde{p_t^*}^{1/(\theta-1)-1} + \beta\xi_p E_t \frac{\lambda_{t+1}}{\lambda_t}\left(\frac{\widetilde{p_t^*}}{\widetilde{p_{t+1}^*}}\right)^{1/(\theta-1)-1}\left(\frac{\pi_t^{\gamma_p}\overline{\pi}^{1-\gamma_p}}{\pi_{t+1}}\right)^{1/(\theta-1)} X_{t+1}^1 \tag{48}$$

$$X_t^2 = Y_t \widetilde{p_t^*}^{1/(\theta-1)} + \beta\xi_p E_t \frac{\lambda_{t+1}}{\lambda_t}\left(\frac{\widetilde{p_t^*}}{\widetilde{p_{t+1}^*}}\right)^{1/(\theta-1)}\left(\frac{\pi_t^{\gamma_p}\overline{\pi}^{1-\gamma_p}}{\pi_{t+1}}\right)^{\theta/(\theta-1)} X_{t+1}^2 \tag{49}$$

$$\theta X_t^2 = X_t^1 \tag{50}$$

$$s_t = (1-\xi_p)\widetilde{p_t^*}^{\frac{1}{\theta-1}} + \xi_p \left(\frac{\pi_t}{\pi_{t-1}^{\gamma_p}\overline{\pi}^{1-\gamma_p}} \right)^{\frac{1}{\theta-1}} s_{t-1} \quad (51)$$

$$1 = \xi_p \pi_t^{\frac{\theta}{1-\theta}} (\pi_{t-1}^{\gamma_p}\overline{\pi}^{1-\gamma_p})^{\frac{\theta}{\theta-1}} + (1-\xi_p)(\widetilde{p_t^*})^{\frac{\theta}{\theta-1}} \quad (52)$$

$$\frac{w_t}{e_t} = z_t \alpha \left[\frac{\kappa_t}{e_t N_t} \right]^{1-\alpha} \quad (53)$$

$$r_t^k = z_t (1-\alpha) \left[\frac{\kappa_t}{e_t N_t} \right]^{-\alpha} \quad (54)$$

$$f_t^1 = z_t \frac{q_t}{e_t} (w_t^*)^{\psi} + \beta \xi_w \left(\frac{w_t^*}{w_{t+1}^*} \right)^{\psi} \frac{\lambda_{t+1}}{\lambda_t} (\pi_t^{\gamma_w} \cdot \overline{\pi}^{1-\gamma_w})^{\psi} f_{t+1}^1 \quad (55)$$

$$f_t^2 = w_t N_t + \beta \xi_w \left(\frac{w_t^*}{w_{t+1}^*} \right) \frac{\lambda_{t+1}}{\lambda_t} \frac{(\pi_t^{\gamma_w} \cdot \overline{\pi}^{1-\gamma_w})}{\pi_{t+1}} f_{t+1}^2 \quad (56)$$

$$\alpha \phi_1 f_t^1 = f_t^2 \quad (57)$$

$$w_t = \xi_w w_{t-1} \frac{(\pi_{t-1}^{\gamma_w} \cdot \overline{\pi}^{1-\gamma_w})}{\pi_t} + (1-\xi_w) w_t^* \quad (58)$$

$$z_t = \left(\frac{w_t}{e_t} \right)^{\alpha} (r_t^k)^{1-\alpha} \alpha^{-\alpha} (1-\alpha)^{-(1-\alpha)} \quad (59)$$

$$s_t Y_t = (e_t N_t)^{\alpha} (\kappa_t)^{1-\alpha} - \Phi \quad (60)$$

$$Y_t = C_t + G_t + I_t + (\gamma_1(u_t - 1) + \frac{\gamma_2}{2}(u_t-1)^2) K_{t-1} \quad (61)$$

$$\frac{R_t}{\overline{R}} = \left(\frac{\pi_t}{\overline{\pi_t}} \right)^{\rho} \quad (62)$$

In the steady state, we'll assume that monetary policy achieve its objective, that is, that inflation is constant and equal to the target and the gross interest rate reaches its new steady state value: $\pi_t = \pi_{t+1} = \pi = \overline{\pi}$ and $R_t = R_{t+1} = R = \overline{R}$.

We also assume that all capital is effectively used, which means $\kappa = K$, implying $u = 1$.

Then, applying the usual definition of steady state, we find from the capital accumulation equation 41:

$$I = \tau K$$

From the household first order conditions for optimal consumption (42) and bonds holding (44), we have:

$$\lambda = [C(1-h)]^{-\sigma_c}(1-h\beta)$$

$$R = \pi/\beta$$

Using the first order conditions of the household for capital (45) and investment (46), we can obtain:

$$q = 1$$

$$1/\beta = r^k + (1-\tau)$$

Which implies, using (44):

$$r^k = \gamma_1$$

This means that parameter γ_1 is restricted by: $\gamma_1 = 1/\beta - 1 + \tau$.

Using the aggregate price law of motion (52):

$$\widetilde{p_t^*} = 1 \tag{63}$$

Combining the result above with the auxiliary equations (48) and (49) and applying the result in equation (50), we can obtain:

$$X^1 = zY/(1-\beta\xi_p)$$

$$X^2 = Y/(1-\beta\xi_p)$$

$$\theta X^2 = X^1 \rightarrow z = \theta$$

The price dispersion equation (51) implies:

$$s = 1$$

From the intermediate producer first order condition for capital demand (54), we can find the capital per effective worker:

$$\frac{K}{eN} = [z(1-\alpha)/(\gamma_1)]^{1/\alpha}$$

Applying this condition in the intermediate producer production function in its aggregate form, we obtain:

$$\frac{q}{e} = \left(\frac{K}{eN}\right)^{1-\alpha} N = [z(1-\alpha)/\gamma_1]^{\frac{1-\alpha}{\alpha}} N$$

Then, using the above condition in the auxiliary equation (55), we have:

$$f^1 = \frac{1}{(1-\beta\xi_w\pi^\psi)}\frac{zqw^\psi}{e} \rightarrow f^1 = \frac{1}{(1-\beta\xi_w\pi^\psi)}\left(\frac{z(1-\alpha)}{\gamma_1}\right)^{\frac{1-\alpha}{\alpha}} zNw^\psi$$

We also have from (56):

$$f^2 = wN/(1-\beta\xi_w)$$

Then, combining both of these conditions in (57):

$$\frac{\alpha\phi_1}{(1-\beta\xi_w\pi^\psi)}\left(\frac{z(1-\alpha)}{\gamma_1}\right)^{\frac{1-\alpha}{\alpha}} zNw^\psi = \frac{wN}{(1-\beta\xi_w)}$$

We obtain a expression for the real wage in steady state:

$$w = \left[\left(\frac{\alpha\phi_1(1-\beta\xi_w)}{(1-\beta\xi_w\pi^\psi)}\right)\left(\frac{z(1-\alpha)}{\gamma_1}\right)^{\frac{1-\alpha}{\alpha}} z\right]^{\frac{1}{1-\psi}}$$

The equation for the real wage law of motion provides us with:

$$w = w^*$$

Then, combining the steady state real wage with the first order condition of the intermediate producer for labor, we can find the steady state expression for effort:

$$e = \frac{w}{\alpha z}\left(\frac{K}{eN}\right)^{\alpha-1} \rightarrow e = \frac{w}{\alpha z}\left(\frac{z(1-\alpha)}{\gamma_1}\right)^{\frac{\alpha-1}{\alpha}}$$

In order to find the aggregate employment in steady state, we use the effort equation (43):

$$N = 1 - \left(\tfrac{1}{\phi_2}\left[w^{\psi}(1-\phi_3) - \tfrac{\psi e}{\phi_1} - (\phi_0 - \phi_2 - \phi_3)\right]\right)^{-\frac{1}{\psi}}$$

Since we have fully determined expressions for s, e, K and N, we can find aggregate output in steady state:

$$Y = \left(\tfrac{1}{s}\right)\left[(eN)^{\alpha}(K)^{1-\alpha} - \Phi\right]$$

Then, assuming a fixed value for government expenditure $G = \overline{G}$, we find consumption by using the aggregate demand law (61)

$$C = Y - I - G$$

A.1.1 Finding the scale parameters ϕ_0 and ϕ_1

We also made an additional assumption, just as Croix et al. (2010), that in the steady state, employment is equal to 95% and effort is constant and equal to 1.

In order to make this possible, we leave the parameters ϕ_0 and ϕ_1 free to vary, according to the new steady state value of inflation.

Assuming the values $N = 0.95$ and $e = 1$ to be true, we use the labor demand condition of the intermediate producer (53) to find:

$$\tfrac{w}{e} = z\alpha\left[\tfrac{\kappa}{eN}\right]^{1-\alpha} \rightarrow w = z\alpha[z(1-\alpha)/(\gamma_1)]^{(1-\alpha)/\alpha}$$

Then, combining this condition with equation (57) in steady state, we can define ϕ_1 as:

$$\tfrac{\alpha\phi_1}{(1-\beta\xi_w\pi^{\psi})}\left(\tfrac{z(1-\alpha)}{\gamma_1}\right)^{\frac{1-\alpha}{\alpha}} zNw^{\psi} = \tfrac{wN}{(1-\beta\xi_w)} \rightarrow$$

$$\phi_1 = \frac{w^{1-\psi}}{z\alpha}\frac{(1-\beta\xi_w\pi^{\psi})}{(1-\beta\xi_w)}\left(\frac{z(1-\alpha)}{\gamma_1}\right)^{-\frac{1-\alpha}{\alpha}} \tag{64}$$

From the effort equation (43), having expressions for the real wage and ϕ_1, we can find ϕ_0 as:

$$\phi_0 = [w^{\psi}(1-\phi_3) - \phi_2\left(\frac{1}{1-N}\right)^{\psi} + \phi_2 + \phi_3) - \frac{\psi}{\phi_1}] \tag{65}$$

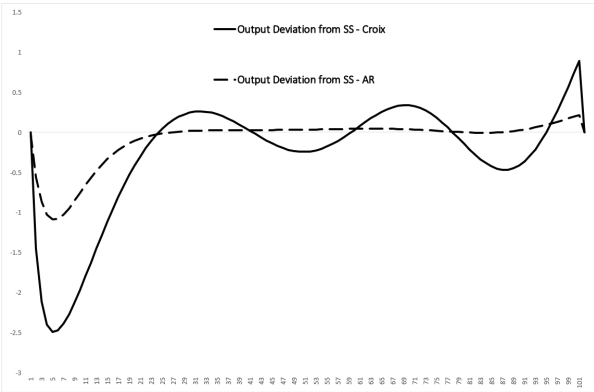
Note that ϕ_0 and ϕ_1 depend upon other important parameters, such as ψ, ϕ_2 and ϕ_3, and of the steady state inflation π. This is important because in our simulations, we alter the steady state inflation and in our sensitivity analysis, we alter ψ, ϕ_2 and ϕ_3, meaning that ϕ_0 and ϕ_1 also changes.

B Additional Simulations

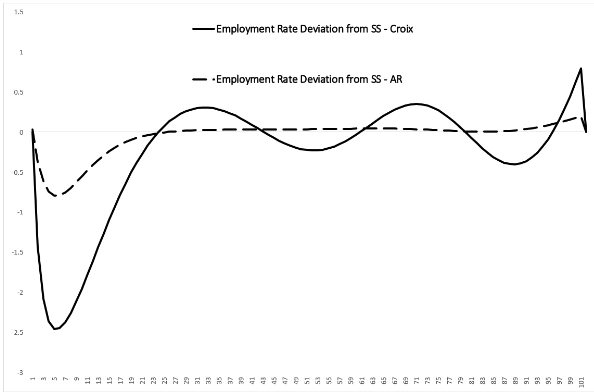
B.1 Disinflation from 6% to 2%

B.1.1 Fair Wage vs AR Benchmark - Disinflation from 6% to 2%

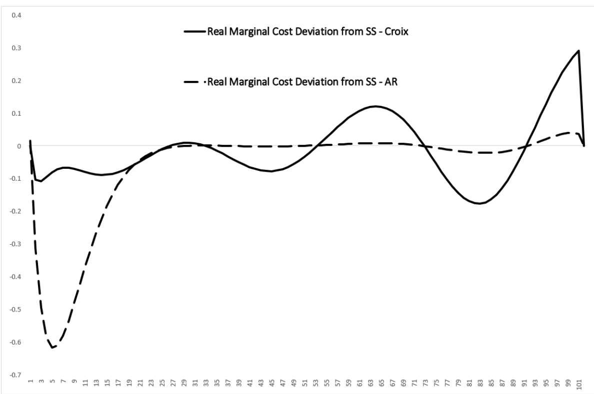
Figure B.4: Model Dynamics - Fair Wage Croix vs AR Benchmark



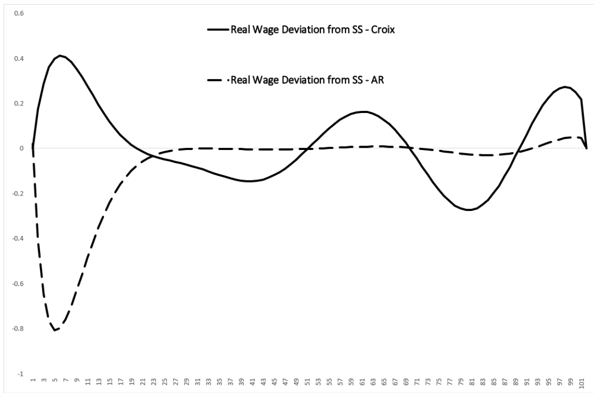
(a) Output deviation



(b) Employment deviation



(c) Marginal Cost deviation

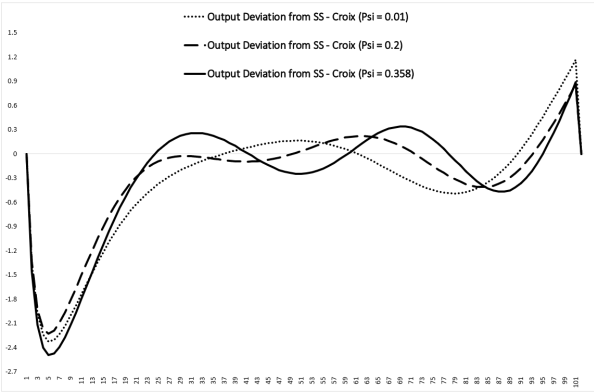


(d) Real Wage deviation

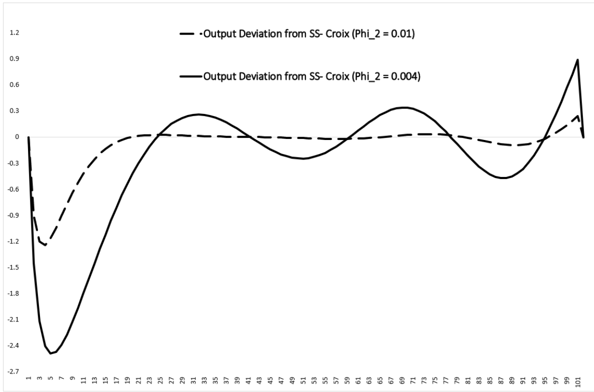
Notes: The figure displays the dynamics for output, employment, real marginal cost and real wage in terms of deviation from its steady state value, during the disinflation, where $\pi^*_{high} = 6\%$ and $\pi^*_{low} = 2\%$. The solid line corresponds to the Croix Fair Wage model, while the dashed line corresponds to the benchmark AR model.

B.1.2 Fair Wage Robustness - Disinflation from 6% to 2%

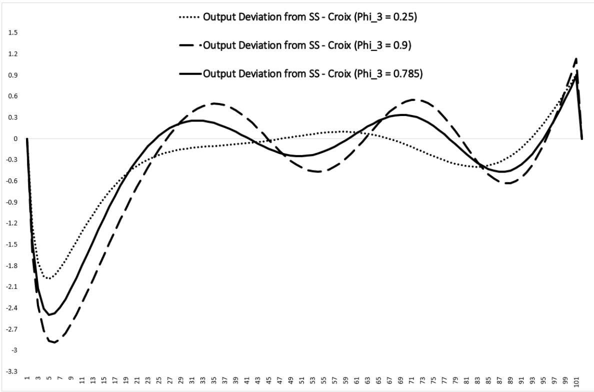
Figure B.5: Output Dynamics for $\pi_{old} = 6\%$ to $\pi_{new} = 2\%$ - ψ, ϕ_2 and ϕ_3



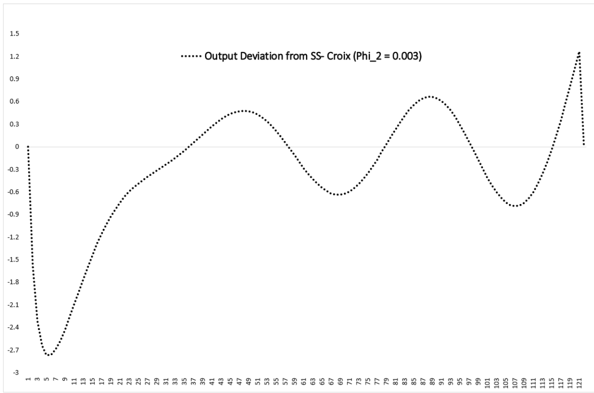
(a) Output deviation - ψ



(b) Output deviation - ϕ_2



(c) Output deviation - ϕ_3



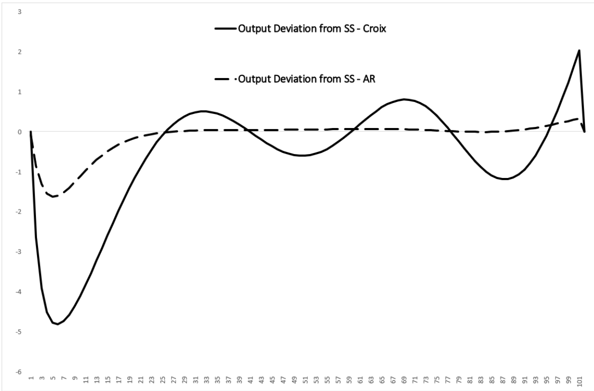
(d) Output deviation - $\phi_2 - 0.003$

Notes: The figure displays the dynamics for output, for different values of ψ, ϕ_2 and ϕ_3, during the disinflation, where $\pi^*_{high} = 6\%$ and $\pi^*_{low} = 2\%$. The solid line corresponds to the Croix Original calibration, while the dashed line corresponds to $\psi = 0.2$, $\phi_2 = 0.01$ and $\phi_3 = 0.9$ and the dotted line to $\psi = 0.01$, $\phi_2 = 0.003$ and $\phi_3 = 0.25$. The dynamics for $\phi_2 = 0.003$ is exhibited separately with 120 periods in the simulation.

B.2 Disinflation from 8% to 2%

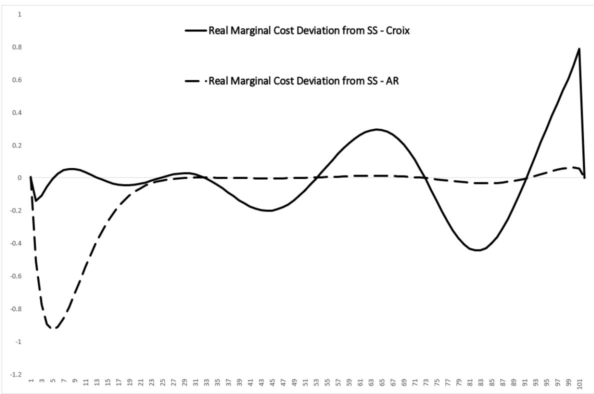
B.2.1 Fair Wage vs AR Benchmark - Disinflation from 8% to 2%

Figure B.6: Model Dynamics - Fair Wage Croix vs AR Benchmark

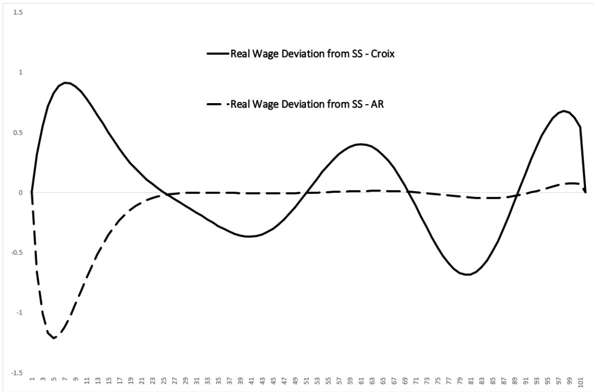


(a) Output deviation

(b) Employment deviation



(c) Marginal Cost deviation

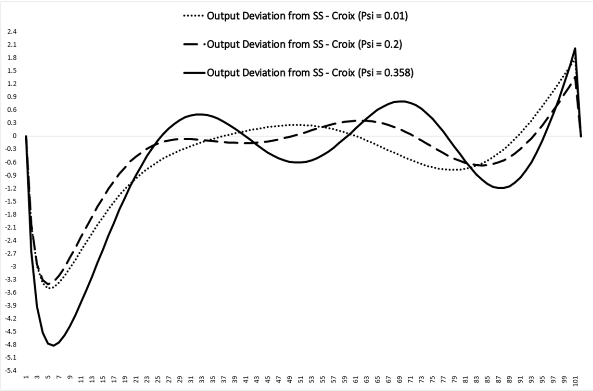


(d) Real Wage deviation

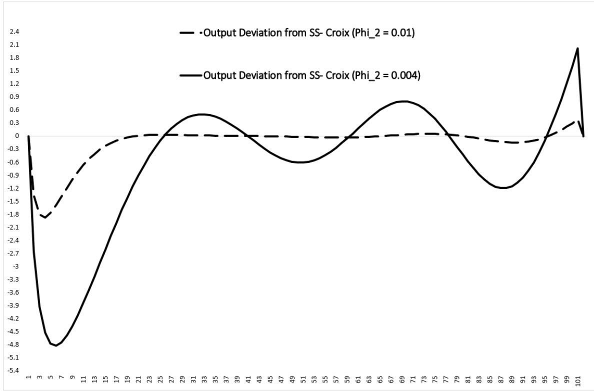
Notes: The figure displays the dynamics for output, employment, real marginal cost and real wage in terms of deviation from its steady state value, during the disinflation, where $\pi^*_{high} = 8\%$ and $\pi^*_{low} = 2\%$. The solid line corresponds to the Croix Fair Wage model, while the dashed line corresponds to the benchmark AR model.

B.2.2 Fair Wage Robustness - Disinflation from 8% to 2%

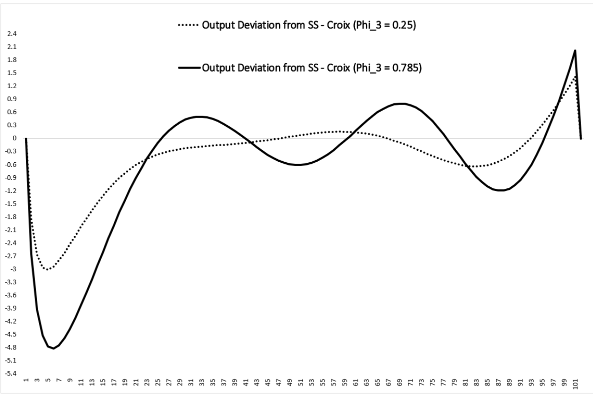
Figure B.7: Output Dynamics for $\pi_{old} = 8\%$ to $\pi_{new} = 2\%$ - ψ, ϕ_2 and ϕ_3



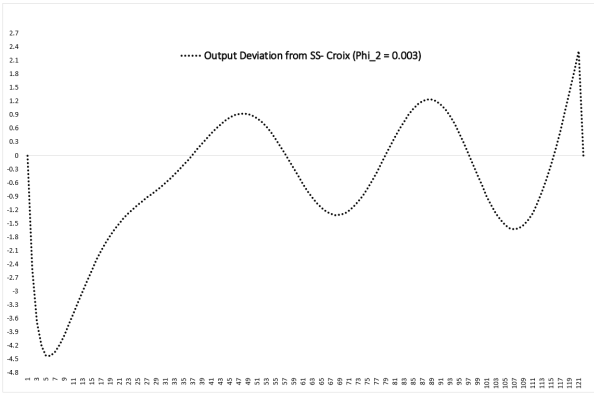
(a) Output deviation - ψ



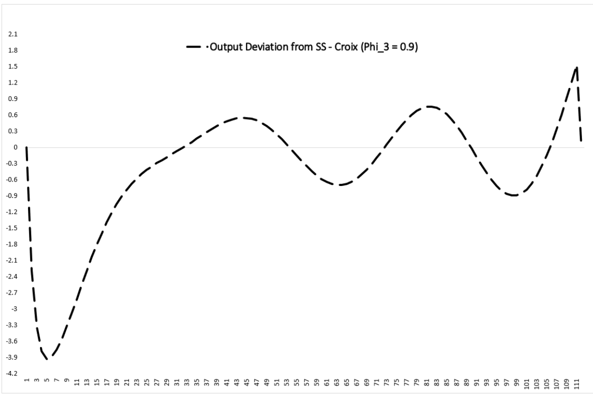
(b) Output deviation - ϕ_2



(c) Output deviation - ϕ_3



(d) Output deviation - $\phi_2 = 0.003$



(e) Output deviation - $\phi_3 = 0.9$

Notes: The figure displays the dynamics for output, for different values of ψ, ϕ_2 and ϕ_3, during the disinflation, where $\pi^*_{high} = 8\%$ and $\pi^*_{low} = 2\%$. The solid line corresponds to the Croix Original calibration, while the dashed line corresponds to $\psi = 0.2$, $\phi_2 = 0.01$ and $\phi_3 = 0.9$ and the dotted line to $\psi = 0.01$, $\phi_2 = 0.003$ and $\phi_3 = 0.25$. Output dynamics for both $\phi_2 = 0.003$ and $\phi_3 = 0.9$ is exhibited separately, with 120 and 110 periods in the simulations, respectively.