The impact of COVID-19 on house prices in Northern Ireland: price persistence, yet divergent?

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Abstract

The recent onset of the COVID-19 pandemic has had a pervasive impact on all economies and indeed housing markets. This research investigates the regional impact of the pandemic on the Northern Ireland housing market and provides a unique opportunity to measure short-term reactions to epidemic shocks. Applying a unique dataset, the research measures whether price switching effects are evident as a consequence of the epidemic, and to what extent. In order to achieve this, the research applies spatial lag models to account for the effect of COVID-19 on housing market pricing behaviour. The findings show that the autocorrelation of house prices increased after COVID-19, revealing price persistence driven by behavioural changes. The results further show that a price divergent effect is observable, with the detached sector 'leading' the price changes. This price divergence is also apparent for rural dwellings and for neighbourhoods with higher socio-economic standing making them more resistant to the outbreak of COVID-19. This is an important finding as it reveals that epidemics of this nature impact upon housing markets in a heterogeneous way in the short-term, with a clear premium observed for larger housing in healthier and wealthier areas, which may serve to reinforce housing market inequalities.

Introduction

The ubiquitous spread of COVID-19 in early 2020 was declared as a global emergency on January 30, 2020 (WHO, 2020), and has had a detrimental effect on global healthcare systems with a ripple effect on all aspects of society (Nicola *et al*., 2020). In response to the onset of this 'black swan' epidemic[1], all Governments across the globe have adopted extraordinary and unprecedented measures in order to 'flatten the curve' (Allen-Coghlan & McQuinn, 2020), enforcing border shutdowns, travel restrictions, national 'lockdowns', business closures, forbearance on mortgage payments with the associated fluctuations in stock prices and rising inflation expectations resulting in shocks within all national economies (Capponi et al., 2020; Anenberg & Scharlemann, 2021).

The implications of such market closures and economic disturbance to local, regional and national economies has led to a widely held view that the pandemic, similar to other catastrophic events, has culminated in a combined supply and demand shock, evidenced by changes in aggregate consumption patterns and behaviours, notably affecting the major factors driving overall housing demand and its composition (Giesecke *et al*., 2012; Duca et al., 2021). As Cheshire et al. (2021) highlight, the onset of the pandemic in the UK resulted in a marked contraction in non-essential construction activity, revealing housing completions fell by 65% when comparing with corresponding trends in the year previous, with transaction volumes also witnessing a sharp downward adjustment in the short-term. Evidence also highlights that the socio-economic implications of the pandemic are many and varied

[1] See: Resilient leadership responding to COVID-19 | Deloitte insights. available at:https://www2.deloitte.com/global/en/insights/economy/covid-19/heart-of-resilient-leadership-responding-to-covid-19.html

(Nicola *et al*., 2020), which has tended to impact upon the structural and topographical nature of housing markets – such as compromising affordability due to changes in income levels, unemployment and borrowing capacity. In contrast, research has also indicted the resilience of house prices throughout the pandemic as a consequence of government support and stimulus packages coupled with loose monetary policy and low interest rates which have served to maintain house prices over the long-term. As Duca et al. (2021) highlight, this elasticity displays noteworthy differences in house price appreciation reflecting the heterogeneous effects of the pandemic on national economies and housing markets.

Indeed, a strong and pervasive 'behavioural' undertone within and across most (advanced) housing markets has emerged due to the psychological effects of the pandemic, impacting upon the composition of housing market demand and supply. This has principally been channelled through changes in buyer and seller behaviour and market demand tastes – primarily for 'space'. This as Cheshire et al. (2021) claim, has resulted in a shift in scarcity-driven demand for particular types of properties - namely larger housing with evidence of price increases notable for detached houses relative to other types within both the UK and the US (Duca et al., 2021).

Of importance is the dissimilar nature of the price trajectories and obvious regional effects of price changes across the various property types driven by these tastes and preferences in light of COVID-19. The analysis undertaken by Chesire et al. (2021) for the UK noted that transaction prices for the higher priced segments of the market, that of detached and semi-detached, recovered almost instantaneously in the immediate aftermath of the COVID-shock, whereas pricing levels for smaller property types were more subdued due to the other multifarious forces that shape the dynamics of house prices. Equally, the study of Duca et al. (2021) highlighted that post-pandemic price trends appear consistent with that of a *K*-shaped recovery which is suggestive that price improvements are more apparent for educated and wealthier households. Thus, initial research exploring the consequences of the pandemic suggest that it has arguably served to distort the relationship between income levels and the trajectory of changes in house prices manifesting in unequal income distribution - or the *stretching* of the income distribution (Cheshire et al., 2021). Further, Furceri et al. (2020) aver that the immediate effects of the epidemic has seemingly amplified regional disparity between house prices, wealth inequality, compromised geographic mobility and extenuated the inequality between owners and private renters in the U.K. (Blakeley, 2021).

For the regional U.K. devolved administration of Northern Ireland, previous to the epidemic, the housing market was beginning to show signs of stable growth with nominal quarterly price inflation (UU HPI, Q4 2019) in the wake of the decision to leave the European Union. The exogenous drawn out political events within the U.K. from 2016 brought uncertainty to the housing market, particularly in relation to market demand as a result of wider economic uncertainty. For NI, this uncertainty was somewhat heightened by the political sensitivities surrounding the customs union protocol and the *de facto* customs border. Consequently, the housing market in NI over this period witnessed limited price growth and saw consumer confidence curtailed through Brexit uncertainty, political instability and a tenuous economic position. Nonetheless, during 2019 and particularly over the second half of 2019, the housing market showed signs of recovery with market sentiment optimistic with consecutive quarterly price inflation which continued to increase into 2020 demonstrating more stable market conditions (UU HPI, Q4 2019; Q1 2020).

The onset of COVID-19, resulting 'closure' of the housing market and its subsequent 'reopening' has resulted in some notable trends, particularly in terms of market psychology as buyers and sellers alike have evaluated their housing options and lifestyle choices. The post-COVID-19 market, in terms of price performance, continues to 'heat' underpinned by sizeable levels of market demand. Indeed, research has continued to evaluate the housing market and pinpoints heightened transaction levels after the first lockdown period, the highest since 2005, strong levels of trading-up activity and relocation, particularly for semi-detached and larger detached properties (UU HPI, Q1 2021) – a trend in parallel with the wider UK. There is also evidence of a divergence between asking prices and sale agreed prices – reflecting a seller's market (UU API, 2021). This price inflation alongside the continued imbalances in terms of housing supply and other factors continue to impact on the housing market in NI. Wider market dynamics at play such as the ongoing global supply chain issues arising from the response to the pandemic have been well-documented, and Northern Ireland has not been immune to these challenges. Figures compiled by the Construction Employers Federation (CEF) recently reported[2] rising material costs and materials shortages, with inelastic supply in sectors of the market further causing sharp price inflation, particularly in the detached sector. This is important as research by McCord et al. (2019) and more recently Lo et al. (2021) previously highlighted that the detached sector 'acts as a causal price leader' with price filtration effects radiating into other market sectors with knock-on consequences for the private rental sector.

Further, in terms of the impact of health inequality and deprivation, recent government research in NI has established some notable relationships. Recent reports published by the Department of Health entitled "*Coronavirus related health inequalities*"[3] have documented the level of infection rates, hospital admissions and COVID-19 related deaths relative to deprivation rankings and in relation to rural and urban locations. These reports highlighted that infection rates in the 10 percent most deprived areas are almost two-thirds higher than infection rates in the 10 percent least deprived areas - and more

[2] CEF NI. Materials shortages and cost increases threaten viability of construction sector, 7th July 2021.
[3] See: https://www.health-ni.gov.uk/publications/coronavirus-related-health-inequalities-december-2020

than one and a half times the NI average. They also note that infection rates in urban areas were over a third higher than infection rates recorded in rural areas[4] (DoH, December 2020).

With regards to hospital admissions, the findings also highlighted health inequalities specific to deprivation. The reported statistics showed that the inequality gap between the 10 percent most and least deprived areas for confirmed COVID-19 admissions was notably higher than for all admissions, with the admission rate in the 10 percent most deprived areas some 50 percent higher than in the least deprived areas. This effect was also noticeable in a spatial context when comparing standardised admission rates at the Local Government District (LGD) level (DoH, December 2020). The analysis showed the Belfast LGD, the largest conurbation across Northern Ireland, to comprise the highest admission rates, with Fermanagh and Omagh LGD, one of the most rural regions of NI, to have the lowest levels of admissions. This spatial impact also noted a dichotomy between rural and urban effects, with standardised infection and admission rates lowest in rural areas. When considering death rates, the research revealed that death rates in urban areas and mixed urban/rural areas were double than in rural defined locales. The analysis also indicated that COVID-19 death rates were almost two-fifths higher in the 10 percent most deprived areas relative to the 10 percent least deprived areas. Similar to mixed urban-rural areas, the death rate in urban areas was double the rate seen in rural areas (DoH, December 2020).

The effect of pandemics or (global) health emergencies on housing markets is a relatively unexplored area, and more specifically there is a lack of research linking COVID-19 and housing prices within the UK context (Francke & Korevaar, 2020). Consequently, this paper investigates the regional impact of the COVID-19 pandemic on the housing market within Northern Ireland. The COVID-19 epidemic provides a unique opportunity to measure housing market short-term reactions to epidemic shocks. As such, there remains many questions and limited empirical insight and rigor as to the effects on pricing behaviour and uniformity since the onset of the pandemic such as: how did housing market pricing behaviour respond during an epidemic? Is this response heterogeneous? is there evidence of differential pricing effects in relation to socio-economic standing and inequality? and do infection rates have an impact on market pricing?

Accordingly, using a unique dataset derived from a leading market agency firm[5], we attempt to measure and explain whether short-term price switching effects are evident, and to what extent these vary in relation to property types, i.e. we examine whether the initial impact (shock) of COVID-19 has had a differential impact across housing segments in the short-term. Further, in light of recent government

[4] See DoH report for a fuller breakdown of the standardised infection rates.
[5] Ulster Property Sales (UPS).

research which has identified the role of deprivation in relation to COVID-19 health inequalities, we test whether neighbourhoods with lower (higher) levels of income deprivation, educational attainment and accessibility deprivation have helped contribute to unequal pricing effects due to COVID-19. To do so, several spatial-lag models are constructed in order to capture direct and indirect effects of the pandemic on pricing performance and behaviour. The analysis is further extended to account for interaction terms between key neighbourhood determinants such as urban-rural classification and deprivation to establish whether socio-economic standing has had an impact on driving pricing performance in the post-COVID-19 period. Finally, we test whether infection rates have comprised an effect on property prices.

Literature

Traditionally, very few studies have evaluated epidemic risks on the real estate market or indeed the effect of pandemics or health emergencies on housing markets - although a growing body of research is emerging. Numerous studies have examined the role of natural disasters and house prices (Hallstrom & Smith, 2005; Smith et al., 2006; Zhang & Peacock, 2009; Mueller et al., 2009; Bosker et al., 2019; Apergis, 2021), which have all revealed marked differences in behaviour of buyers and sellers, willingness to pay premiums and discounts, and that responses to disasters are a consequence or combination of local economic and demographic factors characterised by socio-economic status and driven by the different financial capacities of homebuyers.

Epidemics and house prices

In terms of epidemics, research has tended to examine them from a social and economic perspective (Heng et al, 1998; Schrecker & Bambra, 2015; Alazzam et al,, 2013), with only a limited number of studies conventionally examining epidemics and their impact upon housing markets. In a systematic review, Francke & Korevaar (2021) reviewed evidence from historical pandemic outbreaks from the 17th-century plague in Amsterdam and 19th-century cholera outbreak in Paris. Using micro-level transaction data, they found that both outbreaks resulted in sizable declines in house prices between ten and thirteen percent, particularly in the short-term. Despite the large observed corrections, they did find that the price shocks were temporary, with both cities reverting to their original (price) path trajectories, indicating price distortions were unaffected to major shocks originating from epidemics. With more specific reference to the SARs epidemic in the early 2000's, the study conducted by Wong (2008) explored the reaction of the housing market and house prices using panel data on 44 housing complexes in Hong Kong. Their study found price declines of up to three percent and 1.6 percent on average, noting that housing market characteristics limited any *real* price shock. This finding was also apparent in a later study by Argyroudis & Siokis (2019) who also illustrated that the underlying dynamical structure of the housing market was impacted by certain events like the SARS epidemic.

COVID-19 pandemic and house prices

The recent COVID-19 epidemic has seen much more increased empirical investigation, particularly in a housing market context across a number of disparate strands, namely; the efficiency of monetary policy (Apergis, 2021), socio-economic implications (Nicola et al., 2020), mortgage forbearance (Capponi et al., 2020; Anenberg & Scharlemann, 2021) and the role of financialisation and inequality (Blakeley, 2021). In contrast with the previous research findings into epidemics, early research on COVID-19 tends to display mixed findings with preliminary evidence showing both house price buoyancy and house price deterioration (Ouazad, 2020). The study undertaken by Wang (2021) employing individual level transaction data, explored the effect of COVID-19 on house prices across five regions in the US which varied in economic features and lockdowns. Applying an augmented difference-in-differences method with nonparametric smoothing to ensure similarity in the control and treatments, the author reveals that all but one of the market areas displayed house price growth, noting some markets areas displayed a 'lead' effect which the author infers is a consequence of stronger housing market fundamentals, better amenities and less dependence on service industries.

In a comparable study, Duca et al. (2021) discovered that variances in house prices across countries were a product of their economic base, revealing locations that are more dependent on tourism displayed slower price appreciation. The authors also observed differences in price trajectories, noting that condominiums pricing levels in some locations have declined relative to the price of detached houses. The authors contend that this is due to behaviour factors and preferences suggesting that wealthier households demand more space and larger dwellings in more peripheral or peri-urban locales which has impacted upon the realignment of house prices as a consequence of COVID-19 lockdowns. This finding is also evident in the work of Ouazad (2020) who examined urban housing markets, particularly the role of 'shocks' and fundamentals. The research illustrated that despite such large shocks induced by the COVID-19 epidemic, the dynamic nature of prices in the short-run is consistent with the market's expectations of resilience. Ouazad (2020) also averred that, particularly within metropolitan areas, housing demand increased more rapidly than in less dense localities and in neighbourhoods farther away from urban centres which they deem is consistent with households' adaptation to changing conditions.

Keeping with short- and long-run pricing shocks, Del et al. (2020) specified a real estate pricing model to evaluate the short- to medium-term COVID-19 effects on housing prices. Employing a "prey–predator" model developed by Lotka–Volterra (Lotka, 1925), they revealed short-run house price declines of 4.2% and medium-run declines of 6.5% between late 2020 and early 2021 which they attributed to the reduction in consumption and decreases in workers' per capita income as a result of increased unemployment.

Studies have also attempted to measure reported COVID-19 cases and the effect on pricing performance. D'Lima et al. (2020) for the US, reported decreases in house prices within states who were in lockdown, and empirically found that a unit increase in contagion rates decreased house prices in affected states by circa 5.1% - after the effective shutdown dates. Parallel research from the Chinese perspective has also examined the number of cases and the impact on house prices. The study undertaken by Qian et al. (2021) using monthly data at the community-level of confirmed COVID-19 cases, applied a Difference-In-Difference method and showed price declines of 2.5% of house prices of the communities with confirmed COVID-19 cases. Interestingly, the authors run parallel pre-trend test and the placebo test to confirm the results and also established that the COVID-19 impact tended to persist for three months with the extent of the effect increasing with time. Moreover, the authors revealed that the impact of COVID-19 on house prices only existed in regions with higher infection levels or with worse medical treatment conditions.

A concomitant study by Liu and Tang (2021) also evaluated the impact of COVID-19 on the real estate market using a community-level panel dataset of 34 major cities in China. The authors observed that communities with increased levels of verified COVID-19 cases observed declines in average prices by 1.3% relative to communities with limited confirmed cases, illustrating that prospective homebuyers are willing to pay a premium equivalent to approximately 1.3% of the average housing price to avoid health risks. Whilst showing a price decline effect in the short run, the authors ascribe the response of the housing market to be heterogeneous due to community and city characteristics, although equally note that any price declines are ephemeral and returned to their original path developments following the epidemic shock.

Evaluation of the extant literature reveals some unique and insightful aspects to the nature, level and longevity of the effect of COVID-19 on housing markets and price performance. These existing studies have also illustrated that price declines are attributed to the 'shock' in the immediate aftermath but then appear to recover. Although, it is noteworthy that there seems to be differences in price trajectories within different housing segments and within particular markets as suggested by Nicola et al. (2020). The magnitude of the dissimilar price trajectories across housing types, appears driven by idiosyncratic demand tastes and preferences in distinct market locales and suggests that socio-economic-demographic characteristics may also be driving the differential pricing effects. The literature has therefore demonstrated that COVID-19 has arguably altered housing market volatility, market structures and the realignment of house prices, certainly in the short-term. This paper proceeds to investigate the impact of COVID-19 in the U.K. context with the regional jurisdiction of Northern Ireland and its short-term effect on the housing market.

Data and Methodology

Data

The sales data and accompanying attributes utilised within this study is derived from the largest independent chain of residential estate agency practices, Ulster Property Sales (UPS) which has fourteen branches strategically geographically spread across Northern Ireland and covers a large cross-section of the residential real estate market[6]. The data comprised a number of attributes pertaining to date of instruction, acceptance date and completion date alongside property address, property type, bedrooms and achieved prices. The property addresses were incorporated into GIS software (QGIS and ArcView3.3) 7 and a series of spatial joins undertaken to encompass wider built environment and socio-economic datasets with the property information.

To account for socio-economic characteristics, we test the local variation of these variables using the Multiple Deprivation Measures (MDM) produced by the Northern Ireland Statistics and Research Agency (NISRA). This measure of deprivation provides a mechanism for ranking areas in the order of the most deprived to the least deprived and is characterised by Seven distinct domains[8] of deprivation which are made up from one or more indicators. Thus, MDMs are incorporated to assess the price performance during COVID-19 relative to the constituent domains of MDM. The role of urban structure was also incorporated in order to establish and measure if the impact of COVID-19 has driven, or differentiated price changes in terms of urban-rural classification[9]. This was achieved by layering the house price data against the Settlement Development Limit shapefiles available from the NISRA. As the settlement development limits and government district boundaries are not co-terminus, the data was converted to centroids (as opposed to polygons) to facilitate the best fit between the datasets.

COVID-19 health statistics are recorded on the NI Department of Health COVID-19 Dashboard[10]. This Dashboard provides COVID-19 reported statistics relating to COVID-19 testing, hospital inpatients and admissions, deaths, hospital occupancy and care home outbreaks at varying spatial levels and scales

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[6] UPS is a strategically placed chain of estate agents representative across key urban and rural housing market areas within NI, with their sales (transaction) data historically representing by volume approximately one quarter of the NI house Price Index.

[7] Two different programs were used as they comprise a different range of functions required for further modelling purposes.

[8] The Seven domains of deprivation are: Income Deprivation Domain; Employment Deprivation Domain; Health Deprivation & Disability Domain; Education, Skills & Training Deprivation Domain; Access to Services Domain; Living Environment Domain; Crime & Disorder Domain. The ranks of the 7 domains are weighted and combined, to provide a ranking of multiple deprivation (MDM) for the 890 SOAs (NISRA, 2017:2).

[9] The urban-rural classifications are derived from NISRA from local development limits and development plans. NISRA classify Urban as falling within Development Settlement Limits, with Rural defined as those areas which fall outside the Settlement limits.

[10] Available at : https://app.powerbi.com/view?r=eyJrIjoiODJjOGE3ZDUtM2ViNy00YjBlLTllMjktOTNjZjlkODJhODU4IiwidCI6ImU3YTEzYWVhLTk0MzctNGRiNy1hMjJiLWNmYWE0Y2UzM2I2ZSJ9

and is updated periodically. Within this study, we examine COVID-19 infection rates at the LGD level in order to compare with deprivation statistics and reporting and due to the incomplete time series data at any other permissible spatial scales whilst ensuring sample representativeness. Admission rates were not obtainable at any meaningful spatial geography being only available at the Health and Social Care Trust level which are only broken down into a high-level (five) geographic regions[11] and do not align with housing sub-markets. Further, on a technical point, the government designated some key regionally based hospitals as 'COVID-only hospitals' for admitting patients. Thus examining admissions would not be correctly aligning hospitalisation admission information with the underpinning housing market and pricing information.

The time period of investigation was purposely chosen for two important sampling considerations: First, it has to minimise the effect arising from other exogenous but irrelevant factors such as political and macroeconomic turbulence (e.g. Brexit) on the dependent variable so that we can achieve a *ceteris paribus* condition for analysis. Second, it should contain a sufficiently large degree of data variation in order to statistically observe and compare the market performance before and after the outbreak of COVID-19. Hence, a nine-quarter period, from Q1 2019 to Q1 2021, was selected for examination. The initial database was scrutinised and purged based on removal of missing information and erroneous data entry, leaving 3,335 transaction data for analysis.

Further scrutiny of the sales information revealed that the analysis is based on 1,931 (58%) sales which were pre-COVID-19 and 1,404 (or 42%) post-COVID-19, providing representativeness in the samples for analysis purposes. When further examining the composition of sales transactions by property type, the data also shows relative consistency between the pre- and post-COVID periods[12]. We further incorporated Cartesian co-ordinates to the dataset in order to analyse the data using spatial hedonic models. Every observation therefore contains a tailored but comprehensive set of information at both the property and neighbourhood levels. Where appropriate, the variables are transformed into binary or categorical state with a full description of the attributes observable in Table 1.

Table 1 Description of variables and data sources

Methodology

11 The five geographic regions are: Belfast, Northern, South Eastern, Southern and Western.

[12] In terms of number of sales transactions, the detached, semi-detached, terrace and apartment sectors respectively accounted for 17.61%, 40.05%, 32.73% and 9.61% of the entire market before the outbreak of COVID-19 (Q12019 -Q12020). The composition became 20.99%, 39.72%, 30.35% and 8.94% thereafter (Q22020 – Q12021).

Since the pioneering work of Rosen (1974), there has been a general consensus amongst real estate academics that the hedonic pricing method offers a statistically reliable and efficient analytical tool to model real estate prices. This regression-based method is designed to explain and/or forecast dwelling prices using a system of equations that accounts for historical transaction prices as a function of different property and neighbourhood attributes. However, as noted by Dublin et al. (1999), the traditional hedonic pricing approach may not accurately account for geographic locations and other important spatial information of the dwellings in an explicit manner, which more often than not leads to estimation inefficiency and biased statistical inference as a result of the existence of spatially autocorrelated errors. Against this theoretical backdrop, this study employs the spatial-lag model (SLM) for real estate pricing developed by Can (1992), to examine the effect of COVID-19 on the residential market in Northern Ireland. According to Can (1992), SLM is statistically appealing in that it is parsimonious with the spatial autoregressive term(s) capturing a large amount of information related to the geographic nature of the property, resulting in fewer independent variables to be incorporated in the equation[13].

Broadly speaking, a SLM determines that the sale price of a property can be expressed as a function not only of its physical attributes, but also of the prior transaction prices of other properties in close proximity. In other words, the price of the subject property is spatially "lagged" in relation to the prices of adjacent properties, and hence there should be a functional inter-relationship between the price of the former and those of the latter. In practice, such spatial lag (SL) pricing effects is acknowledged and accounted for by property traders and appraisers through the comparable sales valuation method used to estimate real estate prices (Can and Megbolugbe, 1997). The SL method has therefore been widely employed in the literature to study various issues and problems in real estate such as Kim et al. (2003) and McCord et al. (2018), who investigate the impact of air quality on residential property pricing; and Haider and Miller (2000) who quantitively measure the degree of externality that improved infrastructure development could bring in terms of change in property price. In the following subsections, a number of SLMs are specified to incorporate the effect of COVID-19 on pricing behaviours accounting for important neighbourhood and locational information. All equations are estimated using Ordinary Least Squares (OLS) methods[14].

[13] This also reduces concerns in relation to omitted variable bias.

[14] We note that Maximum Likelihood Method is commonly employed for SLM for real estate market studies due to the bi-directionality of spatial association of properties – the price of a dwelling determines and is determined by the price of another dwelling. However, the SLMs in our study are designed in such a way that current prices were restricted to be dependent on prior prices, but not vice versa, implying that our regression equations are not endogenous. Therefore, the OLS estimation method produces consistent and asymptotically efficient results under the i.i.d assumptions. This is confirmed by employing standard diagnostic tests.

Traditional Hedonic Model

To examine the effects of different property-level and neighbourhood attributes on property prices, we formulate the following traditional hedonic regression equation as our base model:

$$lnP_{i,t} = c + \sum_{k=1}^{K} \alpha_k S_k + \sum_{m=1}^{7} \beta_m N_m + \sum_{n=1}^{8} \gamma_n T_n + e \quad (1)$$

Where $lnP_{i,t}$ is the natural logarithm of the transaction price of property price *i* at time *t*; *c* is a constant term; S_k is structural attribute k of the property; N_m is neighbourhood attribute m; T_n is a quarterly time dummy.

We further generate a number of sequential hedonic models based on Equation 1 to test for the collective and individual effects arising from different combinations of attributes embedded in S_k and N_m. In our models, S_k incorporates property size and property type, which is categorised as detached, semi-detached, terraced or apartment. N_m is a set of dummy variables that covers the local government districts in Northern Ireland, which proxy the general neighbourhood quality enjoyed by a given property. α_k, β_m and γ_n are regression coefficients to be estimated for S_k, N_m and T_n respectively.

Spatial Lag Hedonic Model

Based on Equation 1, we further develop a series of SLMs which can be expressed as:

$$lnP_{i,t} = c + \rho \sum_{j=1}^{n} W_{i,j} lnP_{j,t-h} + \sum_{k=1}^{K} \alpha_k S_k + \sum_{m=1}^{7} \beta_m N_m + \sum_{q=1}^{8} \gamma_q T_q + e \quad (2)$$

The main rationale behind the SLM is to include a spatio-temporal term, $\sum_{j=1}^{n} W_{i,j} lnP_{j,t-h}$ into the regression equation[15]. $P_{j,t-h}$ is the price of property *j*, transacted at time *t-h*, with $h \leq 3$ months in the models[16]. W is a spatial weight that measures the structure of the spatial proximity between property *i* and property *j*.

The spatial weight is constructed as property traders would give a heavier weight to dwellings that are more proximate to the subject property in the price determination process. The most commonly used specifications for spatial weighting in SLM include inverse distance, inverse distance-squared and

[15] Based on the comparable-sales method of valuation, it is assumed that sellers or traders use evidence of recently transacted dwellings in close proximity to determine the price of the subject property.

[16] Note: we initially tested for Structural breaks using the Schwarz and LWZ criterions in order to determine when and whether there is a significant change in our data. The overall analysis across the various property types and at the aggregate position illustrated a structural break at Q22020. The full structural and breakpoint tests are available upon request.

inverse exponential distance (Equation 2.1)[17]. Mathematically, W can take one of the following three forms:

$$W_1 = \frac{1}{d_{i,j}}\ ;\ W_2 = \frac{1}{d_{i,j}^2}\ ;\ W_3 = \frac{1}{e_{i,j}^d} \tag{2.1}$$

Where $d_{i,j}$ denotes the Euclidean distance between property i and j.

Given that the summation of all spatial weights is equal to 1, i.e. $\sum_{j=1}^{n} W_{i,j} = 1$, the spatial autoregressive term $W_{i,j}\, P_{j,t-h}$ represents a weighted average of all spatially lagged price information for property i within a three-month (quarterly) period[18]. The coefficient, ρ, therefore suggests the extent to which traders extract price information from previous transactions to determine current property price. Thus, if past pricing information is relevant and important, the coefficient ρ should be non-zero and statistically significant, signalling that property prices are spatially auto-correlated.

To explore whether the pandemic has any effect upon the spatial autocorrelation in property prices, we include an interaction term, $\sum_{j=1}^{n} W_{i,j} lnP_{j,t-h} * COVID$, yielding Equation 3 with μ being its coefficient . In this regard, $COVID$ is a dummy variable which is equal to one if the property was sold in or after 2020Q2 which represents the period of market closure; μ is positive (*negative*) and statistically significant If, and only if, COVID-19 strengthens (*depresses*) the spatial autocorrelation in property prices.

$$lnP_{i,t} = \mathrm{c} + \rho\sum_{j=1}^{n} W_{i,j} lnP_{j,t-h} + \mu\sum_{j=1}^{n} W_{i,j} lnP_{j,t-h} * COVID + \sum_{k=1}^{K} \alpha_k S_k + \sum_{m=1}^{7} \beta_m N_m + \sum_{q=1}^{8} \gamma_q T_q + \mathrm{e} \tag{3}$$

We further conjecture that the pandemic could have altered, at least temporarily, the spatial preference of homebuyers who are in favour of more living space over other considerations such as proximity to city centre. We posit that the nation-wide lockdowns alongside the new working practices such as workplace flexibility since COVID-19 might have changed the balance of demand for housing, weighting towards larger homes that provide more space to work from home. To confirm this, we develop and test Equation 4 which includes an interaction term linking number of bedrooms (Bed) and the dummy variable for COVID-19:

[17] See Cliff and Ord (1981), Basu (1998) and Dublin (1998) for a comprehensive review for the spatial weights.
[18] We initially tested the autocorrelation on a monthly basis and found no difference in terms of the sign and magnitude of the coefficients. We retained the quarterly analysis to ensure sample representativeness.

$$lnP_{i,t} = c + \rho\sum_{j=1}^{n} W_{i,j} lnP_{j,t-h} + \sum_{k=1}^{K} \alpha_k S_k + \sum_{m=1}^{7} \beta_m N_m + \sum_{q=1}^{8} \gamma_q T_q + \varphi \sum_{i=1}^{n} Bed_i COVID + e \quad (4)$$

We further examine the effects that a number of socioeconomic (SE) attributes within a locality in which the property is situated have on property price by constructing Equation 5. This is incorporated into the modelling framework to investigate whether the spectrum of socio-economic attributes including income, education, employment, health, environment, access, crime and deprivation measures reveal differential effects in relation to COVID-19 and price 'shocks' or behaviours. Accordingly, an interaction term linking SE and COVID is incorporated to investigate whether each SE has any differential impact on property price after the COVID shock.

$$lnP_{i,t} = c + \rho\sum_{j=1}^{n} W_{i,j} lnP_{j,t-h} + \mu\sum_{j=1}^{n} W_{i,j} lnP_{j,t-h} * COVID + \sum_{k=1}^{K} \alpha_k S_k + \sum_{m=1}^{7} \beta_m N_m + \sum_{q=1}^{8} \gamma_q T_q + \sum_{r=1}^{8} \emptyset_r SE_r + \sum_{r=1}^{8} \Omega_r SE_r \, X \, COVID + e \quad (5)$$

Further, we examine the impact of the degree of contagiousness of COVID-19 on property prices within the modelling framework (Equation 6). We employ data on the quarterly COVID-19 infection rates (I) by local government district published by the Department of Health (NI) to create an additional regression model for the period of 2020Q2 to 2021Q1. Since a more populous LGD naturally tends to have more housing transactions, I is therefore adjusted by dividing it by the amount of housing stock within the given LGD.

$$lnP_{i,t} = c + \rho\sum_{j=1}^{n} W_{i,j} lnP_{j,t-h} + \mu\sum_{k=1}^{K} \alpha_k S_k + \sum_{q=1}^{8} \gamma_q T_q + \xi\sum_{t}^{3}\sum_{r=1}^{7} I_{r,\,t} + e \quad (6)$$

Results and findings

Descriptive findings

Examination of the price movements and descriptive statistics show some important insights into both market and pricing behaviour due to the 'market closure' as a consequence of the COVID-19 'lockdown' period. Figure 1 depicts the temporal movements of the four property sectors alongside the aggregate market during the sample period and shows the differential response of market pricing across the four sectors due to COVID-19. As evidenced in Figure 1, the detached segment displayed a steep and instantaneous trajectory demonstrating high price elasticity whereas the remaining three market sectors,

, witnessed gradual price growth, albeit more sustained and seemingly ‘lagged’, after the outbreak of COVID-19. The apartment sector reveals COVID-19 to display a negative impact and shock. We surmise that given that the apartment sector in Northern Ireland has historically been dependent on the amount of foreign direct investment as well as the demand of high-income local and international workers residing in the CBD of Belfast, it is not surprising to observe a short-term shrinking of the market segment when the overall business industry was severely hit by the pandemic. In addition, the more lagged and suppressed price changes in the immediate aftermath of lockdown in the apartment segment may be further explained by the lack of demand due to the perception of being ‘locked-in’ or ‘trapped in space’ as a consequence of their inability to relocate. Indeed, it stands to reason that this may be due to a ‘wealth-health’ effect where particular segments of the urban population such as younger and lower skilled cohorts could not afford to relocate from urban environments and escape the pressures of lockdown - invariably due to housing market and income inequalities.

Figure 1 Price movements of the property sub-markets between 2019Q1 and 2021Q1

The descriptive statistics evidenced in Table 2 also exhibit the gravity of the COVID-19 effect and further illustrate the dynamic, heterogeneous and divergent impact upon the market sectors and their respective pricing performance. At the overall market level, immediate post-lockdown or the reopening of the housing market in Q2 2020 observed an 11.77% price increase or ‘shock’. What is interesting to note is the increase in both the Lower- and Upper Quartile price movements, alongside the increasing average price, across the overall housing market over the investigation period. This symbolises that the market observed a shift in the overall level of the price distribution and overall increases towards transactions for higher priced properties. When considering the detached sector, Q2 2020 witnessed an 11.60% quarterly price increase with both sizeable surges in the average prices and across the quartile ranges confirming the shift in appetite and preference for more expensive and invariably larger housing.

The statistics illustrate that the semi-detached and terrace segments of the market observed less pronounced price growth of 9.05% and 5.40% respectively, immediately after the market reopened, and interestingly whilst showing these average price increases did not reveal any dramatic or notable change to their respective pricing distributions. What is interesting to note however is the more elongated or sustained price growth in the post-lockdown period of the semi-detached sector, and to a lesser extent the terrace segment of the market relative to the detached sector. The analysis shows that both the semi-detached and terrace segments maintained sizeable levels of price increases (growth) for two quarterly periods and also displayed increases in the lower- and upper quartiles throughout the remainder of 2020 – again representative of subtle movements within the price distribution to more expensive properties.

In contrast, the apartment sector displayed negative price shocks in both quarter two and quarter three of 2020, only displaying a noteworthy price increase change in quarter four of the year. Thus, these initial findings suggest that the detached sector leads the market immediately upon 'reopening' with an instantaneous and sharp positive price shock which immediately dropped back to normal price change levels, whereas the semi-detached and terrace sectors witnessed less pronounced immediate price shocks, but these increased over the ensuing quarters. This strongly suggests that there was a 'race for space' and signs of a 'lagged' filtration effect within the market in response to COVID-19. Indeed, this sits in accordance with existing research undertaken by McCord et al. (2019) which established that stylised facts of lead–lag relationships across property types was evident, and that uni-directional market filtration transmission pricing signals were in operation, transmitting from the more liquid owner-occupier-led detached and semi-detached market segments.

Table 2 Descriptive statistics at the aggregate level and by market sector

The residential real estate market of Northern Ireland has also witnessed a dramatic change in terms of liquidity represented by transaction volumes in the first half of 2020 due to the uncertainty stemming from the pandemic. As Figure 2 portrays, the total number of transactions reveals that there was a considerable reduction (57%) immediately after the COVID-19 outbreak and the subsequent national 'lockdown' in the U.K. market between Q1 2020 and Q2 2020, with all four submarkets following broadly the same steep download trend. However, the 'reopening' of the housing market, allied with macroprudential stimulus, 'furlough' schemes and the introduction of temporary fiscal impetus in the form of a UK-wide stamp duty holiday[19] in a preventative bid to shield a potential housing market downturn, quickly observed a rebound in terms of transaction volume, surging during Q2 2020 – Q3 2020 by 303% from Q2 2020 levels and 70% from Q1 2020 levels, pre-COVID-19.

Figure 2 Transactions levels across property types over the COVID period

Spatial lag-models

The empirical findings emanating from the study examine a suite of hedonic regression models for real estate prices which explicitly account for the effect of COVID-19 on the Northern Ireland housing market. Table 3 reports the key results of the models derived from Equations 1 to 3 using different combinations of independent variables with Models 1 and 2 providing the baseline traditional OLS hedonic models showing results highly consistent with expectations and some stylised facts in the literature. As observed by the signs and magnitude of the regression coefficients, property size as proxied by number of bedrooms is positively correlated to house price; the detached market (the base

[19] Introduced in July 2020 which exempted payments of stamp duty for the first £500,000 of the property value.

group) is the most sought after in terms of pricing, followed by semi-detached, apartment and terraced. We further observe that dwellings located in urban areas tend to command lower prices, a finding similar to Helbich (2015), who empirically found that homebuyers are willing to pay a premium for neighbourhoods in suburban municipalities.

Applying the initial spatial lag model (Model 3) using the inverse distance spatial weight specification as described in Equation 2.1, the coefficient on the spatial lag autocorrelation term (S.A.) equates to 0.6889 and is statistically significant at the 1% level, indicating that house prices are autocorrelated over space. In other words, house prices tend to move in tandem with one another: neighbourhoods characterised by properties of higher (lower) prices generally result in a higher (lower) price of the subject property. Of particular importance is the coefficient on the interaction term, *S.A. x COVID*, which is also positive (0.1924, $p<.001$) and statistically significant at the 1% level. This finding reveals that spatial autocorrelation in house prices increased after the outbreak of COVID-19, signalling that real estate buyers and traders tended to infer prior transaction prices even more extensively for price information due to the decreased market liquidity and subsequent 'reopening' of the market due to the pandemic. For robustness and confirmation of the finding, we employed an inverse exponential distance spatial weight SLM (Model 4), with the results largely in line with those of Model 3 in terms of the signs and statistical significance of the key coefficients. Indeed, Model 4 is marginally superior in view of its slightly higher R^2 and Adjusted R^2. Accordingly, we apply the spatial weight of inverse exponential distance for the remaining SLMs in our analysis[20].

To investigate whether differential impacts by health and wealth inequality in neighbourhoods could have a price effect due to COVID-19, we apply the spectrum of socio-economic factors (Model 5)[21]. The results exhibit that the coefficients of all factors are of the expected signs, in particular, the results for Income, Education, Employment, Accessibility, Crime and MDM are statistically significant at the 1% level. In order words, this indicates that properties in areas of better quality with respect to income, education and employment carry a price premium, whereas neighbourhoods of higher crime rates and MDM are likely to depress property values (Table 3). It is further noteworthy that by examining the size of the coefficients, Employment exhibits the largest impact on price, followed by Education, Income and Accessibility. On the other hand, the negative effect that MDM has on price is approximately six times as large as that of Crime based on comparison of the size of their regression coefficients[i]. However, it must be caveated that our diagnostic tests on the Variance Inflation Factors of the regression coefficients reveal possible multicollinearity between Education, Health and

20 As detailed in Section 3, we also undertake the SLM analysis using inverse squared distance as spatial weight. The results are consistent with those obtained using the other two spatial weight specifications with a slightly lower explanatory power. Full results are available upon request.
21 As aforementioned, NISRA measures the quality of each of the factors by ranking the neighbourhood in which the subject property is located relative to all other neighbourhoods in Northern Ireland. The results reveal that for Income, Education, Employment, Health, Environment and Accessibility, a higher rank signals a better neighbourhood quality with respect to that particular factor, whilst the opposite holds for the rest of the factors (i.e. Crime and MDM).

Employment (VIFs > 10). Therefore, we develop additional models (see Models 14 - 21) which only incorporate one SE variable in the hedonic regression equation. Further examining whether there is a price differential for properties in urban areas as opposed to rural locales after the outbreak of COVID-19, we introduce a further interaction term, *Urban x COVID*. The analysis (Model 6) reveals that the coefficient of the regressor is negative (-0.0510, p<.05), and significant at the 5% level, inferring that the prices of properties in rural areas have been affected more, and seen heightened prices after COVID-19 than more urban-based dwellings, other things being equal.

Model 7 investigates the relationship between number of COVID-19 infection cases (I) within a LGD, measured quarterly, and property price. Consistent with findings of previous studies such as Liu and Tang (2021), the coefficient on I is negative and statistically significant at the 5% level, indicating that the transmissibility of the disease within a locality did have a noticeable detrimental effect on property pricing in the short-run, after controlling for housing stock of the LGD. To identify whether COVID-19 has changed the taste of homebuyers who may seek larger homes in the search for more living space, Model 8 applies the coefficient on the interaction term of *Bed* and COVID, φ, finding a positive and statistically significant effect (0.04, p<.001). This implies that homebuyers tended to value space more after the outbreak of the pandemic, with, one bedroom, on average now worth approximately 4% more than it was before COVID-19.

Table 3 Determinants of the N.I. residential property market

We further examine whether the pricing effects of property types so differences due to the onset of COVID-19 (Models 9-13) by integrating more interaction terms, such as *Detached x COVID* (Table 4). The findings exhibit that only the detached sector displays a statistically significant positive pricing effect (0.0866, p<.001), or put another way, the detached submarket interacts positively with *COVID* with respect to price, significant at the 1% level, indicating that the prices of detached properties have been affected more after COVID-19 than the other property types. Indeed, whilst the semi-detached and terrace sectors do display a positive interaction with COVID-19, they do not meet any conventional level of statistical significance. The apartment sector shows a negative interaction with *COVID*. These findings serve to reinforce our aforementioned propositions.

Table 4: Effects of Covid 19 on pricing by residential property type

In order to examine the dynamics between the socio-economic variables and the outbreak of COVID19, an interaction term linking *COVID* and each socio-economic factor (SE) is introduced into the regression equation, with the results presented in Table 5 (Models 14 to 21). The analysis exhibits Education, Employment, Health, Environment and Accessibility determinants to all be statistically significant at the 5% level, showing that their impacts on pricing behaviour have become more pronounced after the onset of the COVID-19 healthcare crisis. Put differently, the pricing of a dwelling located in a neighbourhood of a higher socio-economic rank is more resistant to the economic uncertainty caused by COVID-19, seemingly suggesting that traders and homebuyers have shifted their demand tastes preferring housing assets that are of better quality tiers and located in a more rural areas and neighbourhoods of better socio-economic standing.

Table 5 Effects of Covid 19 with respect to socio-economic attributes

Discussion

Extant studies into epidemics and COVID-19 such as Francke & Korevaar (2021), Duca et al. (2021) and Ouazad (2020) illustrated that price shocks were ephemeral to major shocks originating from epidemics and demonstrating price reversion back to original path trajectories. This initial finding is also observed within this study which has revealed escalation in the pricing effects as a result of COVID-19, however one of differential growth trajectories which radiate from the detached sector and more latterly the semi-detached and terrace segments of the market. This elasticity of house prices is in accordance with the studies of Wang (2021), Duca et al. (2021), Ouazad (2020) and Liu & Tang (2021) which also revealed differences in price trajectories and that house price change in the wake of COVID-19 was heterogeneous across the housing types. Interestingly, the findings revealed that the 'reopening' of the housing market displayed a very different price trajectory for the apartment sector, and evidence of a lagged effect relative to the rest of the housing segments. This is also concomitant with the findings of Duca et al. (2021) which observed condominium pricing levels to decline and lag the pricing behaviour of the other sectors – notably detached.

The findings of this study are further in parallel with Quazad (2020) who suggested that the dynamic nature of prices in the short-run is consistent with heightened housing demand and households' adaptation and changes in aggregate consumption patterns, notably affecting the major factors driving overall housing demand and its composition. This 'race for space' borne out by the psychological implications of lockdown, and also the ability to work from 'anywhere', is also evidenced within the findings of this study with discernible 'lead' price increases observable for the detached segment of the market and the increased value relating to property size. This is also reflective and characteristic of filtering processes due to behaviour factors and preferences which emerged when examining the nature and changes within the price distribution in both the pre- and post-COVID-19 environment.

The study of Wang (2021) remarked that differential pricing effects due to COVID-19 were notable across market areas due to stronger housing market fundamentals, and interestingly better amenities, with Duca et al. (2021) also noting that this is also a consequence of wealthier households demanding more space in more peripheral or peri-urban locales. Our findings are similar in that they show that there has been an increased effect of price changes for rural locales, and are in keeping with Liu & Tang (2021), Wang (2021) and Argyroudis & Siokis (2019) who clearly revealed that the underlying dynamical structure of the housing market due to neighbourhood and community characteristics assisted this price divergence. The results from this study equally suggest that underlying neighbourhood determinants, and particularly house prices in locales of higher socio-economic standing were more resistant to the uncertainty and effects of the pandemic and witnessed increased price growth due to preference for housing in these areas. This may also be explained by underpinning pre-existing inequalities within and across housing markets which has been made more material by the crisis. In other words, the crisis seems to have borne these inequalities out when examining the price behaviour relative to deprivation.

Previous academic research such as D'Lima et al. (2020), Qian et al. (2021) and Liu & Tang (2021) have shown that contagion rates comprise ephemeral negative effects on house prices in the short-run and illustrated that was heterogeneous due to community and city characteristics. Within NI, research undertaken by the Department of Health notably exhibited that health inequalities were evident for infection rates relative to deprivation ranking and in urban areas. This research further tested infection rates and house prices with the results indicating that housing prices are strongly and negatively associated with the level of transmissibility of COVID-19 at the district prefecture. Put differently, the higher the (stock-adjusted) infection rate of COVID-19 within a LGD, the greater the decline in property prices. The findings are of both economic and social significance in that they not only contribute to the understanding of the risk-aversion nature of homebuyers and property traders in times of epidemics which are viewed as negative externalities, but perhaps more crucially, illustrate how effective and timely prevention and public control measures such as community closure management, quarantines and social distancing, and the general awareness of public hygiene could have a profound impact on the wider economy, including the property market, providing empirical justifications for government interventions in a time of public health crisis and economic vulnerability.

Conclusions

This study sought to establish the housing markets immediate response in the wake of the COVID-19 epidemic at the regional jurisdiction of Northern Ireland. In terms of market pricing, the paper revealed a positive interaction term signalling that house prices increased differentially after the outbreak of COVID-19 clearly revealing the nature of the epidemic on changing housing market signals and demand tastes - invariably through bidding-up and trading-up activities. This indicates that in the short-term the

COVID-19 pandemic has fostered some habitual and behavioural changes on housing choice and preference and evoked 'a psychological shock' on the Northern Ireland housing market.

Indeed, four key findings emerge out of this research investigation, namely; (*i*) pricing behaviour in the short-term due to COVID-19 has impacted the housing market and house types differently exhibiting different path trajectories and house price appreciation; (*ii*) there is a clear urban-rural effect of COVID-19 on house prices with price switching effects having driven demand in terms of pricing behaviour for rural dwellings. This further highlights the behavioural ramifications of the pandemic on demand preferences and tastes and illustrating how epidemics can alter housing market structure and composition as observed when further testing for property size; (*iii*) socio-economic differences appear to have driven price differentials – suggestive of a 'health-wealth' divide due to COVID-19. Indeed, the research has provided emerging evidence of socio-economic implications of the pandemic inferring that neighbourhoods with higher employment, income and education ranking were more resistant to the outbreak of COVID-19 in terms of market pricing and price growth; (iv) higher infection rates reveal larger house price declines. This is an important finding as it illustrates that the onset of epidemics of this type and nature impact upon housing markets in the short-term in a differential way, with a clear premium observed for healthier and better ranked neighbourhoods and that infection rates have a negative effect on prices. This dynamic has only served to heighten housing market affordability concerns which were already pressing due to changes in income levels, unemployment and borrowing capacity especially for those on lower incomes and positioned within more transient employment. This has arguably signalled an alarming effect of unequal income distributions relative to house price trends which may also have reinforced housing market inequalities and more specifically wealth inequality. The findings arguably suggest that pre-existing inequalities have been amplified and channelled through the housing market by the onset of the healthcare crisis.

As the housing sector plays an important role in the national economy, the findings of this study suggests that government fiscal and monetary policy counter measures enacted to 'shield' both the economy and housing market from the effect of the pandemic have culminated in some notable market patterns and distortions which may or may not continue to alter market dynamics and behaviour for the foreseeable future. Looking forward, the 'artificial' climate in which economic and housing market activity has been operating within, coupled with the emerging challenges which are surfacing such as inflation, mounting unemployment, increased government debt costs and the uneven and stuttering economic recovery, will continue to impact on housing markets and pose downside risks. Indeed, whilst a new market pricing level has been set, this also brings into question more uncertainties for pricing levels moving forward as the strong tailwind of the behavioural response of households subsides and the truer short versus long-run shocks emerge. There remain deep structural issues across most advanced housing markets in terms of ongoing global supply chain issues and building and material costs which can only serve to impact on the delivery of future housing supply and preserve pricing levels within the market, at least in the short- to medium-term. This may be temporary - but it may not - and could be an ongoing issue as governments try to balance the economic recovery, inevitable tax increases and consumer spending.

In terms of policy, this study has provisionally illustrated that a potential dichotomy exists which has arguably widened housing market inequalities and policymakers need to carefully consider these issues through the implementation of corresponding macroprudential and real estate policies. Indeed, policy measures enacted by government during times of epidemics of this scale and nature need to be carefully managed and implemented, with more consideration given to the behavioural and psychological signals evident in the market and how this then plays out in terms of adverse or differential effects across locations based on local and regional market fundamentals and drivers.

Whilst the research measures the impact and effect of the most recent COVID-19 pandemic on the performance of house prices within Northern Ireland, and despite showing key spatial characteristics play a role in altering the pricing landscape and impacted on housing market structure, future research should also investigate the longer-term implications of the epidemic on pricing behaviour and role of (macro) economic determinants and macroprudential policy changes, and specifically the SDLT stimulus, throughout the COVID-19 epidemic to establish how these impacted upon or contributed to house price movements. Certainly, within the confines of this study, the role of SDLT as a precautionary fiscal impetus necessitates further examination and attention, as the UK government was the only government to introduce such a measure. Further, whilst this study has identified that there has been a short-term market reaction and there appears to be lead-lag effects of the pandemic on pricing performance, future research should investigate the 'causal' dynamics of price changes to measure this price propagation in both the short- and long-term. Finally, given that the price changes are behavioural or psychological in nature, more research is needed to assess the impact of market demand and also further consider the role of rental market performance and accessibility as a consequence of COVID-19.

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i **Endnotes:**

The original modelling produced a further model as a robustness check for the previous hedonic models by removing all LGD variables. The signs and statistical significance of all key variables displayed results largely consistent with those of Models 1 to 5. Unsurprisingly, there is only a slight reduction in the explanatory power (Adjusted R^2=0.5717) compared to the other models (Adjusted R^2=0.5895), indicating that our spatial lag models are indeed statistically powerful in capturing spatial information of real estate.

Tables and Figures

Table 1 Description of variables and data sources

Variable	Description	Data Source
Transacted price	The achieved transacted price of the property	UPS
Property type	The type of property. For example 1 if detached; 0 otherwise.	UPS
Number of Bedrooms	The number of bedrooms within the property.	UPS
LGD	The Local Government District the property in located within	NISRA
Multiple Deprivation Measure (domains)	Ranking of MDM domains from least deprived to most deprived across each SOA	NISRA
Rural-urban classification	The composition of SOAs by their urban, rural determination	NISRA

Table 2 Descriptive statistics at the aggregate level and by market sector

Aggregate	Mean	Min	Max	LQ	UQ	SD	Q % change
2019Q1	134,879	39,999	775,000	125,000	157,613	68,206	-1.94%
2019Q2	140,270	42,500	570,000	97,000	159,371	65,666	4.00%
2019Q3	142,474	40,000	630,000	94,988	165,625	73,538	1.57%
2019Q4	141,358	49,000	430,000	93,125	164,000	66,290	-0.78%
2020Q1	142,429	46,250	1,000,000	91,500	164,950	85,245	0.76%
2020Q2	159,189	49,500	1,430,000	100,000	180,000	87,172	11.77%
2020Q3	164,289	48,000	900,000	105,000	190,000	90,116	3.20%
2020Q4	167,122	38,000	800,000	111,000	200,000	91,231	1.72%
2021Q1	164,389	55,000	740,000	113,875	196,250	77,350	-1.63%
Detached	**Mean**	**Min**	**Max**	**LQ**	**UQ**	**SD**	**Q % change**
2019Q1	212,223	112,500	775,000	156,750	230,000	99,993	1.02%
2019Q2	217,677	92,000	420,000	160,000	255,000	77,749	2.57%
2019Q3	218,838	62,500	630,000	160,000	241,000	98,269	0.53%
2019Q4	224,436	60,000	430,000	165,000	277,750	85,369	2.56%
2020Q1	227,800	115,000	1,000,000	162,500	242,500	137,106	1.50%
2020Q2	254,225	135,000	1,430,000	199,375	329,625	82,596	11.60%
2020Q3	255,181	72,500	900,000	185,000	300,000	100,661	0.38%
2020Q4	260,449	80,000	800,000	187,000	290,000	119,429	2.06%
2021Q1	245,072	100,000	740,000	166,500	290,000	95,113	-5.90%
Semi-detach	**Mean**	**Min**	**Max**	**LQ**	**UQ**	**SD**	**Q % change**
2019Q1	137,353	48,000	287,000	115,000	157,125	39,903	-3.56%
2019Q2	140,702	42,500	570,000	117,500	150,000	49,276	2.44%
2019Q3	146,957	56,000	485,000	115,875	165,625	54,720	4.45%

2019Q4	148,688	49,000	299,950	125,000	164,713	47,167	1.18%
2020Q1	145,949	50,000	495,000	119,463	160,250	55,943	-1.84%
2020Q2	159,161	76,000	585,000	125,125	170,000	77,316	9.05%
2020Q3	168,385	52,500	635,000	130,000	177,500	74,540	5.80%
2020Q4	171,248	70,000	590,000	130,000	196,000	66,424	1.70%
2021Q1	170,521	60,000	410,000	135,000	196,500	54,279	-0.42%
Terrace	**Mean**	**Min**	**Max**	**LQ**	**UQ**	**SD**	**Q % change**
2019Q1	96,444	39,999	234,000	75,000	117,500	34,681	0.89%
2019Q2	106,476	49,950	360,000	79,475	125,000	45,392	10.40%
2019Q3	110,008	40,000	420,000	78,500	129,000	53,976	3.32%
2019Q4	103,328	50,000	189,000	79,338	124,000	31,637	-6.07%
2020Q1	101,664	46,250	348,000	75,000	119,375	43,117	-1.61%
2020Q2	107,152	52,000	345,000	80,000	115,000	52,549	5.40%
2020Q3	116,164	48,000	410,000	80,000	137,000	54,802	8.41%
2020Q4	110,787	38,000	299,950	82,000	136,000	39,611	-4.63%
2021Q1	116,055	55,000	240,000	87,838	137,125	37,381	4.75%
Apartment	**Mean**	**Min**	**Max**	**LQ**	**UQ**	**SD**	**Q % change**
2019Q1	99,581	41,995	210,000	73,588	116,250	37,309	-9.07%
2019Q2	97,742	44,000	175,000	73,250	124,213	33,403	-1.85%
2019Q3	103,014	45,000	205,000	73,000	126,225	36,358	5.39%
2019Q4	100,774	55,000	215,000	74,000	121,750	36,411	-2.17%
2020Q1	112,758	48,000	230,000	68,000	151,000	53,094	11.89%
2020Q2	104,131	49,500	168,000	83,000	120,000	34,175	-7.65%
2020Q3	103,430	46,000	232,000	78,750	115,250	35,921	-0.67%
2020Q4	114,222	50,000	196,000	94,988	127,625	33,197	10.43%
2021Q1	110,560	60,000	195,000	87,500	128,450	28,320	-3.21%

Table 3 Determinants of the N.I. residential property market

DepVar=ln(sale price)	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7	Model 8
Constant	11.179 (0.0464)***	11.251 (0.0499)***	3.2403 (0.6317)***	8.0640 (0.2549)***	9.5397 (0.2468)***	6.3652 (0.6032)***	6.8150 (0.3693)***	7.675 (0.1987)***
Year2019Q2	0.0538 (0.0254)**	0.0540 (0.0254)**	0.0202 (0.0244)	0.0332 (0.0243)	0.0212 (0.0225)	0.0133 (0.0225)	NA	0.0307 (0.0242)
Year2019Q3	0.0421 (0.0251)*	0.0392 (0.0251)	0.0036 (0.0242)	0.0148 (0.0240)	0.0131 (0.0223)	0.0075 (0.0222)	NA	0.0114 (0.0239)
Year2019Q4	0.0499 (0.0270)*	0.0466 (0.0269)	0.0045 (0.0259)	0.0236 (0.0257)	0.0219 (0.0239)	0.0116 (0.0239)	NA	0.0199 (0.0257)
Year2020Q1	0.0442 (0.0271)	0.0449 (0.0270)*	0.0244 (0.0259)	0.0248 (0.0258)	0.0338 (0.0239)	0.0327 (0.0238)	NA	0.0224 (0.0258)
Year2020Q2	0.1089 (0.0352)***	0.1056 (0.0352)***	-2.2050 (0.9157)**	-0.9771 (0.3771)	-0.7710 (0.3492)**	-1.5247 (0.8568)*	-	-0.0651 (0.0587)
Year2020Q3	0.1139 (0.0239)***	0.1077 (0.0239)***	-2.2624 (0.9191)**	-0.9923 (0.3776)***	-0.7670 (0.3497)**	-1.5501 (0.8599)*	0.0142 (0.0396)	-0.0768 (0.0533)
Year2020Q4	0.1155 (0.0261)***	0.1105 (0.0261)***	-2.2852 (0.9204)**	-0.9922 (0.3778)***	-0.7786 (0.3499)**	-1.5688 (0.8611)*	0.1348 (0.0577)**	-0.0755 (0.0539)
Year2021Q1	0.1489 (0.0284)***	0.1436 (0.0284)***	-2.2677 (0.9212)**	-0.9495 (0.3775)**	-0.7281 (0.3495)**	-1.5367 (0.8629)*	0.1284 (0.0497)***	-0.0342 (0.0550)
Bedroom	0.2382 (0.0101)***	0.2370 (0.0101)***	0.2218 (0.0097)***	0.2218 (0.0097)***	0.2117 (0.0090)***	0.2067 (0.0090)***	0.2438 (0.0183)***	0.2034 (0.0119)***
Bedroom x COVID	-	-	-	-	-	-	-	0.0431 (0.0160)***
S.A. (lag) [i]	-	-	0.6889 (0.0545)***	0.2742 (0.0218)***	0.1176 (0.0214)***	0.3897 (0.0523)***	0.3899 (0.0308)***	0.3123 (0.0169)***
S.A. x COVID (lag)	-	-	0.1924 (0.0780)**	0.0888 (0.0320)***	0.0714 (0.0296)**	0.1382 (0.0726)**	NA	-
Semi-detached	-0.2994	-0.2947	-0.2964	-0.2927	-0.2778	-0.2718	-0.2735	-0.2919

	(0.0191)***	(0.0191)***	(0.0182)***	(0.0182)***	(0.0171)***	(0.0170)***	(0.0334)***	(0.0182)***
Terrace	-0.6024 (0.0209)***	-0.5965 (0.0209)***	-0.5574 (0.0201)***	-0.5543 (0.0200)***	-0.4872 (0.0193)***	-0.4755 (0.0193)***	-0.5256 (0.0375)***	-0.5527 (0.0200)***
Apartment	-0.4191 (0.0309)***	-0.4162 (0.0308)***	-0.4209 (0.0295)***	-0.4219 (0.0294)***	-0.4020 (0.0275)***	-0.3996 (0.0274)***	-0.3925 (0.0558)***	-0.4232 (0.0294)***
Urban	-	-0.0785 (0.0204)***	-	-	-	-0.0310 (0.0268)**	-	-
Urban*Covid	-	-	-	-	-	-0.0539 (0.0324)*	-	-
Infection	-	-	-	-	-		-0.0353 (0.0117)***	-
LGD2	0.1544 (0.0249)***	0.1503 (0.0249)***	0.0602 (0.0244)**	0.0948 (0.0239)***	0.1487 (0.0248)***	0.1140 (0.0249)***	-	0.0935 (0.0234)***
LGD3	0.2340 (0.0206)***	0.2407 (0.0206)***	0.1612 (0.0202)***	0.1877 (0.0198)***	0.2285 (0.0197)***	0.2028 (0.0120)***	-	0.1866 (0.0198)***
LGD4	0.0523 (0.1114)	0.0291 (0.1113)	-0.0596 (0.1064)	-0.0471 (0.1061)	0.1301 (0.0995)*	0.1177 (0.0992)	-	-0.0396 (0.1061)
LGD5	0.3409 (0.0269)***	0.3325 (0.0270)***	0.1769 (0.0274)***	0.2357 (0.0263)***	0.1635 (0.0258)***	0.1115 (0.0263)***	-	0.2331 (0.0263)***
LGD6	0.0373 (0.0322)	0.01874 (0.0325)	-0.0143 (0.0309)	0.0331 (0.0307)	0.0368 (0.0297)	-0.0058 (0.0297)	-	0.0312 (0.0307)
LGD7	-0.0614 (0.3635)	-0.1293 (0.3631)	-0.1215 (0.3467)	-0.1101 (0.3458)	0.0532 (0.3204)	-0.0021 (0.3197)	-	-0.0969 (0.0307)
LGD8	0.1169 (0.0289)***	0.0848 (0.0300)***	-0.0246 (0.0287)	0.0317 (0.0278)	0.1556 (0.0285)***	0.0934 (0.0293)***	-	0.0322 (0.0278)
Income Rank	-	-	-	-	0.0003 (6.56E-05)***	0.0003 (6.54E-05)***	-	-
Education Rank	-	-	-	-	0.0004 (7.19E-05)***	0.0003 (7.19E-05)***	-	-
Employment Rank	-	-	-	-	0.0005 (0.0001)***	0.0004 (0.0001)***	-	-
Health Rank	-	-	-	-	0.0002 (0.0001)	0.0002 (0.0001)	-	-
Environment Rank	-	-	-	-	1.13E-05 (3.32E-05)	4.38E-06 (3.33E-05)	-	-
Access Rank	-	-	-	-	0.0001 (4.27E-05)***	0.0002 (4.68E-05)***	-	-
Crime Rank	-	-	-	-	-0.0001 (4.55E-05)**	-9.85E-05 (4.54E-05)**	-	-
MDM Rank	-	-	-	-	-0.0006 (0.0002)***	-0.0005 (0.0002)***	-	-
No. of Obs	3335	3335	3335	3335	3335	3335	1404	3335
R-squared	0.4721	0.4744	0.5199	0.5225	0.5932	0.5963	0.4402	0.5224
Adjusted R-squared	0.4691	0.4712	0.5169	0.5195	0.5895	0.5925	0.4366	0.5194
B-P-G [ii]	0.8410	0.6500	0.6837	0.6477	0.7406	0.5965	0.7900	0.7294
VIF [iii]	No	No	No	No	Yes	Yes	No	No
DW [iv]	2.1129	2.1129	2.3891	2.3464	2.4634	2.5516	2.3069	2.3475
R. RESET [v]	3.7289	3.0550	2.2543	3.5744	2.7973	3.3047	1.0340	3.0797
Moran's I [vi]	0.2782**	0.2677**	0.0471	0.0427	0.0331	0.0329	0.0548	0.0523
F-statistic	156.02	149.57	170.87	172.63	160.63	157.35	121.79	172.59
Prob (F-statistic)	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

[i]Spatial weight=1/d for Models 1-3, and =exponential distance for Models 4-8. (Determined by R2, standard error in parathesis); [ii]B-P-G indicates the F-statistic of Breusch-Pagan-Godfrey Test for heteroskedasticity, showing all models are homoscedastic; [iii]VIF refers to Variance Inflation Factors with "No" indicating no multicollinearity in the regression analysis, "yes" otherwise. The results of Models 5 and 6 suggest that the VIFs of Education, Health and Employment are above than 10, implying possible multicollinearity. We therefore develop Models 14-21 to examine the effect of the socio-economic variables separately; [iv]DW refers to Durbin Watson Statistic for serial correlation; [v]R. RESET refers to the F-statistic of Ramsey Regression Equation Specification Error Test with results indicating no functional misspecifications for all models examined. [vi] Moran's I depicts the z-score of the Moran's I of regression residuals using an inverse distance specification which determines the degree of spatial autocorrelation in regression residuals; "***", "**" and "*" indicate statistical significance at the 1%, 5% and 10% level respectively.

Table 4: Effects of Covid 19 on pricing by residential property type

Dep Var= ln (sale price)	Model 9	Model 10	Model 11	Model 12	Model 13
Constant	8.0876 (0.2589)***	8.1635 (0.2579)***	8.1662 (0.2610)***	8.1639 (0.2579)***	8.1331 (0.2622)***
Year2019Q2	0.0296 (0.0243)	0.0301 (0.0244)	0.0300 (0.0243)	0.0301 (0.0244)	0.0300 (0.0244)
Year2019Q3	0.0028 (0.0241)	0.0031 (0.0241)	0.0028 (0.0241)	0.0027 (0.0241)	0.0031 (0.0241)

Year2019Q4	0.0150	0.0160	0.0159	0.0157	0.0156
	(0.0258)	(0.0259)	(0.0259)	(0.0259)	(0.0259)
Year2020Q1	0.0227	0.0233	0.0233	0.0233	0.0232
	(0.0259)	(0.0259)	(0.0259)	(0.0259)	(0.0259)
Year2020Q2	-0.9202	-1.0458	-1.0412	-1.0259	-1.0329
	(0.3804)**	(0.3795)***	(0.3905)***	(0.3789)***	(0.3950)***
Year2020Q3	-0.9403	-1.0668	-1.0619	-1.0462	-1.0540
	(0.3810)**	(0.3800)***	(0.3912)***	(0.3795)***	(0.3958)***
Year2020Q4	-0.9432	-1.0719	-1.0672	-1.0520	-1.0561
	(0.3812)**	(0.3802)***	(0.3913)***	(0.3796)***	(0.3959)***
Year2021Q1	-0.8981	-1.0238	-1.0191	-1.0039	-1.0120
	(0.3808)**	(0.3799)***	(0.3910)***	(0.3793)***	(0.3957)***
Bedroom	0.2364	0.2408	0.2407	0.2406	0.2353
	(0.0096)***	(0.0095)***	(0.0095)***	(0.0095)***	(0.0097)***
S.A. (lag) [i]	0.2696	0.2633	0.2634	0.2635	0.2668
	(0.0220)***	(0.0220)***	(0.0222)***	(0.0219)***	(0.0222)***
S.A. X Covid	0.0832	0.0957	0.0946	0.0935	0.0898
	(0.0323)***	(0.0323)***	(0.0330)***	(0.0322)***	(0.0331)***
Semi-detached	-0.2197	-0.2355	-0.2438	-0.2438	-0.2282
	(0.0194)***	(0.0207)***	(0.0175)***	(0.0175)***	(0.0226)***
Terraced	-0.4814	-0.5040	-0.5057	-0.5044	-0.4951
	(0.0208)***	(0.0192)***	(0.0220)***	(0.0191)***	(0.0240)***
Apartment	-0.3362	-0.3546	-0.3552	-0.3434	-0.3398
	(0.0291)***	(0.0283)***	(0.0283)***	(0.0331)***	(0.0346)***
Detached X Covid	0.0866		-	-	0.1154
	(0.0304)***	-			(0.0420)***
Semi-detached X Covid	-	0.0190	-	-	0.0379
		(0.0253)			(0.0433)
Terrace X Covid	-	-	0.0032		0.0233
			(0.0269)	-	(0.0556)
Apartment X Covid	-	-		-0.0290	0.0506
				(0.0421)	(0.0447)
Urban	-0.0724	-0.0754	-0.0759	-0.0762	-0.0731
	(0.0196)***	(0.0196)***	(0.0196)***	(0.0196)***	(0.0197)***
LGD2	0.1106	0.1148	0.1152	0.1151	0.1099
	(0.0242)***	(0.0242)***	(0.0242)***	(0.0242)***	(0.0243)***
LGD3	0.2112	0.2147	0.2149	0.2148	0.2101
	(0.0202)***	(0.0201)***	(0.0201)***	(0.0201)***	(0.0202)***
LGD4	-0.0366	-0.0435	-0.0433	-0.0432	-0.0370
	(0.1067)	(0.1068)	(0.1068)	(0.1068)	(0.1067)
LGD5	0.2364	0.2399	0.2399	0.2397	0.2358
	(0.0265)***	(0.0265)***	(0.0265)***	(0.0265)***	(0.0265)***
LGD6	0.0419	0.0425	0.0422	0.0419	0.0409
	(0.0312)	(0.0312)	(0.0312)	(0.0312)	(0.0312)
LGD7	-0.0763	-0.0953	-0.0992	-0.0980	-0.0840
	(0.3474)	(0.3478)	(0.3478)	(0.3477)	(0.3476)
LGD8	0.0276	0.0287	0.0290	0.0287	0.0279
	(0.0290)	(0.0291)	(0.0291)	(0.0291)	(0.0291)
No. of Obs.	3,335	3,335	3,335	3,335	3,335
R^2	0.519816	0.518721	0.518640	0.518707	0.520020
Adjusted R^2	0.516334	0.515231	0.515150	0.515218	0.516101
B-P-G [ii]	0.7833	0.8806	0.8248	0.7899	0.7940
VIF [iii]	No	No	No	No	No
DW [iv]	2.3110	2.3040	2.3051	2.3060	2.3110
R. RESET [v]	4.3752	4.6801	4.9194	4.7823	4.3772
Moran's I [vi]	0.0456	0.0467	0.0462	0.0462	0.0442
F-statistics	149.2997	148.6459	148.5981	148.6381	132.6990
Prob (F-statistic)	0.0000	0.0000	0.0000	0.0000	0.0000

[i]Spatial weight=1/ exponential distance(Determined by R2, standard error in parathesis); [ii]B-P-G indicates the F-statistic of Breusch-Pagan-Godfrey Test for heteroskedasticity, showing all models are homoscedastic; [iii]VIF refers to Variance Inflation Factors with "No" indicating no multicollinearity in the regression analysis, "yes" otherwise; [iv]DW refers to Durbin Watson Statistic for serial correlation; [v]R. RESET refers to the F-statistic of Ramsey Regression Equation Specification Error Test with results indicating no functional misspecifications for all models examined; [vi] Moran's I depicts the z-score of the Moran's I of regression residuals using an inverse distance specification which determines the degree of spatial autocorrelation in regression residuals; "***", "**" and "*" indicate statistical significance at the 1%, 5% and 10% level respectively.

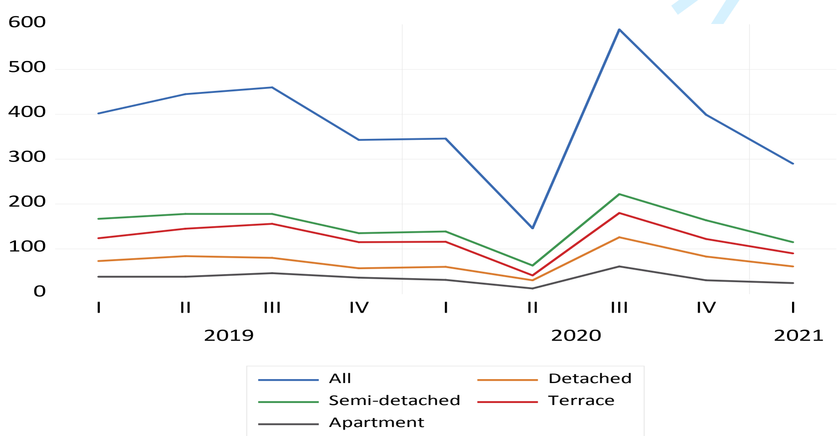
Table 5 Effects of Covid 19 with respect to socio-economic attributes

Dep Var= ln (sale price)	Model 14	Model 15	Model 16	Model 17	Model 18	Model 19	Model 20	Model 21
Constant	8.7405	9.0677	8.8064	8.7542	7.6995	7.8209	8.1154	8.9195
	(0.2588)***	(0.2591)***	(0.2595)***	(0.2604)***	(0.2564)***	(0.2556)***	(0.2682)***	(0.2651)***
Year2019Q2	0.0252	0.0283	0.0309	0.0308	0.0190	0.0263	0.0300	0.0317
	(0.0237)	(0.0233)	(0.0236)	(0.0237)	(0.0247)	(0.0244)	(0.0247)	(0.0238)
Year2019Q3	0.0180	0.0114	0.0176	0.0153	0.0039	0.0097	0.0072	0.0169
	(0.0235)	(0.0231)	(0.0234)	(0.0234)	(0.0244)	(0.0242)	(0.0245)	(0.0235)
Year2019Q4	0.0430	0.0319	0.0330	0.0328	0.0163	0.0254	0.0292	0.0410
	(0.0252)*	(0.0248)	(0.0251)	(0.0251)	(0.0262)	(0.0259)	(0.0262)	(0.0252)
Year2020Q1	0.0404	0.0321	0.0374	0.0358	0.0131	0.0203	0.0288	0.0399
	(0.0253)*	(0.0248)	(0.0251)	(0.0252)	(0.0262)	(0.0259)	(0.0263)	(0.0253)
Year2020Q2	-0.8407	-0.4294	-0.4254	-0.2417	-0.4504	-0.2146	-0.8071	-0.7024
	(0.3901)**	(0.3919)	(0.3935)	(0.3961)	(0.3883)	(0.3845)	(0.4056)**	(0.4038)*
Year2020Q3	-0.8101	-0.4027	-0.3953	-0.2138	-0.4433	-0.1972	-0.7912	-0.6666
	(0.3911)**	(0.3930)	(0.3946)	(0.3972)	(0.3892)	(0.3853)	(0.4065)*	(0.4050)*
Year2020Q4	-0.8156	-0.4087	-0.3965	-0.2152	-0.4459	-0.2061	-0.7951	-0.6712
	(0.3911)**	(0.3930)	(0.3947)	(0.3973)	(0.3892)	(0.3853)	(0.4065)**	(0.4050)*
Year2021Q1	-0.7590	-0.3567	-0.3425	-0.1660	-0.3942	-0.1548	-0.7431	-0.6161
	(0.3910)**	(0.3929)	(0.3946)	(0.3972)	(0.3891)	(0.3851)	(0.4064)*	(0.4050)
Bedroom	0.2165	0.2082	0.2168	0.2137	0.2214	0.2212	0.2357	0.2308
	(0.0095)***	(0.0094)***	(0.0094)***	(0.0095)***	(0.0099)	(0.0098)***	(0.0096)***	(0.0093)***
S.A. (lag) [i]	0.2068	0.1822	0.2038	0.2099	0.3224	0.3074	0.2626	0.1828
	(0.0226)***	(0.0225)***	(0.0226)***	(0.0226)***	(0.0219)***	(0.0216)***	(0.0232)***	(0.0231)***
S.A. x Covid	0.0746	0.0392	0.0377	0.0215	0.0370	0.0104	0.0723	0.0620
	(0.0337)**	(0.0338)	(0.0340)	(0.0342)	(0.0332)	(0.0329)	(0.0351)**	(0.0352)*
Semi-detached	-0.2637	-0.2298	-0.2412	-0.2298	-0.2682	-0.2829	-0.1870	-0.1889
	(0.0174)***	(0.0172)***	(0.0173)***	(0.0174)***	(0.0181)***	(0.0183)***	(0.0173)***	(0.0165)***
Terraced	-0.4639	-0.4234	-0.4460	-0.4347	-0.5283	-0.5293	-0.4180	-0.3814
	(0.0191)***	(0.0192)***	(0.0192)***	(0.0195)***	(0.0199)***	(0.0202)***	(0.0194)***	(0.0184)***
Apartment	-0.3788	-0.3473	-0.3525	-0.3432	-0.3951	-0.4074	-0.2934	-0.2855
	(0.0283)***	(0.0279)***	(0.0282)***	(0.0283)***	(0.0294)***	(0.0295)***	(0.0284)***	(0.0272)***
Income Rank	0.0004 (3.26E-05)***	-	-	-	-	-	-	-
Income Rank X Covid	5.76E-08 (4.90E-08)***	-	-	-	-	-	-	-
Education Rank	-	0.0005 (3.02E-05)***	-	-	-	-	-	-
Education Rank X Covid	-	9.92E-08 (4.98E-08)**	-	-	-	-	-	-
Employment Rank	-	-	0.0004 (3.05E-05)***	-	-	-	-	-
Employment Rank X Covid	-	-	1.29E-07 (4.99E-08)***	-	-	-	-	-
Health Rank	-	-	-	0.0004 (3.13E-05)***	-	-	-	-
Health Rank X Covid	-	-	-	1.68E-07 (5.19E-08)***	-	-	-	-
Environment Rank	-	-	-	-	0.0001 (2.70E-05)***	-	-	-
Environment Rank X Covid	-	-	-	-	2.81E-07 (5.46E-08)***	-	-	-
Access Rank	-	-	-	-	-	9.38E-06 (3.20E-05)	-	-
Access Rank X Covid	-	-	-	-	-	4.81E-07 (5.27E-08)***	-	-
Crime Rank	-	-	-	-	-	-	-0.0002 (3.82E-05)***	-
Crime Rank X Covid	-	-	-	-	-	-	4.50E-05 (5.70E-05)	-
MDM Rank	-	-	-	-	-	-	-	-0.0004 (3.20E-05)***
MDM Rank X Covid	-	-	-	-	-	-	-	5.93E-05 (4.87E-05)
No. of Observations	3,335	3,335	3,335	3,335	3,335	3,335	3,335	3,335
R^2	0.5419	0.5566	0.5465	0.5445	0.5065	0.5156	0.5019	0.5388
Adjusted R^2	0.5396	0.5543	0.5442	0.5422	0.5039	0.5131	0.4994	0.5364
B-P-G [ii]	1.2578	1.1246	1.1707	1.1328	1.0221	1.1009	1.0683	1.2020
VIF [iii]	No	No	No	No	No	No	No	No
DW [iv]	2.3816	2.3479	2.3384	2.3283	2.2833	2.2893	2.2875	2.3535
R. RESET [v]	4.1141	3.8832	3.7099	3.4114	3.3526	3.5108	3.5072	3.6367
Moran's I [vi]	0.0539	0.0551	0.0542	0.0544	0.0537	0.0528	0.0559	0.0540
F-statistics	230.86	244.94	235.12	233.28	200.23	207.66	196.65	227.00
Prob (F-statistic)	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

[i]Spatial weight=1/ exponential distance(Determined by R2, standard error in parathesis); [ii]B-P-G indicates the F-statistic of Breusch-Pagan-Godfrey Test for heteroskedasticity, showing all models are homoscedastic; [iii]VIF refers to Variance Inflation Factors with "No" indicating no multicollinearity in the regression analysis, "yes" otherwise; [iv]DW refers to Durbin Watson Statistic for serial correlation; [v]R. RESET refers to the F-statistic of Ramsey Regression Equation Specification Error Test with results indicating no functional misspecifications for all models examined; [vi]Moran's I depicts the z-score of the Moran's I of regression residuals using an inverse distance specification which determines the degree of spatial autocorrelation in regression residuals; "***", "**" and "*" indicate statistical significance at the 1%, 5% and 10% level respectively.

Figure 1 Price movements of the property sub-markets between 2019Q1 and 2021Q1

Figure 2 Transactions levels across property types over the COVID period



Reviewer(s)' Comments to Author:

Reviewer: 1

Comments to the Author
Follow-up question (6): That may be so, but is not changes in implicit prices for the number of bedrooms also a potential COVID effect that you do not account for if it is included in the time dummies?

We thank the reviewer for the response. We have run a further interaction term (model 8) to examine and report the findings.

Follow-up question (7): I agree that R2 is not that important, but sometimes it signals that we might have problems with omitted variable bias. What is correlated with Covid-19 and not included in the model? How about BREXIT? Could this be a BREXIT effect? I think it needs to be addressed.

This is why we employed the SLM as this helps with any potential issue relative to OMV because it can help capture both direct and indirect effects. The Brexit effect we feel was previously an issue for the general U.K. market and more specifically N.I. given the uncertainty it had for market transactions and dampening pricing levels as prospective buyers were nervous. The time series was selected carefully to consider these other political exogeneities and their potential impact. As per the market evidence, both in terms of anecdotal evidence and price changes, the general NI market by-and-large had recovered from the uncertainty of any potential Brexit shocks with it showing stable price increases notable over 2019.

We included in the paper the following statement to rationalise this "The time period of investigation was purposely chosen for two important sampling considerations: First, it has to minimise the effect arising from other exogenous but relevant factors such as political and macroeconomic turbulence (e.g. Brexit) on the dependent variable so that we can achieve a *ceteris paribus* condition for analysis."

Follow-up question (9): Ok, but which table is it? I would like to see the property type composition before and after COVID. You establish that the lockdown impacts houses prices, but did it also impact what is sold? In figure 2, it is shown that the apartment transaction is less common as a proportion of all sales after quarter 2 2020. Is the estimated parameter of COVID an effect of fewer apartment sales after the outbreak or an effect of behaviour changes?

In terms of composition, Apartment transactions reduced from 9.61% to 8.94%. The remaining sectors show detached to increase from 17.61% to 20.99%, semi-detached to see a marginal reduction from 40.05% to 39.72% with terrace showing a reduction from 32.73% to 30.35%.

We had included this in the footnotes (Footnote 12). "In terms of number of sales transactions, the detached, semi-detached, terrace and apartment sectors respectively accounted for 17.61%, 40.05%, 32.73% and 9.61% of the entire market before the outbreak of COVID-19 (Q12019 -Q12020). The composition became 20.99%, 39.72%, 30.35% and 8.94% thereafter (Q22020 – Q12021)."

Follow-up question(10): The parameter estimate of URBAN is negative both before and after COVID, and there is a behaviour change, but that cannot explain the negative sign before. Is URBAN correlated with property type? Are detached houses more common in RURAL? I want a better explanation of why it is expected that URBAN will have a negative impact both before and after COVID. In my context, that result would be considered to be very strange.
The Urban coefficient shows an increase in the magnitude of the negative sign which we feel suggests that in the post-COVID period has served to increase the effect contextualised by the market actors pushing towards the urban fringe for space. So this we feel is driven by behavioural change as the

reviewer suggests. Detached (single rural dwellings) would be characteristic of the NI housing market, with smaller (denser) terrace housing in inner city areas etc. more reflective of the urban housing defined areas, with larger urban housing tending to straddle the development limits. Recent analysis in a report undertaken by the Forum for Better Housing In NI entitled "Creating a more integrated, sustainable housing market for Northern Ireland" Showed that 79% of the new build residential applications are for single dwellings, of which only 4,660 or 31.2% were inside settlement development limits with 68.8% of applications were in greenbelt locations, for planning applications between 2015 to 2018. So the negative sign previous to the COVID effect we feel is a general market norm. Rural detached housing generally show larger plot sizes, house sizes and command premiums. The other factor may be due to city/urban externalities such as congestion and noise/air pollution which would also impact on the negative coefficient and explain why this has increased during times of public healthcare crises.

Reviewer: 2

Comments to the Author
The paper is a serious redraft based on the comments of the four referees. This is well done.
I think the paper is considerably improved by this redraft and makes more appropriate claims on behalf of its empirical findings.
There are still one or two words I would omit, such as 'seismic'.

We have gone through and undertaken a detailed edit and removed such phrases.

I noted on p.19 discussing inequalities that that authors use my reviewer comments from the first draft almost verbatim - I would suggest that they find other words to make the same points.

Apologies – we liked the phraseology. We have altered this in our own words.

The one key point outstanding for me is in the brief discussion of Stamp Duty Land Tax (SDLT). The UK was unusual in providing a temporary fiscal impetus to strengthen the housing market. Critics eg the Resolution Foundation have argued that this brought forward transactions and left a cliff edge when it was ended - not only that but international evidence suggests both the market recovery and race for space we saw in the UK and in the paper (without a permissive tax break). This has led critics to argue that the SDLT intervention was not progressive in incidence terms and unnecessary in terms of whether a market stimulus was actually required in the first place, and may have contributed to greater market volatility. I think at the very least the paper should make more of this (it was after all internationally rare to do such a thing) and could, in further research, consider testing the impact of the SDLT tax relief on the market in NI.

We acknowledge the reviewers point, which is a good one. We have attempted to insert a brief discussion on this. This is something which we believe is subject to further research as have included this in the conclusions. The phased removal of SDLT is not yet clear on market pricing/behaviour as this was finally removed on October 1st 2021. So as the reviewer suggests can be subject to further scrutiny when a few more quarters of data can be used or become available.